
The 2020 Nitrate Report with the results of the monitoring of the effects of the EU Nitrates Directive Action Programmes
The 2020 Nitrate Report with the results of the monitoring of the effects of the EU Nitrates Directive Action Programmes

RIVM report 2020-0184
Colophon

© RIVM 2021
Parts of this publication may be reproduced, provided acknowledgement is given to the National Institute for Public Health and the Environment (RIVM), stating the title and year of publication.

DOI 10.21945/RIVM-2020-0184

B. Fraters (author), RIVM
A.E.J. Hooijboer (author), RIVM
A. Vrijhoef (author), RIVM
A.C.C. Plette (author), Directorate-General for Public Works and Water Management/Water, Traffic and the Environment
N. van Duijnhoven (author), Deltares
J.C. Rozemeijer (author), Deltares
M. Gosseling (author), Statistics Netherlands
C.H.G. Daatselaar (author), Wageningen Economic Research
J.L. Roskam (author), Wageningen Economic Research
H.A.L. Begeman (author), Netherlands Enterprise Agency

Contact:
Dico Fraters
Centre for Environmental Monitoring
dico.fraters@rivm.nl

This study was commissioned by the Ministry of Infrastructure and Water Management and the Ministry of Agriculture, Nature & Food Quality as part of project no. M/270109, Fertiliser Policy Support.
Synopsis


The Nitrate report 2020 containing the results of monitoring effects of the EU Nitrates Directive action programmes

Over the past thirty years, the Netherlands government has taken measures to reduce nitrogen and phosphorus concentrations. This has improved the quality of ground and surface water.

However water quality is not yet adequate everywhere. The nitrate concentration is too high in the upper metre of groundwater of more than half of the farms in the Sand and Loess regions. This also applies to the upper metre of groundwater in more than 30 of the approximately 200 groundwater protection areas. Also, a large part of the surface waters is not yet of the desired quality, and the concentrations of nitrogen and phosphorus are too high.

After 2015, the excess of nitrogen and phosphorus increased. Since 2018 this has been reinforced by the dry summers. During drought, plants grow less well, so that they take up less nitrogen and phosphorus from the soil. Also less nitrate is broken down in the soil, which means that more leaches to ground and surface water. For example, the nitrate concentration in ditch water on farms doubled in the period 2016 to 2019. Nevertheless, the nitrate concentration in ground and surface water in this period was on average lower than in the four years before.

Nitrogen and phosphorus are substances in fertilisers that farmers use to make crops grow better. An excess of nitrogen and phosphorus can leach to ground and surface water and pollute it. Nitrate is one of the forms in which nitrogen occurs in the soil and water.

The improved water quality is mainly due to farmers having used increasingly less fertiliser. This reduced the excess of nitrogen and phosphorus in the soil. This also means that less nitrate leaches with rainwater to deeper layers in the soil and ends up in the groundwater. The less nitrogen and phosphorus there is in soil and groundwater, the less flows to surface water.

It is important to have clean ground and surface water that can be used for the production of drinking water. Clean surface water also ensures that a larger variety of plants and animals can live in the water.

Keywords: nitrates Directive, Nitrate Report 2020, Water Framework Directive, fertiliser policy, agricultural practice, groundwater and surface water quality, nitrate, nitrogen, phosphorus, eutrophication
Publiekssamenvatting

De Nitraatrapportage 2020 met de resultaten van de monitoring van de effecten van de EU Nitraatrichtlijn actieprogramma's

De afgelopen dertig jaar heeft de Nederlandse overheid maatregelen genomen waardoor de concentraties stikstof en fosfor sterk zijn gedaald. Hierdoor is de kwaliteit van het grond- en oppervlaktewater verbeterd.

Maar de waterkwaliteit is nog niet overal voldoende. In de bovenste meter van het grondwater van meer dan de helft van de landbouwbedrijven in de Zand- en Lössregio is de nitraatconcentratie te hoog. Dit geldt ook voor de bovenste meter van het grondwater in ruim dertig van de circa 200 grondwaterbeschermingsgebieden. Ook voldoet een groot deel van de oppervlaktewateren nog niet aan de gewenste kwaliteit en zijn de concentraties stikstof en fosfor er te hoog.


Stikstof en fosfor zijn stoffen in mest die landbouwbedrijven gebruiken om gewassen beter te laten groeien. Een teveel aan stikstof en fosfor kan wegspoelen naar het grond- en oppervlaktewater en dat vervuilen. Nitraat is een van de vormen waarin stikstof voorkomt in de bodem en het water.


Het is belangrijk om schoon grond- en oppervlaktewater te hebben waar drinkwater van kan worden gemaakt. Ook zorgt schoon oppervlaktewater ervoor dat er meer verschillende planten en dieren kunnen leven in het water.

Kernwoorden: nitraatrichtlijn, Nitraatrapportage 2020, Kaderrichtlijn Water, mestbeleid, landbouwpraktijk, grondwater- en oppervlaktewaterkwaliteit, nitraat, stikstof, fosfor, eutrofiëring
Preface

This report was commissioned by the Ministry of Infrastructure and Water Management, on their own behalf and on that of the Ministry of Agriculture, Nature and Food Quality (hereinafter also “IenW” and “LNV” respectively). It has been drawn up in order to comply with the obligation set out in Article 10 of the European Nitrates Directive, which requires a report to the European Commission every four years on progress made towards achieving the directive’s objective. The Nitrates Directive aims to reduce water pollution caused by nutrients from agriculture and prevent further pollution. The directive requires member states to take measures to achieve the objectives. This report summarises the policies as implemented, summarises the results of the monitoring programmes for assessing the effectiveness of the Action Programmes implemented for the Nitrates Directive and provides a prognosis of the effects of the ongoing (sixth) Action Programme setting out the planned policy for 2018-2021.

The report uses various terms that are not generally known or that are sometimes used in a different sense; a glossary of terms has therefore been added.

Dico Fraters, Arno Hooijboer, Astrid Vrijhoef, Sandra Plette, Nanette van Duijnhoven, Joachim Rozemeijer, Monique Gosseling, Co Daatselaar, Jamal Roskam, Hiskia Begeman
Contents

Glossary of terms and abbreviations — 13

Summary — 15

1 Introduction — 29
   1.1 General — 29
   1.2 The Nitrates Directive — 29
   1.3 Monitoring obligation — 31
   1.4 Reporting obligation — 31
   1.5 The Nitrate Report — 32
   1.5.1 Scope and accountability — 32
   1.5.2 Explanatory notes to the report — 33
   1.6 Source — 33
   1.7 Summary of previous reports — 34

2 National monitoring programme — 35
   2.1 Introduction — 35
   2.2 Monitoring agricultural practices — 35
      2.2.1 General — 35
      2.2.2 Collecting data on agricultural practices — 35
      2.2.3 Processing data about agricultural practices — 39
   2.3 Monitoring the effectiveness of fertiliser policy — 41
      2.3.1 General — 41
      2.3.2 Data collection about farms (Minerals Policy Monitoring Programme – LMM) — 41
      2.3.3 LMM data processing — 50
   2.4 Monitoring the status and trends for nitrate in the groundwater — 53
      2.4.1 General — 53
      2.4.2 Groundwater data collection — 53
      2.4.3 Groundwater data processing — 54
   2.5 Monitoring the status and trends for nitrate in water that is used for producing drinking water — 55
      2.5.1 General — 55
      2.5.2 Data collection regarding untreated water for drinking water production — 55
      2.5.3 Data processing for raw water used for drinking water production — 56
   2.6 Monitoring status and trends of nutrients in surface waters and their eutrophication status — 58
      2.6.1 General — 58
      2.6.2 Data collection for surface waters — 59
      2.6.3 Data processing for surface waters — 62
   2.7 Sources — 67

3 Agricultural practices — 73
   3.1 Introduction — 73
   3.2 Developments in agricultural policy and regulation — 73
      3.2.1 Periods — 73
      3.2.2 A sketch of recent developments — 73
      3.2.3 Nitrate Vulnerable Zones — 74
      3.2.4 Regulating the use of nitrogen and phosphate fertilisers — 75
3.2.5 Regulation of animal manure production and surpluses — 81
3.2.6 Regulating the application of fertiliser — 83
3.3 Developments in agriculture — 84
3.3.1 Land use — 84
3.3.2 Number of farms — 85
3.3.3 Livestock — 87
3.3.4 Excretion of nitrogen and phosphorus in animal manure — 88
3.4 Nutrient balances — 90
3.4.1 Nitrogen and phosphorus balances in agriculture — 90
3.4.2 Soil balances for nitrogen and phosphorus — 93
3.5 Developments in agricultural practices — 96
3.5.1 Manure transport and manure processing — 96
3.5.2 Manure storage capacity — 98
3.5.3 Fertilisation practices — 98
3.5.4 Crop cover during the winter period — 100
3.5.5 Water consumption — 101
3.5.6 Ammonia emissions — 102
3.5.7 Compliance with fertiliser legislation — 102
3.6 Knowledge development and dissemination, communication and supporting policy — 104
3.6.1 Knowledge development and dissemination — 104
3.6.2 Communication — 110
3.6.3 Supporting policy — 111
3.7 Cost-effectiveness — 116
3.8 Source — 118

4 Effects of Action Programmes on agricultural practices and nitrate concentrations in the water on farms — 125
4.1 Introduction — 125
4.2 Agricultural practices — 126
4.2.1 General — 126
4.2.2 Arable farming — 126
4.2.3 Dairy farming — 127
4.2.4 Other livestock farms — 130
4.3 Nitrate concentrations — 133
4.3.1 Overview at the national level — 133
4.3.2 Sand Region — 141
4.3.3 Loess Region — 144
4.3.4 Clay Region — 145
4.3.5 Peat Region — 146
4.4 Consideration of trends in nitrogen surplus and nitrate concentration — 147
4.5 Source — 152

5 Groundwater quality — 153
5.1 Introduction — 153
5.2 Nitrate in groundwater at depths of 5 to 15 metres — 153
5.3 Nitrate in groundwater at depths of 15 to 30 metres — 161
5.4 Nitrate in groundwater at depths of over 30 metres — 168
5.5 Discussion of the trends in agricultural practices and nitrates in groundwater — 173
5.6 Source — 175
6 Freshwater quality — 177
6.1 Introduction — 177
6.2 Nutrient load in fresh surface waters — 178
6.3 Nitrate concentration in freshwater — 183
6.3.1 Winter average nitrate concentration — 183
6.3.2 Winter maximum nitrate concentration — 185
6.3.3 Nitrate concentration – annual average — 187
6.4 The eutrophication of fresh surface waters — 188
6.4.1 General status — 188
6.4.2 Chlorophyll-α — 189
6.4.3 Nitrogen and phosphorus — 192
6.5 Discussion of the trends in agricultural practices and quality of fresh surface waters — 197
6.6 Source — 205

7 Marine and coastal water quality — 207
7.1 Introduction — 207
7.2 Nutrient load in marine and coastal waters — 207
7.3 Nitrate concentrations in marine and coastal waters — 209
7.4 Eutrophication in marine and coastal waters — 213
7.4.1 General status; the eutrophication characteristic — 213
7.4.2 Inorganic nitrogen (DIN) — 214
7.5 Discussion of the trends in agricultural practices and quality of saltwater bodies — 217
7.6 Source — 223

8 The future developments in water quality — 225
8.1 Assessment of forecasting options — 225
8.2 The future development of water quality — 226
8.3 Source — 228

With thanks to — 229
Glossary of terms and abbreviations

**Action Programme (Nitrates Directive):** a programme to be drawn up by each country to ensure compliance with the objective of the Nitrates Directive. A number of elements are mandatory.

**Artesian groundwater:** groundwater in a confined aquifer, a permeable layer bounded both above and below by a less permeable layer. As a result, the hydraulic head within the aquifer may be higher than the upper boundary of the aquifer (it is therefore also called pressurised groundwater or confined groundwater).

**FADN:** Farm Accountancy Data Network (“BIN” in Dutch), a monitoring network that collects information from around 1500 agricultural and horticultural farms about the agricultural economy and technical management.

**Statistics Netherlands:** CBS, the country’s statistical agency

**Derogation (Nitrates Directive):** permission granted in specific and precisely defined circumstances and under various conditions to deviate from the obligation stated in the Nitrates Directive to apply a maximum of 170 kg nitrogen from animal manure per hectare per year.

**DIN:** dissolved inorganic nitrogen, the sum of nitrogen in the forms of nitrite (NO$_2^-$), nitrate (NO$_3^-$) and ammonia (NH$_4^+$).

**Eutrophication characteristic:** the evaluation of the eutrophication status of the surface water bodies into three classes (namely non-eutrophic, potentially eutrophic or eutrophic) based on the biological condition and/or the nutrient status of the water bodies.

**Eutrophic:** excessively food-rich water in which the biology is inconsistent with the desired situation because it is too rich in nutrients (excess nitrogen and/or phosphorus).

**Phreatic groundwater:** groundwater in a permeable layer (aquifer) that is not bounded above by a less permeable layer; the groundwater table is free to vary in height.

**Application standard:** the standard for the maximum amount of animal manure or the maximum total amount of plant-available nitrogen or phosphate that may be applied per hectare per year.

**WFD:** Water Framework Directive

**LMG:** National Groundwater Quality Monitoring Network, a monitoring network with about 350 permanent observation wells where groundwater samples are taken at various depths.

**LMM:** Minerals Policy Monitoring Programme, a monitoring network in which the water quality is measured at about 450 farms and the agricultural practices are recorded via the FADN. The LMM consists of a Basic Monitoring Network and a Derogation Monitoring Network.

**MNLSO:** Agriculture-Specific Surface Waters Monitoring Network, comprising a selection of about 170 regional water bodies for which agriculture is the only anthropogenic source of nutrients.

**Soil nutrient surplus:** the difference between the supply of nutrients and their removal in the crops and by the loss of nitrogen by volatilisation at the plot level. The supply of nitrogen via the soil as a result of the breakdown of organic matter and through nitrogen fixation by leguminous plants is also taken into account.
Nutrient surplus: the difference between the supply and removal of nutrients at the farm level or at the level of agriculture as a whole, taking account of the differences in stocks.

Storage capacity: the volume within which livestock manure can be stored responsibly; this is generally expressed as the number of months that a farm can store the manure that is produced on the farm by the animals present.

Potentially eutrophic: food-rich water in which the biology is consistent with the desired situation despite it being too rich in nutrients (excess nitrogen and/or phosphorus).

Application period: timeframe within the year during which applying manure is permitted.

Leachates: the water that drains out of the root zone of a plot of land – this can be water that goes to the ditches via drainage tubes, the water in the uppermost metre of the groundwater or the moisture in the soil layer just below the root zone if the groundwater is deeper (more than five metres below the surface).

Loss standard: a standard for the maximum nutrient surplus per hectare per year, for which no levy has to be paid for any exceedance.

Feed conversion ratio: a measure of the efficiency for converting feed given to the animal into an increase in bodyweight.

Plant-available nitrogen: the sum of the amount of nitrogen in animal manure that is taken up by the crop just as well as nitrogen in artificial fertilisers plus the amount of nitrogen in artificial fertilisers.
Summary

Introduction
Every four years, RIVM produces an overview of the then prevailing practices in the agricultural sector and of the quality of the groundwater and surface waters in the Netherlands. This looks at the nutrients nitrogen and phosphorus and the associated eutrophication of surface waters and the nitrate concentrations in groundwater and surface water. This report, the 2020 Nitrate Report, emphasises the developments between the latest four-year period (2016-2019) and the preceding one (2012-2015). Additionally, the trends between 1992 and 2019 are described.

This report is the fulfilment of obligations arising from Article 10 of the Nitrates Directive, which requires a report to the European Commission every four years on progress in improving water quality. The water quality data that this report is based on was submitted as required to the European Commission before 1 July 2020. The purpose of the Nitrates Directive is to prevent water becoming contaminated by nutrients from agriculture and to reduce contamination where necessary.

To achieve this, all EU member states must draw up an action programme every four years containing measures. The first action programme dates back to 1996. Current water quality reflects the effects of the fourth and fifth action programmes in particular (2010-2013 and 2014-2017 respectively). For that reason, the report also contains a prognosis of the water quality that will be achieved by the current Nitrate Action Programme (2018-2021), the sixth.

This summary of the report addresses the following:
- Dutch fertiliser policy, and its development since 1987 and after introducing the European Nitrates Directive in 1991;
- current agricultural practices and how they are developing;
- The status of and the trends in the groundwater and surface water quality, particularly as regards nitrate concentrations and eutrophication;
- the effects of the action programmes on water quality;
- a prognosis for future developments in water quality;
- and finally a few conclusions.

Dutch fertiliser policy
Even before the Nitrates Directive was introduced in 1991, the Netherlands had adopted legislation to regulate the use of manure. The system of accounting for manure (which began in 1987) was replaced in 1998 by a mineral accounting system (MINAS), which was based on loss standards for nitrogen and phosphorus. The Manure Transfer Contracts (MAO) system came into effect on 1 January 2002 to meet the standards for the quantities of animal manure to be applied, as laid down in the Nitrates Directive. MINAS was rejected by the European Court of Justice in October 2003 and deemed to be an unlawful implementation of the Nitrates Directive. As a result, the Dutch
government decided to drop MINAS and the Manure Transfer Contracts system.

**Phosphorus and phosphate**

Within the agricultural sector, the term ‘phosphate’ is widely used instead of ‘phosphorus’ when discussing fertilisers and fertiliser legislation. Phosphate is a compound containing phosphorus (P) and oxygen (O), defined for agricultural purposes as P₂O₅. One kilogram of phosphorus is equivalent to 2.29 kilograms of phosphate.

The term ‘phosphorus’ is used for reporting the concentrations in surface waters.

The Netherlands introduced a new fertiliser policy in January 2006. This was based on application standards for nitrogen in animal manure and application standards for overall quantities of plant-available nitrogen and phosphate. The standard used for nitrogen in animal manure is set in the Nitrates Directive. For the Netherlands, a farm business may use a higher standard for animal manure (derogation) as long as that business complies with certain conditions and has a derogation permit. The levels that the application standard are set at for the overall quantities of plant-available nitrogen and phosphate depend on the crop and the soil type.

Various application standards were tightened up step by step during the period 2006-2019. From 2010 onwards, the standards for phosphate were made dependent on the phosphate levels in the soil. From 2015 onwards, tighter nitrogen standards applied for crops on sand and loess soils in the sandy southern area and in the loess region than applied for other sandy areas. From 2017 onwards, there have been less stringent nitrogen standards for arable farm crops that in previous years yielded larger crops than average.

In addition to regulation of maximum use of fertilisers, other measures have been introduced or tightened up. One example is a shorter period during which animal manure may be spread (from 2019 onwards this has been shortened by a further two weeks for arable land). The period for which it must be possible to store animal manure (the minimum storage capacity) was extended in 2012 from six to a minimum of seven months. In 2014, an increment was added to that for the availability coefficient of pig manure on sandy soil. This latter item means that when pig manure is applied to sandy soil, less nitrogen may be added from other fertilisers from 2014 onwards than was the case before 2014. Farmers therefore have to apply less animal manure and/or artificial fertiliser if they are to remain within the application standard set for the total amount of plant-available nitrogen. Furthermore, the rule since 2014 has been that farms that make use of a derogation can no longer use artificial phosphate fertilisers. These farms are also required to have at least 80 per cent of the area as grassland instead of 70 per cent as had been required until then.

Another important cornerstone of Dutch fertiliser policy is the regulation of animal manure production and the manure surplus. Various systems have been introduced in the period since 2014 to make these
cornerstones more concrete. That was needed if the problems were to be resolved that had arisen from the gradual increases in European milk quotas since 2009 and their abolition in 2015. These measures meant that dairy herds increased from 2012 onwards and that their emissions of nitrogen and phosphate did too. As a result, the limits that had been agreed with the European Commission were exceeded.

Five systems are involved: the responsible manure disposal system (2014), the system of sustainable growth in dairy farms (2015), the system of animal production rights for pig and poultry farms (which was due to lapse in 2015 but has been retained) and the system of phosphate production rights for dairy farms (2018). The introduction of phosphate production rights was needed to limit the growth of the dairy herd after the number of dairy cows had been forced downwards in 2017. Finally, a more rigorous enforcement strategy for manure was drawn up in 2018 and area-specific enforcement was introduced in areas with a high risk of infringements. These were areas where the water quality was lagging behind or decreasing. The beefed-up enforcement strategy for manure had been made a precondition by the European Commission for obtaining derogation for 2018 and 2019.

During the timeframe of the sixth Nitrate Action Programme (2018-2021), the approach adopted by national government has been that fewer general and more tailored measures ought to let the agricultural sector resolve local water quality issues itself, together with the water boards and water users. Additionally, a fundamental and interactive rethink of manure policy has taken place. Many of those involved in the agricultural sector in fact perceived the current policy as a complex – indeed excessively complex – system of standards and rules, defined in a variety of laws, decrees and ministerial regulations. The idea is that the policy resulting from the rethink should be detailed and introduced over the coming decade and partly defined in the seventh and eighth Nitrate Action Programmes.

**Agricultural practices**

_Agriculture in the period 2016-2019_

The cultivated land area in the Netherlands comprised an average of 1.82 million hectares during the period 2016-2019, covering a little more than half (54%) of the total land area. Of that land under cultivation, 54% consisted of grassland (of which 76% was permanent), 11% of silage maize and 28% of other arable crops. The remainder (approximately 7%) was used for horticulture. There were an average of 54,000 agricultural companies of which 50% were for grazing animals, 20% arable farms, 16% horticultural farms (including permanent cultivation) and 14% were factory farms and mixed farms.

Livestock numbers during this period averaged 4.0 million cattle, 12.4 million pigs, 101 million chickens and 1.4 million sheep and goats. The total amount of manure produced by these animals comprised over 500 million kilograms of nitrogen and 166 million kilograms of phosphate. Those quantities were on average below the ceilings agreed with the European Commission in the given years (504.4 million kilograms of nitrogen and 172.9 million kilograms of phosphate.
respectively). Ceilings were however exceeded in 2016 for phosphate and 2017 for nitrogen.

In that period, over 60% of the nitrogen and almost 53% of the phosphate came from cattle manure. Approximately 25% of the amount of phosphate produced in animal manure was exported or used outside the Dutch agricultural sector; for the amounts of nitrogen, this figure was about 16%. The quantities of nitrogen applied to agricultural land (nitrogen application) averaged 355 kilograms per hectare over this period. Of that, 202 kilograms per hectare came from animal manure, 122 kilograms per hectare from artificial fertiliser and 31 kilograms per hectare via the air (atmospheric deposition) and other sources. Phosphate applications on agricultural land during this period averaged about 79 kilograms per hectare. Of that, 68 kilograms per hectare was from animal manure, 7 kilograms per hectare from artificial fertiliser and 4 kilograms per hectare from other sources.

The nitrogen soil surplus is the difference between the supply of nitrogen and its removal in harvested crops and the quantity that ‘escapes’ into the air (volatilisation). This takes account of the stock level differences at the farms. The nitrogen soil surplus averaged about 128 kilograms per hectare in the period 2016-2018. The soil surplus for phosphate averaged 11 kilograms per hectare.

**Trends in agricultural practices**

The area under cultivation was hardly any smaller in 2016-2019 than in 2012-2015. Between 1992 and 2019, the area decreased by almost 9%. There were 18% fewer farms than in the previous period, whereas the decrease since 1992 was almost 54%. Compared to 2012-2015, the numbers of cattle, pigs and chickens remained almost the same. The numbers of cattle and pigs were about 15% lower than during the first period (1992-1995). The number of chickens was 7% higher than in 1992-1995.

Although the numbers of animals were roughly the same, livestock excreted 5% more nitrogen in 2016-2019 via animal manure than in 2012-2015. This is above all because dairy cattle excrete more nitrogen per animal in the manure. Excretions of phosphate by livestock decreased slightly (by 2.7%). Compared to 1992-1995, emissions of nitrogen and phosphate by livestock decreased by almost 30%. This reduction is due to livestock numbers being smaller in the period 2016-2019 and to each animal excreting less of these nutrients than in the period 1992-1995.

The nitrogen and phosphate surpluses in Dutch agriculture started increasing again since 2015 for the first time in years (see Figure S1). Between 1992 and 2015, the nitrogen surplus halved and there was hardly any phosphate surplus left. The phosphate surplus rose primarily because less phosphate is being removed in the crops. The nitrogen surplus rose after 2015 despite more nitrogen being removed in the crops, not only because more nitrogen is being excreted but also because more artificial fertiliser is being applied. The drought in 2018 also contributed to the increase in the nitrogen surplus. Because the
crops were growing less well, less nitrogen was removed in the harvested crops.

![Figure S1 Trend in the relative surpluses of nitrogen and phosphate in Dutch agriculture. The value for 1970 is indexed as 100. Annual measurements since 1986.](image)

Compared to the previous four-year period (2012-2015), the net removal of manure fell in the areas where a lot is exported (Sand – South and Sand – Central). The net export is the difference between the amounts of manure imported and exported. In several other areas where manure has been imported for a long time, the amounts brought in decreased (e.g. the Southwestern Clay Region) or manure was even exported (e.g. from the Sand – North). In 2016-2019, 5% more manure was disposed of outside the Dutch agricultural sector (including exports) than in 2012-2015. Disposal of manure outside the Dutch agricultural sector has more than doubled since 1994-1995.

During the period 2016-2019, agriculture emitted a little more (2 percent) ammonia to the atmosphere again for the first time than in the preceding four years. Emissions were however still 58% lower than in the period 1992-1995.

The storage capacity for manure has increased with respect to 2012-2015. The mandatory minimum storage capacity for an agricultural company was increased in 2012 by one month from six months to seven. In 2018, 91% of dairy farms, 93% of pig farms and 82% of veal calf farms had facilities for storing all the manure produced for at least seven months. Companies that can demonstrate that the surplus is disposed of or used responsibly do not have to have storage capacity for seven months.
Groundwater and surface water quality

Nitrate concentration in the period 2015-2019

Changes in agricultural practice can be detected more quickly in water draining from an agricultural plot into groundwater and surface water (leachates). By the time that this water reaches the groundwater or surface water, the concentrations of the nutrients will have been diluted. Some of the nitrate will also have been broken down by then. The Dutch authorities therefore decided to monitor the effects of the Nitrate Action Programmes in the leachates. This report also contains the results of nitrate measurements in the groundwater and in the surface waters.

Surface waters and the Water Framework Directive

Not all surface waters in the Netherlands are designated as water bodies in the sense of the Water Framework Directive (WFD). In general, only surface waters of a certain size are deemed to be water bodies and the numerous ditches, canals and other small surface waters in the Netherlands are not included. The WFD does apply to all waters, however: designation as a water body only means that reporting about it is required. Because the WFD objectives apply to all waters, measures must be taken where necessary for any surface water.

This overview for the Nitrates Directive makes a distinction between regional waters as designated for the purposes of the WFD and waters that are agriculture-specific surface waters. There is a certain small amount of overlap between the agriculture-specific waters and the regional WFD waters, but the former also include many smaller surface waters that are not designated in the WFD.

The nitrate concentration becomes lower as the measurements are taken further from the source, the agricultural fields (see Table S1). This applies in the groundwater in terms of the depth at which the measurement is made, and in the surface waters in terms of the distance from the source. The summary below ranks the various types of surface water, based on the extent to which Dutch agriculture affects them. In broad terms, this is the same as ranking the waters from those with the highest nitrate concentrations to those with the lowest. The sequence goes from agricultural ditches via agriculture-specific regional waters, regional WFD waters, national waters and transitional water zones to coastal waters and finally the open sea.

Agriculture has the most effect on nitrate concentrations in leachates and in the water in ditches next to farm fields. The effect in agriculture-specific regional waters is also large, i.e. waters that the ditches flow into and for which agriculture is the only man-made source of nutrients. From the regional WFD waters through to the open sea, sources other than agriculture have an increasing influence. This is above all referring to effluent from wastewater treatment plants, precipitation from the atmosphere (atmospheric deposition) and water coming in from other countries.

The nitrate concentration in the groundwater decreases in the deeper layers. The concentration also decreases with the distance between the source (the agricultural plot) and the surface waters. Two factors play a part in this. The first factor is that nitrate is converted during this
'transport' (denitrification) into nitrogen gas (N₂) and into oxides of nitrogen, such as the greenhouse gas nitrous oxide (N₂O). The second factor is that relatively nitrate-rich water mixes with water at a lower nitrate concentration (dilution), for instance in mixing with water from layers deeper in the ground.

Additional roles are played by time (the age of the water) and the geohydrological conditions. Water that leaches out of a plot is 'young' water (less than five years old). In sandy areas, the groundwater at depths of 5 to 15 metres is about ten years old. Phreatic groundwater (i.e. water for which there are no impermeable soil layers above) at depths of 15 to 30 metres is approximately forty years old. Groundwater at this depth therefore reflects agricultural practices of at least forty years ago.

In clay and peat areas, the groundwater at depths of 5 to 15 and 15 to 30 metres is generally even older. Groundwater in what are known as aquifers (soil layers through which water flows) in clay and peat areas is often wholly or partially confined by a layer of clay with poor water permeability. In these areas, the excess precipitation flows via the ground surface to the surface waters, taking the nutrients with it. Confined or semi-confined aquifers also occur locally in the sandy areas.

Nitrate concentrations in leachates and groundwater in the Peat Region are lower than in the Clay Region. In turn, concentrations in the Clay Region are less than in the Sand Region (see Table S1). This is caused by the differences in the degree to which nitrate is broken down (denitrification). The denitrification capacity is lowest in the Sand Region, higher in the Clay Region and highest in the Peat Region.

The nitrate standard and eutrophication
The EU water quality standard for nitrate of 50 milligrams per litre (equivalent to nitrogen in nitrate of 11.3 milligrams per litre) is intended to protect the drinking water. This standard is too high to achieve good water quality, in ecological terms, for the WFD and a good eutrophication status of the surface waters. The level of 50 milligrams per litre that applies for nitrate, when converted to nitrogen by weight, is three to five times higher than the target value for total nitrogen in surface waters. This nitrate standard therefore does not show properly whether the objective of the WFD and the Nitrates Directive – to prevent or combat eutrophication – is being achieved. To do that, not only the nitrate levels need to be examined but also the total amounts of nitrogen and phosphorus in the water.
Table S1 Average measured nitrate concentration (in mg/litre) and exceedance of the standard of 50 mg/l (as a percentage of the number of measurement points) in groundwater and surface water during the period 2016-2019.

<table>
<thead>
<tr>
<th>Water type</th>
<th>Sand Region</th>
<th>Clay Region</th>
<th>Peat Region</th>
<th>Loess Region</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching from agricultural plots</td>
<td>50 (37%)</td>
<td>30 (18%)</td>
<td>7 (3%)</td>
<td>63 (51%)</td>
<td>-</td>
</tr>
<tr>
<td>Groundwater at a depth of 5-15 metres</td>
<td>31 (17%)</td>
<td>3 (1%)</td>
<td>1 (0%)</td>
<td>-</td>
<td>19 (11%)</td>
</tr>
<tr>
<td>(agriculture)</td>
<td>7 (4%)</td>
<td>2 (0%)</td>
<td>0 (0%)</td>
<td>-</td>
<td>4 (2%)</td>
</tr>
<tr>
<td>&gt; 30 metres (phreatic extraction)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5 (0%)</td>
</tr>
<tr>
<td>Fresh surface water</td>
<td>35 (22%)</td>
<td>21 (8%)</td>
<td>5 (0%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Agricultural ditches</td>
<td>18 (3%)</td>
<td>11 (2%)</td>
<td>4 (0%)</td>
<td>-</td>
<td>14 (2%)</td>
</tr>
<tr>
<td>Agriculture-specific regional waters</td>
<td>16 (4%)</td>
<td>9 (0%)</td>
<td>4 (0%)</td>
<td>22 (0%)</td>
<td>11 (1%)</td>
</tr>
<tr>
<td>Regional WFD waters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11 (0%)</td>
</tr>
<tr>
<td>National waters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Saline surface water</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10 (0%)</td>
</tr>
<tr>
<td>Transitional waters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coastal waters</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2 (0%)</td>
</tr>
<tr>
<td>Open sea</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1 (0%)</td>
</tr>
</tbody>
</table>

1 The percentages in parentheses give the exceedance of the European water quality standard of 50 mg/litre in the period 2015-2019. For water that leaches out of agricultural plots (< 5 metres depth) and farm ditches, this refers to the percentage of farms that exceed the standard of 50 mg/l. For groundwater at depths of > 5 metres, it refers to the percentage of the wells and for surface water it refers to the percentage of monitoring locations.

2 Groundwater depths are given in metres below local ground level.

3 Average nitrate concentration in the winter, the season when leaching affects the surface water quality a great deal.

Eutrophication of surface waters in the period 2016-2019

A large proportion of the WFD surface water bodies are eutrophic or could become so (potentially eutrophic). In this case, 'eutrophic' means that the biological quality (a measure for the presence of the plants and animals that naturally belong in the water) is not as it should be. The concentrations of nutrients also fail to meet the WFD water quality target values for these waters. The term 'potentially eutrophic' means that the biological quality of these waters is acceptable but the nutrient concentrations do not comply with the WFD water quality target values for these waters.

Almost 60 per cent of the WFD fresh water bodies are eutrophic. Almost a third of the waters are not eutrophic and a small fraction are potentially eutrophic.

The picture for the salt waters is different. Half of those waters are potentially eutrophic, i.e. the nutrient concentrations (dissolved
nitrogen) are too high but the biological quality is still good. The quantities of algae in the waters where the biological quality is good are low. In potentially eutrophic waters, there is sufficient nitrogen for the quantities of algae to bloom significantly. The fact that this is not happening probably means that other factors are ensuring that the quantities of algae do not get too high. Examples of such factors are a lack of light, heavy ‘grazing’ by shellfish or plankton, or a lack of nutrients other than nitrogen.

**Trends in groundwater and surface water quality**

*Nitrate concentration*

Nitrate concentrations in the water leaching from farm plots have increased since 2017 in all the regions (see Figure S2). This has very probably been caused by a succession of years with dry summers in which less nitrogen was removed in the harvested crops. As a result, the amount of nitrogen in the soil that could then leach (the nitrogen soil surplus) increased. Conditions that ensure that nitrate in the soil is broken down (denitrification) are also less favoured by dry weather. On top of that, the amount of water available for leaching the residual nitrate from the soil was less (a smaller precipitation excess), which also leads to higher nitrate concentrations.

![Figure S2 Nitrate concentration (as NO₃ in mg/l) in the water that leaches from farm plots per region in the period 1992-2019. The average concentration over the year is given.](source)

Despite the increased nitrate concentrations after 2017, the concentration of the entire period (2016-2019) is on average less than or equal to that in the previous period (2012-2015). The Clay Region is an exception to this: the concentration there increased on about 100 farms from an average of 23 milligrams per litre in 2012-2015 to 30 milligrams per litre in 2016-2019. That increase can be almost entirely ascribed to the high nitrate concentration in 2019. In the Clay Region, we saw relatively stronger rises in the nitrate concentrations in
2019 compared to other regions. In the Sand Region, the concentration decreased from an average of 55 milligrams per litre in 2012-2015 to 50 milligrams per litre in 2016-2019 (approximately 225 farms). The nitrate concentrations in the Peat Region (about 60 farms) and the Loess Region (about 50 farms) have not changed significantly over the latest reporting period with respect to the previous one.

During the period 1992-2017, nitrate concentrations in the water leaching from farm plots decreased (see Figure S2). There were also fewer farms that had nitrate concentrations above the standard of 50 milligrams per litre (see Figure S3). After 2017, both the nitrate concentrations and the percentages of farms with concentrations above the EU standard increased.

![Figure S3 Percentage of farms in the Minerals Policy Monitoring Programme (LMM) that exceeded the EU standard of 50 mg nitrate per litre leaching from agricultural plots, per region for the period 1992-2019.](image)

The average annual nitrate concentration in the groundwater at depths of 5 to 30 metres below ground level remained roughly the same from 1984 (the first year when measurements were made) to 2019, except in the Sand Region. In the groundwater at shallow depths (5 to 15 metres) beneath agricultural land in the Sand Region, the concentration increased between 1984 and 1996 from 38 to 46 milligrams per litre. The concentration fell to an average of 33 milligrams per litre between 2008 and 2011. The concentrations have remained steady since then, although the concentrations in 2018 and 2019 were below 30 milligrams per litre; it is not clear whether they will remain at that level – the concentration fell temporarily in 2008 too. The concentrations in the deeper groundwater (15 to 30 metres) in the Sand Region also fell slightly on average over the period, from 10 milligrams per litre in 1988-1991 to 6 milligrams per litre in 2012-2019.

The nitrate concentrations in fresh surface waters, averaged over the leaching season (winter), have dropped since 1992. This decrease was seen in both the agriculture-specific regional waters and the bodies of
water designated under the WFD. The same decrease was also seen in salt waters. For most of the types of waters, the concentrations fell most during the first 20 years. The decrease has been less rapid since about 2010. There are local cases where the improvement stopped or even where nitrate concentrations increased again slightly.

**Eutrophication**

The water quality in fresh waters improved a little between 2012 and 2018. The percentage of fresh waters that were assessed as eutrophic in 2016-2018 was a little lower than in 2012-2014. The percentage assessed as not eutrophic was somewhat higher. The quality of the salt waters decreased slightly. This is primarily because the classifications of those waters shifted from 'potentially eutrophic' to 'eutrophic'. Those waters initially had excessively high nutrient concentrations but the biological quality was still good. A small deterioration in the biological quality meant that their classification deteriorated.

It was only possible to evaluate the eutrophication of these waters according to the WFD method from 2011 onwards, as the WFD monitoring network for the surface waters only became fully operational after 2010. To show the developments before 2011, general water quality parameters have therefore been studied. Given the average chlorophyll and phosphorus concentrations (see Figure S4 for the former) in fresh WFD waters during the summer, the season when eutrophication effects can occur, water quality improved clearly between 1992 and 2011. That picture can also be seen in the transitional, coastal and open sea waters. The concentration fluctuated strongly after 2011. The chlorophyll concentration has even slightly increased locally in recent years, compared to the period 2012-2015.

![Chlorophyll (μg/l)](image)

*Figure S4 Chlorophyll-α (average summer concentration in μg/l) in fresh surface waters in the period 1990-2019.*
Effects of the action programmes and prognosis for how water quality will develop in future
The measures from a Nitrate Action Programme do not lead to instant water quality improvements. Measures are sometimes only introduced in law during the four-year term of the action programme and/or imposed at the end of the period. Moreover, changes in agricultural practices are sometimes only reflected in the water quality after a long time, as discussed above.

The measures that are implemented pursuant to the action programmes first have a manifest effect in the quality of the water on the farms themselves (leachates and ditch water). The full effect of the measures from the sixth action programme (2018-2021) on nitrate concentrations in leachates and ditch water from agricultural businesses are expected to become visible within five years of all the measures being introduced. It is anticipated that the same will apply for the nitrate concentrations in agriculture-specific waters, and then after some delay for the regional surface waters.

It may take several decades, depending on the depth, before the effects of the measures are seen in the nitrate concentrations in the phreatic groundwater at depths of over 5 metres. These effects will also be difficult to demonstrate because groundwater of various ages and origins gets mixed together. The processes below ground also affect this. The effects of measures will be less clearly expressed in the larger surface waters because other sources then have a relatively large effect. Measurements in these waters are therefore less suitable for creating a clear picture of the results of fertiliser policy early enough. Such measurements are of course still needed so that the quality of these waters can be measured and followed over time.

National Water Quality Analysis
In 2020, the Netherlands Environmental Assessment Agency (hereinafter referred to by its Dutch acronym, the “PBL”) created a picture of the effects that the sixth action programme had on the quality of surface waters. This was done so that the packages of measures for the following round of what are referred to as ‘river basin management plans’ (2022-2027) for the WFD can be drawn up. The PBL envisages the biological quality of the waters improving. There is then moreover substantive data and knowledge that can be used as the basis for modifying the targets. That can be done thanks to new knowledge about the efficacy of measures and thanks to a clearer picture of the feasibility of those measures.

The improved water quality, combined with updates of the WFD standards, means that more waters should meet the biological norms in 2027 than in 2018. However, despite the measures that are to be taken, not all the objectives will be achieved everywhere. If that is to be achieved, the PBL believes that more radical structural measures will be needed for some of the waters.

Conclusions
Since 1987, the Netherlands has managed to turn the increases in nitrogen and phosphate surpluses in agriculture during the period 1950-
1987 around, into a decrease. Nitrate concentrations in the water on farms have decreased as a result and eutrophication of the surface waters has lessened. The improvements are a consequence of measures that Dutch agriculture has taken as a result of the Dutch fertiliser legislation and the European Nitrates Directive. Examples are the tightening of norms for the application of manure and the introduction of fertilisation-free periods in the autumn and winter when the risk of leaching is high.

The production of animal manure and the manure surplus were further regulated between 2014 and 2018. This has been done by defining production rights for dairy cattle and rights for keeping chickens and pigs. This made it possible to get the output of nitrogen and phosphate from livestock back below the ceilings that were agreed with the European Commission in 2002. Those emissions had increased between 2012 and 2016. That was due to the gradual increases in European milk quotas since 2009 and their abolition in 2015.

Nitrate concentrations in the water leaching from farmland have risen since 2017. This has very probably been caused by a run of dry summers for several years.

In the majority of regions, the nitrate concentrations in the water leaching from farmland met the EU norm on average between 2016 and 2019. The concentration was too high at a proportion of farms within these regions.

The nitrate concentrations in the groundwater get lower as the measurements are made deeper down in the groundwater. The concentrations vary little if at all over time. In the shallow phreatic groundwater (at 5 to 15 metres) beneath agricultural land in the Sand Region, the nitrate concentrations may still be falling.

The quality of the surface waters has improved further since the previous period (2012-2015) but the improvements are only small. It is expected that it will not be possible to comply with the WFD norms for surface waters everywhere in 2027 despite the intended measures.
1 Introduction

1.1 General
This report is part of the country report produced by the Netherlands pursuant to Article 10 of the Nitrates Directive. It provides an overview of the fertiliser policy as previously and currently implemented and of the measures that have been taken in the context of the successive Nitrate Action Programmes. It also gives an overview of the status of agricultural practices and the developments therein, as well as of the quality of groundwater and surface water in the Netherlands during the period 1992-2019 regarding the nutrients nitrogen and phosphorus, and it gives an evaluation of the timescales for water quality changes as a result of changes in agricultural practices.

The Nitrates Directive aims both to protect drinking water sources and to prevent eutrophication of the aquatic environment. The Nitrates Directive focuses on limiting the nutrient burden of water caused by agriculture. The name of the directive is confusing, as it is not only about nitrate. To tackle or prevent eutrophication, attention also needs to be paid to nitrogen compounds other than nitrates (see Inset 1.1) and to phosphorus compounds.

This introductory chapter summarises the key obligations under the Nitrates Directive that are consequences of the directive’s objectives (see Section 1.2). The two obligations that are relevant for this report – namely monitoring (see Section 1.3) and reporting (see Section 1.4) – are discussed in detail. Section 1.5 gives a detailed description of the content of this report, the 2020 Nitrate Report. At the end of the chapter, as has indeed been done for all the chapters, there is an overview of the sources (see Section 1.6) plus a summary of the previous reports (see Section 1.7).

1.2 The Nitrates Directive
The European Nitrates Directive (EU, 1991) obliges member states to take various measures to achieve its objectives.

First of all, member states have to list the vulnerable areas within their territory (Nitrate Vulnerable Zones, or NVZ). These are areas where the water drains into freshwater bodies and/or groundwater (see Article 3 and Appendix 1 of the Nitrates Directive) that contain more than 50 mg/l nitrate or could contain that much if the measures described in the directive are not implemented. This also applies to surface fresh waters, estuaries and coastal and marine waters that are now eutrophic or could become so in the near future if the measures described in the directive are not implemented. Secondly, the directive obliges member states to set up Action Programmes for the designated vulnerable zones to achieve the objective of the directive (Article 5). Thirdly, member states are obliged to carry out appropriate monitoring programmes for determining the level of nitrate pollution in the water from agriculture and to investigate the effectiveness of Action Programmes (Article 5, sub 6 – see Section 1.4 for more information). Member states have to
report to the European Commission on the preventive measures they have taken, as well as on the results expected of and achieved by the Action Programmes (Article 10 – see Section 1.3 for more information).

**Inset 1.1 Nitrogen and nitrate**

Nitrogen in the environment is present in various forms. As nitrate (NO$_3^-$), it threatens the quality of drinking water. The standard of 50 mg/l NO$_3^-$ in the Nitrates Directive is a derived value that protects the quality of drinking water. Nitrogen occurs in the soil and water bodies in various other forms too, notably as ammonium (NH$_4^+$) and organically bound nitrogen.

The monitoring data for surface water bodies is intended to produce a picture of two aspects:

- The trend in water quality as the result of a burden of nutrients from various sources, and
- The trend in the ecological quality, focusing on the eutrophication status.

For the first objective, the most suitable data covers nitrate concentrations in the winter period, when biological effects on the concentrations are only small.

For the ecological quality, however, it is data from the summer period that matters and the sum of all forms in which the nutrients nitrogen and phosphorus are present is what matters.

Standards for nitrogen in water bodies are therefore derived for the average value of the total nitrogen concentration in the summer and are of the order of magnitude of 2.5 mg/l of nitrogen. For comparison, 50 mg/l NO$_3^-$ (nitrate) is equivalent to 11.3 mg/l N (nitrogen). The value of 50 mg/l for nitrate is therefore not a yardstick of good ecological quality. That is why chapters 6 and 7, which discuss the status and trends for water bodies, not only look at developments regarding nitrate but also devote a separate section to the eutrophication status of water bodies in the Netherlands, based on the parameters total N, total P and chlorophyll-α.

The Netherlands has not designated any Nitrate Vulnerable Zones but did inform the European Commission in 1994 that it would draw up an Action Programme in line with the Nitrates Directive for the territory of the Netherlands as a whole. According to a study in 1994 (Werkgroep Aanwijzing / Designation Working Group, 1994), agriculture is an important source of nitrate emissions into the groundwater and/or freshwater bodies and/or coastal waters. The working group therefore reached the conclusion that an Action Programme needed to be put into effect for the entire country. This conclusion was confirmed by a study carried out in 2010, following on from the Snijder motion in parliament about designating nitrate vulnerable zones (Schoumans et al., 2010).
1.3 Monitoring obligation

Member states that have designated vulnerable zones have different obligations from member states that apply their Action Programmes to their entire national territory.

Member states that designated vulnerable zones had to monitor nitrate concentrations in freshwater bodies and groundwater for at least one year within two years of notification of the directive (i.e. before the end of 1993) and to repeat that programme of checks at least every four years. This had to be done in order to identify vulnerable zones and revise the list of vulnerable zones. Monitoring to allow vulnerable zones to be identified does not have to be carried out by the same authority that monitors the effectiveness. The effectiveness of the Action Programme is monitored so that the impact of the measures taken on water quality can be assessed.

Member states that apply their Action Programme throughout their territory – like the Netherlands – must monitor nitrate concentrations in fresh water and groundwater to determine the level of nitrate pollution from agricultural activities. The directive does not set a time limit in this case. Given that the first Action Programme came into force on 20 December 1995, monitoring had to be carried out before that date in order to obtain the baseline situation.

The Nitrates Directive provides limited advice on implementing the monitoring. In fact, only a few monitoring guidelines are given for indicating vulnerable zones (see Article 6 and Appendix IV of the directive).

The European Commission sent a draft guideline for the monitoring process, in line with Article 7 of the directive, to the member states for comments in 1998. Revised versions were submitted in 1999, 2003 and 2004, but a finalised version has not been published yet. A guideline is not binding. The monitoring guideline is intended to define each of the types of monitoring and to propose possible working methods for the member states. Additionally, the Commission wants to ensure that it is possible to compare the monitoring systems of the member states against each other. Efforts have been made in particular for monitoring for the Water Framework Directive (WFD) and for the Groundwater Directive (GWD), for which ‘guidance’ documents have appeared. Additionally, there was a study several years ago into harmonisation of the monitoring and reporting for the WFD, the Nitrates Directive and what is known as the ‘State of the Environment’ (SoE), although this has as yet not produced any specific results.

1.4 Reporting obligation

Appendix 1 to the Nitrates Directive contains a description of the obligation to issue a report to the Commission about the preventive measures that have been taken and their results, and about the expected results of the measures in the Action Programme. That appendix sets out what information must be included in the reports that are produced every four years. In the Netherlands, this is a task for the
ministries of Infrastructure and Water Management (IenW and Agriculture, Nature & Food Quality (LNV).

Reporting obligations:
1. A description of the preventive measures that have been taken as per Article 4. According to that article, a code for Good Agricultural Practices (GAP) plus a promotional programme must have been drawn up within two years after the directive is published.
2. A chart in which the following information is shown: (a) surface waters that are affected by pollution or could become so; (b) the locations of the designated vulnerable zones, broken down into existing zones and those that have been designated since the previous report.
3. An overview of the monitoring results that were obtained to allow the vulnerable zones to be designated, including an explanation of the considerations leading to the designation of each vulnerable zone or to the revision of the list of vulnerable zones.
4. A summary of the Action Programmes that have been drawn up, in particular making the following aspects clear:
   a. the measures that are required relating to the use of artificial fertiliser, the storage capacity for manure and other restrictions on the application of artificial fertiliser, plus the measures that are prescribed in the GAP code;
   b. setting the maximum amount of nitrogen from animal manure that may be applied per hectare, namely 170 kg/ha;
   c. any extra or extended measures that have been taken to compensate for measures that were insufficient to achieve the directive’s objectives;
   d. a summary of the results of the monitoring programmes so that the effectiveness of the Action Programmes can be assessed;
   e. the member state’s assumptions about the anticipated timescale within which the measures in the Action Programmes are expected to have an effect, with an indication of the uncertainties in those assumptions.

This report focuses on points 4d and 4e of the reporting obligations, presenting the results that can be used for evaluating the effectiveness of the Action Programmes as a whole. Reporting on the results of the monitoring for the derogation is being done separately and is moreover done annually; see Lukács et al. (2020) for the most recent report.

1.5 The Nitrate Report

1.5.1 Scope and accountability
By mid-2020, the member states must have submitted their countries’ reports under the EU Nitrates Directive to the European Commission. In addition to the report, an associated data file with water quality data for the period 2015-2019 must be provided plus the text of their current fertiliser legislation and the associated decrees and regulations. The seventh national report covers the period from 20 December 2014 to 20 December 2019. The report should contain the results of the programmes that monitor the effectiveness of the Action Programme (point 4d in Section 1.3) plus an estimate of the anticipated timescale
within which the measures in the Action Programmes are expected to have an effect in the designated surface waters (point 4e in Section 1.3).

As was the case for the previous reports, the ministries that are responsible for the report for the Netherlands (see Section 1.3) requested the EU Nitrates Directive Monitoring Report Working Group (hereinafter also the “WEUM”) to draw up a report about the two topics mentioned above. The report you are reading now is the result of the activities of that working group.

The starting point for this report was the reporting guideline published by the Commission in 2020 (EC, 2020a, 2020b). This means that, in contrast to the earlier reports, the water quality data for the final year of the reporting period (i.e. 2019 in this case) has also been included. Given the efforts that were required to obtain this data in good time (before 1 July), to check it and to be able to provide it to the European Commission in the correct format, it was not possible to finalise the report before 1 July as well.

1.5.2 Explanatory notes to the report
This report consists of an introduction (this chapter), a description of the monitoring programmes and accountability for the data and methodology used (Chapter 2), a summary of the key policy developments and measures taken in the context of fertiliser policy since 1987, as well as developments in agriculture and agricultural practices (Chapter 3), the results of the monitoring programmes for obtaining a picture of the effectiveness of the Action Programmes (Chapter 4), the results of the monitoring programmes for assessing the trends in water quality (chapters 5 to 7), a prognosis for the trends in water quality in the future (Chapter 8) and a summary of the results in the previous chapters with conclusions. For the reader's convenience, a summary has also been given at the beginning of the report. To make sure that the chapters containing the results of the monitoring programmes can be read independently of one another, a separate listing of the sources used is given at the end of each chapter.

1.6 Source
1.7 Summary of previous reports

2016/2017 (English):

http://www.rivm.nl/bibliotheek/rapporten/2017-0050.pdf

2012 (English):
http://www.rivm.nl/bibliotheek/rapporten/680716008.pdf

2008 (English):
http://www.rivm.nl/bibliotheek/rapporten/680716003.pdf

2004 (English):

2000 (Dutch):
National monitoring programme

2.1 Introduction
There are various subprogrammes in the Netherlands for monitoring agricultural practices and the aquatic environment. Those subprogrammes focus on the following aspects: agricultural practices (see Section 2.2), the effectiveness of fertiliser policy (Section 2.3), the groundwater (see Section 2.4), water that is used for producing drinking water (see Section 2.5) and both fresh and saline water bodies (see Section 2.6). The subprogrammes are being carried out under the responsibility of various institutions and organisations.

This chapter gives a brief summary of the way the monitoring efforts have been set up within these subprogrammes. A general description has also been included of both the data collection and data processing methods. Details of the collection and processing of data can be found in the publications listed in the sources section.

2.2 Monitoring agricultural practices
2.2.1 General
Agricultural practices in the Netherlands are monitored in several ways. The monitoring programmes are discussed in the following section. Subsection 2.3.3 then explains the calculation of a mineral balance, the production and excretion of animal manure and nutrients, and the manure storage capacity.

2.2.2 Collecting data on agricultural practices
There are two agricultural monitoring programmes in the Netherlands: the Agricultural Census and the Farm Accountancy Data Network (FADN). Additionally, there are checks that the regulations are being observed.

Agricultural Census
Statistics Netherlands (hereinafter also “CBS”) collates general information for all farms about matters such as the areas under crops, the numbers of farm animals and organic farming (CBS StatLine, 2020). This annual data collection process is known as the Agricultural Census. The Agricultural Census is related to a European agricultural census, the Farm Structure Survey (FSS) that is held three times every ten years.

Farm structure surveys have been held for more than a century now and annually since the Second World War. The Agricultural Census was originally a CBS survey and later a joint survey by the CBS and the ministry of agriculture. Since 2002, it has been part of what is known as the 'combined declaration', carried out by the Netherlands Enterprise Agency (hereinafter also the “RVO”, formerly the Regulatory Service).

Up until 2009, the economic scale of agricultural businesses was expressed in ‘nge’ (Dutch Scale Units). From 2010 onwards, this was replaced by SY (Standard Yield). The SY is a standardised measure for the economic scale of agricultural businesses, based on the average...
annual yield per crop or category of animal. SY standards are determined for each crop type and for each category of animal. They are based on average values over a five-year period that are updated every three years. The SY of a farm is the sum of the individual SY figures for all its crops and animals. Based on the SY components for the various crops and animals within the overall SY, the farm is categorised into a farm type.

As of 2010, the threshold value for including farms when the Agricultural Census is published changed from 3 nge to 3,000 SY. The threshold value of 3,000 SY (and previously 3 nge) is only enough to exclude very small farms, for instance those with a single dairy cow or 100 m² of bell peppers. The change in threshold value had almost no effect on the size of the population included, incidentally. The proportion that is not covered by the Agricultural Census is negligible in terms of economic scale.

Starting from 2010, the categorisation by farm type and area also changed. In addition to a different basis and a slightly modified calculation method for determining the farm type, tree nurseries were no longer classified as farms with permanent cultivation. Tree nurseries are now classified as horticultural. Going the other way, open-field vegetables using arable methods are no longer deemed to be horticultural. The areas of arable-farmed vegetables are included in the arable farming area.

The changes from 2010 onwards have been implemented in StatLine for the reporting year 2000 onwards. This recalculation of the Agricultural Census data from 2000 to 2009 means that the series in StatLine are comparable as a time sequence. This report, and in particular Chapter 3, also uses data from before 2000, that has been adjusted so that the time series are comparable.

**Farm Accountancy Data Network**

Wageningen Economic Research collects more specific information about agricultural economics and technical management through the Farm Accountancy Data Network (FADN) (Lodder and De Veer, 1985; Vrolijk, 2002; Poppe, 2004). This information about agricultural management contains relevant technical information about the environment such as nutrient logs (imported and exported nutrients, including stock level differences), use of pesticides, water and energy consumption, application of artificial fertilisers and grazing frequency.

1,500 farms from the Agricultural Census are included in the FADN. They were selected using a random stratified sample and therefore constitute a representative selection of the Dutch agricultural sector. The Dutch local FADN network is part of a larger European Farm Accountancy Data Network (EU Regulation 79/65/EEC). Farms within the Dutch FADN are visited annually. Up until 2006, 15 to 20% of the farms included were replaced each year. Since 2006, that replacement process has been limited to farms that close down, move to a different region or stop participating for some other reason. As a result, the turnover rate for the farms is limited to 3 to 5%.
The Dutch FADN represents about 75% of the total number of farms and over 90% of the agricultural area and recorded agricultural production in the Netherlands (measured both in nge and in SY) (Roskam et al., 2020). Because of the switch in units from nge to SY, the remainder of the report will use nge as the economic measure where it is based on FADN data through to 1999 and SY from 2000 onwards.

To guarantee the representative nature of the FADN, farms of less than 16 nge or less than 25,000 SY (for which agriculture is generally not the main activity) will not be included in the network. Farms (especially glasshouse horticultural businesses) of larger than 1200 nge are less suitable for collecting data and have therefore not been included in the network either. As of the introduction of the SY, there is no upper limit on the size.

**Checking compliance with the regulations**

The Fertilisers Act comprises various systems. There are for instance rules focusing on the production of manure (animal production rights systems), the use of manure (application standards system) and the marketing of manure inside and outside the Netherlands (manure processing system and responsible growth of dairy farming). The systems are complemented by rules that put ‘good agricultural practices’ into effect. Administrative regulations ensure that the rules as drawn up can be monitored effectively.

**Application standards**

The amount of fertiliser used by a farm in a year will be calculated on using production, supply and removal figures for animal manure and the changes in stock levels on the farm on an annual basis. The balance of that calculation is set off against a farm’s space for applying it in the year in question. If there was no space on land that was in use on the farm for the manure that is assumed to have been applied, it is assumed that the application standards were breached.

A distinction is made between the following three application standards:

- the application standard for animal manure: the maximum amount of nitrogen that can be applied to or incorporated into the soil in the form of animal manure or a derogation from this standard;
- the nitrogen application standard for fertilisers;
- the phosphate application standard for fertilisers.

**Animal holding rights systems**

The heart of the animal holding rights systems is the ban on commercially producing animal manure from pigs, poultry or dairy cattle without production rights. An assessment is made at the end of a calendar year of whether a farm has met this requirement. Three types of animal production rights are distinguished:

- pig production rights;
- poultry production rights;
- phosphate production rights.

**Manure processing obligation**

Livestock farmers who produce more manure (phosphate) than can be used according to the application standards on land (including nature
reserves) that is in use on their own farms have been required since 2014 to have part of the surplus processed.

Rules for responsible growth of dairy farming/land-based growth of dairy farming
From 2015, the growth achieved by a dairy farm since 2013 must be accounted for. The growth of a farm after 2013 in terms of kilograms of phosphate produced must be fully usable on its own land or must be processed.

Rules on manure transport
Transport and storage of fertiliser is registered. When transporting manure, farms and intermediaries must complete an Animal Manure Proof of Transport (hereinafter also “VDM”). Various requirements have been set for the transportation and the VDM.

Rules for application/good agricultural practices
In addition to the application standards, the Nitrates Directive requires ‘good agricultural practices’ to be used when spreading fertilisers. There are therefore rules covering aspects such as the periods when spreading is allowed, manure storage capacity and similar.

Administrative regulations
The Fertilisers Act contains a large number of regulations aimed at making it possible to check if a farm is complying with the standards set for the production, application and removal. If a farm does not comply with these administrative regulations, it will be fined.

Approach taken to administrative checks
For the administrative enforcement of the Fertilisers Act, the Netherlands Enterprise Agency (hereinafter also “RVO”) uses two types of investigations: integral inspections and administrative obligations and transport checks. Carrying out an integral inspection means that a farm will be checked as a whole with regard to various elements of the Fertilisers Act, based on various data sources. This can for example be an integral check on the application standards, the duty of accountability, responsible growth of dairy farming and the obligation to process manure. This takes account year on year of the amount of fertiliser used and/or processed by a company annually. The checks carried out on the administrative obligations and transports focus on the forms being submitted and filled in.

Selecting farms
After the farm data is calculated for the first time, the RVO looks at which farms can be seen to be exceeding the standard.

- If the calculations show no exceedance, the RVO concludes that the farm is compliant and thus stops the administrative enforcement process.
- Farms for which an exceedance has been noted are classified into target groups; a selection is then made on the basis of the risk. The risk target groups are e.g. farms with derogation permits; the risk group of intermediary businesses is seen as a high-risk link in the manure chain and is also selected as a priority.
Investigating farms further
Farms are then selected from the various risk groups for further examination. This involves information that is available from the RVO and (where applicable) the report of findings by the Netherlands Food and Consumer Product Safety Authority (hereinafter also “NVWA”). Additionally, the contact may be asked to provide further information. If the regulations are not complied with, the farm first gets an opportunity to refute the intention to impose a penalty by providing alternative data.

Result
Once the investigations have been completed, a determination is made of whether an infraction has taken place. These infractions will be recorded on the basis of facts that have been infringed.
- If a different insight has not been demonstrated to the RVO’s satisfaction after the rebuttal opportunity, the penalty will be imposed. This can also involve imposing an order for incremental penalty payments, issuing a warning or revoking a licence.
- The outcome of the checks can also be used as input for further investigations.

2.2.3 Processing data about agricultural practices
Nitrogen and phosphorus balances
Statistics Netherlands calculates the nitrogen and phosphorus balances for the agricultural sector annually.

When drawing up and analysing balances, supply flows both for farmland and at the farm level must match the outgoing flows, including loss flows (see Figure 3.2). For livestock farming balances, the consumption of roughage and concentrates balances the mineral output of the livestock and the recorded production by the animals. The figures for the balanced items are derived in line with the methodology of the Working Group on Standardisation of data on Manure and Mineral (Van Bruggen & Gosseling, 2019). In the arable soil balance, the output flow “loss to the soil” equals the difference between the input flows and the other output flows. These figures correspond to the soil balance figures on StatLine (CBS StatLine, 2020).

The original method for drawing up the balances was described by Statistics Netherlands almost thirty years ago (CBS, 1992). It is still the basis for the nitrogen and phosphorus balances nowadays.

Occasional adjustments are made to the method as a result of improved understanding. For instance, the input of artificial fertiliser now includes only the part used by the agricultural sector, which means that the use of such fertilisers is some 4 to 8% lower than previously reported. A similar modification in terms of scale is the switch to a different estimation method for determining ‘manure export to destinations outside Dutch agriculture’. This is now consistent with the usual approach used in the NEMA (National Emission Model for Agriculture) (Van Bruggen et al., 2019). The NEMA is the model used to calculate emissions of ammonia, greenhouse gases and particulate matter from Dutch agriculture.
In addition to methodological changes, there are regular modifications to the source statistics; e.g. when a new time series on nitrogen emissions into the atmosphere from 1990 onwards was compiled via the Emissions Inventory. Other imports no longer include nitrogen fixation by free-living bacteria in the soil, whereas nitrogen fixation by clover/grassland, alfalfa and legumes is included. The artificial fertiliser figures from 2016 onwards have also recently been revised.

Nitrogen and phosphorus balance data is published by Statistics Netherlands through StatLine and the Compendium for the Living Environment. In 2017 and 2019, Statistics Netherlands also provided Eurostat with a detailed set of data (series from 1990 onwards including metadata). The two-yearly delivery has been compiled in accordance with a manual (Eurostat/OECD, 2013) that was drawn up in consultation with the EU member states. These figures (StatLine, Compendium for the Environment and Eurostat) are consistent with each other and correspond to the balance data given in Chapter 3 of this report.

These various modifications cause minor changes to the items constituting the balances and in particular in the nitrogen balance; in other words, the figures in this report may differ somewhat from the numbers given in previous reports. Nevertheless, this does not yield a different picture of developments in the nutrient surplus or losses to soil and the atmosphere. The trends are in line with those from earlier reports. There is no problem when comparing years in this report because retrospective adjustments have been made for previous years.

**Excretion and production of nutrients**
Statistics Netherlands calculates the manure and mineral production of the livestock using a nutrient balance per category of animals, combined with the number of animals per category in the Agricultural Census. This method is based on the excretion factors calculated for N and P from the balance, i.e. excretion is the dietary intake minus what is retained in animal products.

The basis for calculating the excretion factors comes from what are known as the “technical parameters”, data about the consumption of livestock feed and animal production per category of animals. Annually updated statistical information is used for this purpose as far as possible.

The results are made available through StatLine and Environmental Data Compendium, including an annual publication about the standardised calculation method and principles used (Van Bruggen & Gosseling, 2019).

**Manure storage capacity**
The manure storage capacity on livestock farms has only been included in the Agricultural Census for a few years of the monitoring periods (1993, 2003, 2007, 2010, 2014 and 2018). One part of the survey is about storage capacity on the farm for animal manure, in which the storage capacity has to be filled in (as a number of months) for various types of manure.
Data on manure production and storage capacity per farm can also be obtained from the Dutch Farm Accountancy Data Network (FADN) (see Subsection 2.2.2), which has a representative selection of Dutch farms. The FADN only contains data on slurry and not solid manure. That data has also been used in this report, more specifically in Chapter 4.

**Processing FADN data**

The methods for calculating nitrogen and phosphate surpluses and for calculating nutrient use via animal manure as set out in Chapter 4 are described in Subsection 2.3.3.

### 2.3 Monitoring the effectiveness of fertiliser policy

#### 2.3.1 General

The effects of the Action Programme are monitored through the regular monitoring programmes for groundwater and surface waters and by a specific programme, the Minerals Policy Monitoring Programme (hereinafter also “LMM”). The LMM was developed for measuring the effects of Dutch fertiliser policy on nutrient emissions (above all, nitrate emissions) from agricultural sources into groundwater and surface water and to monitor the effects of changes in agricultural practices on such emissions. The LMM thereby makes it possible to obtain a picture of the effects of the Action Programmes as well.

The LMM monitors not only the water quality but also the management – i.e. agricultural practices – at farms. The policy measures aim to change agricultural management in such a way that the water quality improves. The quality of the groundwater and surface waters is generally affected not only by agricultural practices but also by other sources of pollution and environmental factors such as the weather. To exclude other diffuse sources of pollution as far as possible, the quality of water leaching from the root zone and ditch water on farms is monitored. The consequences of recent agricultural activities (meaning less than four years ago) on the nitrate concentrations in particular can be observed in these types of water. In the case of phosphorus, the level stocked in the soil (and thereby past fertilisation) can still have a major influence on phosphorus concentrations measured in groundwater and surface waters. To distinguish between the effect of measures to improve water quality on the one hand and the influence of additional factors such as the weather on the other, those additional factors are also monitored. Data collection by the LMM is discussed in more detail in the following subsection (2.3.2). Subsection 2.3.3 discusses the data processing. Further details about the monitoring programme can be found on the websites [https://www.rivm.nl/lmm](https://www.rivm.nl/lmm) and [www.lmm.wur.nl](http://www.lmm.wur.nl), as well as inter alia in Van Vliet et al. (2017), De Goffau et al. (2012) and Fraters & Boumans (2005).

#### 2.3.2 Data collection about farms (Minerals Policy Monitoring Programme – LMM)

**LMM and FADN**

When the LMM monitoring programme was started up in the Sand Region in 1992, a decision was taken to link the LMM and the FADN (see Subsection 2.2.2) because of the many advantages this offers. Linking these networks makes data on agricultural management and water
quality available for all participating farms. Following the evaluation of
the first four-year period, it was decided in 1996 to continue this
cooperation. The character of Dutch agriculture and its highly dynamic
nature made the advantages of linking the FADN and LMM obvious. The
consequence was that companies participating in the LMM were replaced
by new companies after 6 to 7 years because they were actively
replaced in the FADN. Both the Basic Monitoring Network and the
Derogation Monitoring Network have had a fixed composition
since 2006, except for changes resulting from farm-specific
developments that mean specific farms no longer meet the criteria for
participation or because they stop operating. New participants are
recruited in such cases. The reports about the status and trends in water
quality at derogation farms are beyond the scope of this report because
there are already annual reports on them (see for example Lukács et al.,
2020).

Both the FADN and the LMM exclude certain farms from taking part. To
keep the selection representative, farms that are smaller than 16 nge
(or 25,000 SO) or larger than 1,200 nge are not included in the FADN
(see Subsection 2.2.2). In addition to these restrictions imposed by the
FADN, the LMM also applies a criterion that farms must be at least
10 hectares in size if they are to be included in the network.

In 2006, the LMM was extended due to the derogation granted by the
EU for using more than 170 kg nitrogen per hectare in the form of
animal manure on grazing livestock farms. In addition to the regular
monitoring programme (Basic Monitoring Network) for monitoring the
effects of manure policy on water quality on farms in the Netherlands,
the LMM has therefore had a Derogation Monitoring Network since 2006
specifically aimed at monitoring farms with derogations. Farms can take
part in both monitoring networks. Not all farms in the Derogation
Monitoring Network meet all the conditions for being included in the
Basic Monitoring Network, however. Farms that have been selectively
recruited, for instance as participants in projects such as ‘Koeien en
Kansen’ (Cows and opportunities) are not suitable for participation in the
Basic Monitoring Network.

The FADN sample is larger than the LMM sample. To make maximum
use of the information available in the FADN, farms in it that are not
participating in the LMM but do belong to the LMM sample population
have also been used to reflect agricultural practices.

Information about agricultural practices has been recorded annually for
all farms participating in the LMM ever since the LMM started. However,
for various reasons, information from the year preceding the water
sampling is not always available for all farms.

For the same reason that all suitable FADN farms are included for
describing the agricultural practices even if no sampling is done of the
water quality (namely to make the best possible use of the available
information), all farms participating in the Basic Monitoring Network are
used for the water quality reporting, plus randomly chosen dairy farms
from the Derogation Monitoring Network. The results of the sampling are
therefore also included even if no data on agricultural practices was
available for the previous year. The numbers of farms used for agricultural practices consequently differ from those used for water quality. The number of farms participating for water quality varied from year to year over the period 1992-2006 for all regions (see Table 2.2). From 2007 onwards, the number of farms per region has been reasonably constant and data on both agricultural practices and water quality is available for almost all farms. The number of unique farms for each reporting period and each farm type where water samples were taken (see Table 2.3) is greater than the number of farms in the individual years see (see Table 2.2), particularly in the period from 1997 to 2006, when a different set of farms was sampled annually. As a consequence, the average number of annual samples over a four-year period is often much less than 4. A total of more than 6,500 annual farm samplings were done on representative farms for evaluation purposes in the period 1992-2019. Sampling of ditch water was done at all farms in the Clay and Peat regions. In the Sand Region, however, only a limited number of farms have ditches. For that reason, ditch water was sampled at about 55 farms (see Table 2.4).

In the Netherlands, the effects of agricultural activities are seen in the measured nitrate concentrations in leachates after about a year. There are differences between the main soil type regions (Verloop et al. 2006; Meinardi, 2005; Meinardi & Van den Eertwegh, 1997). For that reason, the information collected in FADN about agricultural practices is linked to the LMM water quality measurements in later monitoring periods as shown in Table 2.5.

**Main soil type regions**
The Netherlands is applying the Action Programme for the Nitrates Directive throughout its territory. Nevertheless, the legislation makes distinctions between four soil types (sand, clay, peat and loess) that differ in how vulnerable they are to nitrate leaching and for which the prescribed measures differ (see Section 3.1). Multiple soil types can however occur on a single farm. The dominant type of soil has therefore been determined for each administrative unit in the Netherlands (see following paragraph). These units have been aggregated into what are known as ‘main soil type regions’, which are further referred to just as ‘regions’. The monitoring programmes are oriented to the key regions in the Netherlands: the Sand, Loess, Clay and Peat regions (see Map 2.1, left).

The split within these regions was improved retrospectively in 2012/2013. It is now based on postcode areas, whereas it was previously based on municipal boundaries. The benefit of using these four-digit postcode areas is that they are less likely to change than the boundaries of the municipalities. When municipal boundaries were used, the map had to be updated fairly regularly because of municipal restructuring. The classification based on postcode areas is also more refined, reducing the numbers of discrepancies between the dominant type of soil on a farm and that of the region in which it is located.
The state of the aquatic environment on farms has been described for the four regions. The regions consist of one or more areas (see Map 2.1, right). The boundaries of the sandy soil areas are based on the provincial boundaries:

- Sand North: Friesland, Groningen and Drenthe;
- Sand Central: Overijssel, Gelderland and Utrecht;
- Sand South: Noord-Brabant and Limburg;

This is in line with the division of sandy soils in the Fertilisers Act Implementing Regulation (LNV, 2020).

Map 2.1 LMM classification into main soil type regions (left) and eleven areas (right), with the split into four sandy soil areas within the Sand Region based on the provincial boundaries. The split into areas within the Clay Region and the Peat Region is in line with the standard LMM breakdown.

Main farm types

The LMM focuses on the farm types that use the largest proportions of agricultural land (arable farming and dairy farming). In most regions, other farm types that have farm animals are also included in the LMM (see Table 2.1). These are factory farms (farms with mainly pigs and/or poultry) and other livestock farms. This selection is restricted so that the variation in agricultural practices and water quality within the sample is constrained. This allows better monitoring of changes in agricultural practices and water quality.
Table 2.1 Farm types included in the LMM Basic Monitoring Network, per region.

<table>
<thead>
<tr>
<th>Farm type</th>
<th>Sand Region</th>
<th>Loess Region</th>
<th>Clay Region</th>
<th>Peat Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable farms</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dairy farms</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Factory farms</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other livestock</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

1 These are crop/livestock combinations and extensive livestock combinations.

Sampling and other methods of data collection
Water quality on farms is monitored by sampling and analysing water leaching from the root zone and ditch water (if present). The leachates are measured by:
- sampling water from the soil in the unsaturated zone below the root zone (1.5 and 3.0 metres below ground level) where the groundwater is more than 5 metres below ground level (especially in the Loess Region);
- sampling the upper metre of phreatic groundwater where the groundwater is less than 5 metres below ground level (especially in the Sand, Peat and Clay Regions);
- sampling drain water where the plots of land of a farm are drained using tile drains (Clay Region).

Additional information about natural parameters such as the amount of precipitation and evaporation of water by the crop and from the soil, the fraction of the area for each type of soil and each groundwater depth regime class is collected and used to explain the influence that these natural parameters have on the measured results using additional model calculations (see Subsection 2.3.3).

Sampling unit
The sampling unit used in the LMM is the farm. This unit was chosen because Dutch legislation regulates agricultural practices at the farm level, because agricultural management can be monitored more easily at the farm level than at any other level (e.g. per plot of land) and because agricultural management is also monitored at the farm level in the FADN (see Subsection 2.2.2.). Reporting is however only done at the level of groups of at least ten farms so as to protect the anonymity of the participants.

Monitoring strategy
The monitoring strategy (number of farms, sampling method and sampling frequency) differs between regions and water types. The monitoring strategy depends on the expected change in water quality over time and the magnitude of change that is intended to be detectable, the variation in time and space, the organisational and financial aspects of sampling, and the geohydrological conditions.

Number of farms and sampling frequency
The current number of farms and the sampling frequency in the LMM are based in part on the statistical analysis of the results of the studies carried out in the period 1992-2012. This covers studies in the Sand Region in the period from 1992 to 1995 (Fraters et al., 1998) and in the
Clay Region (Fraters et al., 2001) and Peat Region (Fraters et al., 2002) in the period from 1995 to 2002. The ideal sampling frequency was examined again in 2010 (Ferreira, 2010).

The studies showed that there were three main sources of variation in nitrate concentrations. In decreasing order of importance, these are:

1. differences in nitrate concentrations between farms of the same farm type;
2. differences in nitrate concentrations between years on a single farm;
3. differences in nitrate concentrations between sampling points on a single farm in a given year.

A fourth source of variation was the differences in nitrate concentrations between the farm types, but its contribution was smaller. The outcome of a statistical analysis of the variation shows that taking a limited number of samples from a large number of farms and sampling only a limited number of times on each farm throughout the period that they are taking part in the LMM is more effective than frequently taking a large number of samples at a limited number of farms. Specifically, the fact that nitrate concentration differences between farms are the main source of variation justifies this approach.

As well as statistical considerations, organisational and financial aspects of sampling also play a role in setting up a monitoring programme and in defining the number of farms and the sampling frequency. Consider the effort needed to include a farm in the monitoring network, for instance, and to stay in touch with the participant, the travel time needed between farms and the number of samples a sampling team can take per day at a farm. From that point of view, it is cheaper to take lots of samples on a single farm, with the number of samples set to the number that can be taken in one day. An additional limiting factor is the number of farms taking part in the FADN that are suitable for participation in the LMM.

Until 2006, the number of farms in the FADN that were eligible to take part in the LMM programme was large compared to the number of farms actually needed for the LMM. In the Sand, Loess and Peat regions, the most effective and financially viable strategy was sampling the LMM farms in years 1, 4 and 7 of their participation only. In the Clay Region, where most of the water is artificially drained off by tile drainage and samples are taken from the drain water, sampling farms every year turned out to be more effective and financially viable.

A change took place in 2006 due to the European Commission’s requirement imposed with the derogation granted to allow more nitrogen to be applied per hectare in the form of animal manure than the maximum of 170 kg laid down in the Nitrates Directive. From that year onwards, samples have been taken every year at all farms participating in the LMM.
Table 2.2 Number of farms in the LMM where the water quality was measured during the period 1992-2019.

<table>
<thead>
<tr>
<th>year</th>
<th>Sand Region Dairy farms</th>
<th>Arable farming</th>
<th>Other</th>
<th>Clay Region Dairy farms</th>
<th>Arable farming</th>
<th>Other</th>
<th>Loess Region¹ Dairy farms</th>
<th>Arable farming</th>
<th>Other</th>
<th>Peat Region Dairy farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>67</td>
<td>18</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1993</td>
<td>65</td>
<td>19</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>32</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1995</td>
<td>63</td>
<td>18</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1996</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>14</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1998</td>
<td>16</td>
<td>11</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>17</td>
<td>8</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>24</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>28</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>28</td>
<td>10</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2003</td>
<td>37</td>
<td>18</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>58</td>
<td>15</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>62</td>
<td>14</td>
<td>29</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>118</td>
<td>15</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>104</td>
<td>35</td>
<td>44</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2008</td>
<td>97</td>
<td>34</td>
<td>45</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>104</td>
<td>32</td>
<td>43</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>103</td>
<td>30</td>
<td>47</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>105</td>
<td>33</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>109</td>
<td>39</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>116</td>
<td>36</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>121</td>
<td>38</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2015</td>
<td>134</td>
<td>40</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>136</td>
<td>41</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2017</td>
<td>133</td>
<td>41</td>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>134</td>
<td>42</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>126</td>
<td>40</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

¹ Samples for 2019 in the Loess Region are not yet available for this report.
Table 2.3 Number of farms in the LMM and the number of years\(^1\) in which the water quality was measured for each period during the years 1992-2019.

<table>
<thead>
<tr>
<th>Period</th>
<th><strong>Sand Region</strong></th>
<th><strong>Clay Region</strong></th>
<th><strong>Loess Region</strong></th>
<th><strong>Peat Region</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dairy farms</td>
<td>Arable farming</td>
<td>Other</td>
<td>Dairy farms</td>
</tr>
<tr>
<td>1992/'95</td>
<td>71 (3.2)</td>
<td>19 (2.9)</td>
<td>7 (2.6)</td>
<td></td>
</tr>
<tr>
<td>1996/'99</td>
<td>46 (1.0)</td>
<td>28 (1.0)</td>
<td>31 (1.0)</td>
<td>22 (1.2)</td>
</tr>
<tr>
<td>2000/'03</td>
<td>85 (1.4)</td>
<td>32 (1.4)</td>
<td>42 (1.3)</td>
<td>51 (2.1)</td>
</tr>
<tr>
<td>2004/'07</td>
<td>156 (2.2)</td>
<td>48 (1.6)</td>
<td>88 (1.4)</td>
<td>68 (1.8)</td>
</tr>
<tr>
<td>2008/'11</td>
<td>116 (3.5)</td>
<td>42 (3.1)</td>
<td>64 (2.5)</td>
<td>59 (3.5)</td>
</tr>
<tr>
<td>2012/'15</td>
<td>151 (3.2)</td>
<td>47 (3.3)</td>
<td>36 (2.6)</td>
<td>64 (3.4)</td>
</tr>
<tr>
<td>2016/'19</td>
<td>145 (3.6)</td>
<td>45 (3.6)</td>
<td>38 (3.2)</td>
<td>57 (3.5)</td>
</tr>
</tbody>
</table>

\(^1\) The number in parentheses is the average number of years in which a farm was sampled during the period; 1 means once over the four years and 4 means every year.

\(^2\) Samples for 2019 in the Loess Region are not yet available for this report.

Table 2.4 Number of farms in the LMM in the Sand Region at which ditch water samples were taken.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>26</td>
<td>28</td>
<td>48</td>
<td>48</td>
<td>54</td>
<td>55</td>
<td>55</td>
<td>57</td>
<td>58</td>
<td>53</td>
<td>55</td>
<td>54</td>
<td>54</td>
<td>55</td>
<td>55</td>
</tr>
</tbody>
</table>
Table 2.5 Relationship between data on agricultural practices in a specific year and the water sampling period\(^1\) that has provided the data linked to that agricultural data, for all regions defined in the LMM. Green = agricultural year, dark blue = standard period, light blue = overrun option in cases where weather conditions made it impossible to complete the sampling earlier.

| Month                  | Jan-Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|------------------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Agricultural data      |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Soil moisture          |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| in the Loess Region\(^2\) |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Groundwater            |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| in the entire Sand Region     |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Groundwater            |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Sand Region (Low)\(^3\) |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Groundwater            |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Clay Region\(^3, 4\)   |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Groundwater            |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Peat Region\(^3\)      |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Drain water             |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| ditch water, all regions |         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

1) A somewhat non-standard sampling period was sometimes used in the past. The actual sampling date was always recorded.
2) Sampling only at temperatures of < 20°C and when there was no precipitation.
3) The start of sampling depends on the amount of precipitation. Sufficient precipitation must have fallen before leaching into groundwater occurs. Sampling is started as soon as it becomes possible to sample the drainage water in the area, and by no later than 1 December.
4) The groundwater at farms is sampled twice in the Clay Region; the second round starts in February.
2.3.3 LMM data processing

Nutrient surpluses

The nitrogen and phosphate surpluses in the soil balance, as presented in Chapter 4, are calculated using a method derived from that described and used by Schröder et al. (2004, 2007) and as described in Appendix 2 to the Derogation Report for 2018 (Lukács et al., 2020). This means that, alongside the input quantities of nitrogen and phosphate in organic and artificial fertilisers and the output quantities in crops, allowance is also made for other sources of input, such as net mineralisation of organic substances in peat and reclaimed peat soils, nitrogen fixation by leguminous plants, 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, the sequestration of organic nitrogen in the form of crop residues and organic manure (immobilisation) will be equal to the annual decomposition (mineralisation). An exception to this rule is made for peat and reclaimed peat soils: for these soil types, an input for net mineralisation is taken into account of 160 kg of nitrogen per hectare for grassland on peat soils and 20 kg of nitrogen per hectare for grassland on reclaimed peat soil or for other crops on peat and reclaimed peat soils. It is known that net mineralisation occurs on these soils as a result of groundwater table management, which is needed in order to use the land for agriculture. Schröder et al. (2004, 2007) define the excess going into the soil (known as the ‘soil balance’) as the difference between the amounts of nutrients applied to the ground (partly calculated and partly recorded) and the nutrient yields in the crops (also partly calculated and partly recorded). In this study, the excess going into the soil is calculated from the difference between application and removal at the farm level (Lukács et al., 2020), with the application and removal figures relying largely on records.

Nitrogen in animal manure

To calculate the application of nutrients through animal manure in Chapter 4, the production of manure on the farm is calculated first. In the case of nitrogen, this is the net production, i.e. nitrogen excretion minus gaseous nitrogen losses from the stables and manure storage. Manure production by grazing livestock is calculated by multiplying the average number of animals present by the applicable statutory excretion standards (Netherlands Enterprise Agency/RVO, 2020 and preceding years). Farms using what is known as the BEX guide (Farm-Specific Use of Animal Manure) are an exception to this (see Appendix 2 in Lukács et al., 2020). The stabling balance method is used for manure production by stabled animals, except where insufficient data is available or when the animals are owned by third parties. In that case, the numbers of stabled animals concerned are multiplied by the national excretion standards defined by the Manure and Mineral Figures Standardisation Working Group (Van Bruggen & Gosseling, 2019). Please refer to Lukács et al. (2020) for more details.

Moreover, the quantities of nutrients are registered for all fertiliser inputs and outputs and all fertiliser stocks (artificial fertilisers, animal manure and other organic fertilisers). The quantities of nitrogen and phosphate in the inputs and outputs are determined by sampling. If
sampling has not been done, standardised concentrations for each type of fertiliser are used (RVO, 2020). The initial and final stock levels are calculated using concentrations from the stables balance and/or from the said guide if it was used, or otherwise using standardised figures (RVO, 2020).

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

\[
\text{(Quantity of fertiliser used on farm)} = (\text{Net Production}) + (\text{Initial stock}) - (\text{Final stock}) + (\text{Application}) - (\text{Removal})
\]

The quantities of fertilisers used on arable land are registered directly in the Farm Accountancy Data Network (FADN).

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

\[
(\text{Manure applied on grassland}) = (\text{Manure applied on farm}) - (\text{Manure applied on arable land})
\]

If the proportion of grassland is less than 25% of the total cultivated land, the amounts of fertiliser recorded in the FADN for grassland will be used as the figure for manure applied on grassland. The application of manure on arable land is then:

\[
(\text{Manure applied on arable land}) = (\text{Manure applied on farm}) - (\text{Manure applied on grassland})
\]

This quantity of fertiliser used on grassland comprises fertilisers spread on the land and manure excreted directly by grazing animals on grassland (grassland manure). The quantity of nutrients in grassland manure is calculated for each animal category by multiplying the excretion standards by the percentage of the year that the animals spend grazing (RVO, 2020).

Please refer to Lukács et al. (2020) for more details.

**Weighting of data on agricultural practices**

The farms in the FADN are selected using a stratified sample in which the number of farms per stratum is not always proportional to the number that it represents in the sample population, which means that weighting is needed if the FADN data is to be extrapolated to agricultural practices as a whole (Van der Veen et al., 2014). The standard weightings in the FADN are less applicable for the agricultural practices that are to be described in this report because e.g. the location is not included.

Statistical matching is used for the weighting. Vrolijk et al. (2005) have described that method; it is summarised briefly below. Two datasets are produced as the inputs. The first dataset contains the farms in the sample population (in this case, farms in the Agricultural Census that are between the lower and upper size limits, with at least 10 hectares of...
farmland and covered by the LMM farm types) plus the characteristics that are going to be used for the matching. The second dataset contains the sample farms with the same characteristics (also available from the Agricultural Census). The farm characteristics (also referred to as the ‘imputation variables’) are the basis then used for comparing and matching the sample farms and the target population of farms against each other.

The imputation variables vary somewhat from one farm type to the next; the proportion of grassland is one of the imputation variables for dairy farms, for instance, and the proportion of grain crops is one for arable farms. In statistical matching, the farm characteristics that are known in both the sample and the sample population are used for determining a number of ‘most similar’ sample farms for each farm in the sample population. A distinction can be made here between features that match exactly (or are required to do so) – for example the type – and features of the sample farm that are as similar as possible (or are required to be so) to the farm in the sample population – for example the proportion of grassland. The features that are to be matched as closely as possible can again be weighted according to how important they are deemed to be. Each farm from the sample population is matched to a number of farms from the sample, with those various sample farms being given weightings that all add up to 1. The best matching farm gets the highest weighting (the chance of each of the best matching sample farms being equally similar to the sample population is small).

**Weighting and averaging the nitrate concentrations**

Annual mean nitrate concentrations for regions or farm types and the averages of other parameters are calculated by working out the average for the annual means at the farm level. The average values for each of the four-year periods are calculated by working out the average for each period of all the average farm concentrations per period.

The LMM is a stratified sample in which the number of farms in each stratum is not always proportional to the area of farmland that those farms represent. For example, the number of arable farms in Sand South is now equal to the number of arable farms in the other sandy soil areas. That is to say, 50% of the LMM arable farms in the Sand Region are in Sand South, whereas the land area of these farms in Sand South is only 25% of the total area of arable land in the Sand Region. When calculating an area-weighted average for a category of farms within a region and for the average of a region, the area that a stratum represents is therefore taken into account. The cumulative distributions of farm averages, as shown in Section 4.3, are also area-weighted.

**Statistical analyses and effects observed**

The residual maximum likelihood – or REML – method (Payne, 2000) is used for statistical analysis of the relationship between agricultural management and nitrate concentrations in the water that leaches out of the root zone. This method is used for standardising the measured nitrate concentrations for the effects of the annually fluctuating natural conditions (such as precipitation) and the varying sample (replacement of farms) on the measured nitrate concentrations (Boumans et al.,
2001, 1997), so that the effects of policy are better expressed. This method is available for the programmes in the Sand Region and the Clay Region. The standardisation method has been improved several times, first in 2011 (Boumans & Fraters; 2011) and then in 2016 (Boumans & Fraters, 2017). Detailed precipitation and evaporation data is now used. Instead of the measured nitrate concentration, a measure for nitrate leaching is now used in standardising the nitrate concentration. For this purpose, the measured nitrate concentrations are divided by the relative precipitation surplus in which the nitrate has dissolved. The indexed nitrate concentration is subsequently derived from the indexed nitrate leaching data and an area-weighted average is calculated (Boumans & Fraters, 2017).

The preprocessing of the data and the statistical analyses were carried out using R (R Core Team, 2019) within RStudio (RStudio Team, 2016). The packages nlme (Pinheiro et al., 2019) and emmeans (Lenth, 2019) were used for determining the standardised concentrations and the package spatstat (Baddeley et al., 2015) was used for calculating the area-weighted cumulative distributions. The package dplyr (Wickham et al., 2020) was used for preprocessing the data.

2.4 Monitoring the status and trends for nitrate in the groundwater

2.4.1 General
Monitoring of deeper groundwater (> 5 metres below ground level) is done in the Netherlands the same way as in many other countries (Koreimann et al., 1996), i.e. using permanent wells that have been put in place especially for monitoring purposes. These observation wells are downstream from and just outside the fields, to make sampling easy without hindering the work in the fields. Each observation well has at least two screen (each 2 metres long) at varying depths through which the groundwater can be sampled. The first screen for sampling groundwater at shallow depths (5 to 15 metres depth) is at least 1 to 2 metres below the average lowest groundwater level, but no more than a couple of metres below. It may then be assumed that:
   a) the screen is not in the unsaturated zone, and
   b) the sampled groundwater does come from the adjacent plot.

The quality of the groundwater at this depth reflects the effects of the agricultural practices of approximately ten years ago. For any individual well, this naturally depends on the geohydrological situation at that spot.
This report has used data from the National Groundwater Quality Monitoring Network (LMG).

2.4.2 Groundwater data collection
The National Groundwater Quality Monitoring Network (LMG) was set up between 1979 and 1984 and it consists of approximately 350 monitoring locations, each with an observation well, spread throughout the Netherlands (Van Duijvenbooden, 1987). The key criteria for selecting the locations were the type of soil, the land use and the geohydrological conditions. Groundwater samples are taken at each of these locations at depths of 5 to 15 metres (shallow groundwater) and 15 to 30 metres (medium-deep groundwater) below ground level. Table 2.6a gives the
numbers of monitoring locations used for this study for all types of land use and sampling depths. For the Sand Region, there is also a breakdown into the number of monitoring locations for each of the sandy soil areas (see Table 2.6b).

Table 2.6a The number of monitoring locations for which complete\(^1\) data series are available for the period 1984-2019 for all regions, types of land use and sampling depths.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Depth (metres)</th>
<th>Sand</th>
<th>Clay</th>
<th>Peat</th>
<th>Loess</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-15</td>
<td>121</td>
<td>67</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>120</td>
<td>66</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>Agriculture</td>
<td>5-15</td>
<td>55</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>52</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Nature</td>
<td>5-15</td>
<td>27</td>
<td>22</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>28</td>
<td>20</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>5-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Series were complete or sufficient data was available to produce estimates for the points with missing data (see Fraters et al., 2004).

Table 2.6b The number of monitoring locations for which complete\(^1\) data series are available for the period 1984-2019 for farmland in the Sand Region for each area and sampling depth.

<table>
<thead>
<tr>
<th>Depth (metres)</th>
<th>Sand North</th>
<th>Sand Central</th>
<th>Sand South</th>
<th>Sand West</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-15</td>
<td>42</td>
<td>37</td>
<td>37</td>
<td>5</td>
</tr>
<tr>
<td>15-30</td>
<td>42</td>
<td>37</td>
<td>36</td>
<td>5</td>
</tr>
</tbody>
</table>

\(^1\) Series were complete or sufficient data was available to produce estimates for the points with missing data (see Fraters et al., 2004).

**Sampling frequency**

Samples were taken annually between 1984 and 1998 at the locations; see the results of Reijnders et al. (1998) and Pebesma & De Kwaadsteniet (1997). After an evaluation in 1998 (Wever & Bronswijk, 1998), the sampling frequency was reduced for certain combinations of soil types and depths. In sandy soils, samples are still taken every year for the shallower monitoring locations, whereas samples are only taken for the shallower points every two years for the other soil types (clay and peat). For the deeper-lying points, a sample is taken once every four years, as it is for the shallower monitoring locations where the chloride concentrations are high (above 1000 mg/l because of marine influences). Additionally, locations were discontinued where the monitoring locations were excessively affected by local conditions (e.g. close to rivers and local sources of pollution). The number of locations at which samples are taken annually has thus been cut back from 756 to approximately 350. The National Institute for Public Health and the Environment (RIVM) manages the network and is responsible for interpreting and reporting on the data.

**2.4.3 Groundwater data processing**

The LMG monitoring locations that are affected by riverbank infiltration have not been included in the analysis.

Because of the way the LMG is set up, there are monitoring locations that are not sampled every year. Estimates are made of all missing data
so that incorrect trends that arise from the setup of the monitoring network can be avoided. These estimates are calculated by interpolating the available data at other points in time. For data that is missing at the beginning or end of a series, the initial or final available data point respectively is used for estimating the missing information. The annual average concentrations are simply calculated using the measured concentrations. The average concentration in a period is calculated by working out the mean of the period averages for each location. The breakdown into regions and areas is the same as for the LMM (see Subsection 2.3.2 and Map 2.1). The averages for the Sand North, Sand Central and Sand South areas were determined separately for the LMG monitoring locations in the Sand Region.

2.5 Monitoring the status and trends for nitrate in water that is used for producing drinking water

2.5.1 General

Drinking water companies carry out monitoring programmes that emphasise the quality checks on the water (both groundwater and surface water) that is used for production, on the production process and on the final product. These companies are legally obliged to issue reports annually on the results to ILT (the Human Environment and Transport Inspectorate). Data management is handled by RIVM using the REWAB database (Company Water Quality Records). Drinking water companies report on the quality of drinking water in the REWAB database. The reporting has been done since 2013 by the ILM (Human Environment and Transport Inspectorate) and before that by RIVM. This report uses data about the quality of the groundwater that is used for producing drinking water. Because that groundwater is generally extracted at greater depths, there is a substantial delay between measures being taken in the groundwater protection zones and them affecting the quality of the water that is used for producing drinking water.

2.5.2 Data collection regarding untreated water for drinking water production

Drinking water supplies in the Netherlands have been provided since July 2010 by ten drinking water companies (ILT, 2019). Roughly 55% of drinking water comes from groundwater (Vewin, 2017). A distinction is made between phreatic and Artesian groundwater. A phreatic aquifer is not confined on the upper side by a less permeable layer and its groundwater table is free to vary. Artesian groundwater is confined both above and below by a less permeable layer. As a result, the hydraulic head within the aquifer may be higher than the upper boundary of the aquifer (it is therefore also called pressurised groundwater or confined groundwater). In 2019, there were 159 drinking water production locations that used groundwater. Of those, 90 used phreatic groundwater and 69 used Artesian groundwater. There are 16 locations where drinking water is produced from river bank groundwater, dune infiltration water and surface water bodies (see Table 2.7). The average depth of groundwater from phreatic ground strata that is used for drinking water production is 45 metres. The average filter depth ranges from 30 metres to 65 metres. 70% of the sources have average depths of > 30 metres; 30% of the sources are at depths of less than 30 metres.
The concentration is measured for a ‘chain’ that consists of several linked wells. A monitoring location often consists in turn of several such chains (De Wit et al., 2020). The minimum, maximum and average are determined for the chains for each monitoring location. Measurements are made multiple times per year for each monitoring location (between 1 and 4 times), and sometimes monthly or weekly.

2.5.3 Data processing for raw water used for drinking water production

An additional database has been set up for processing the data about drinking water to take account of the issue of the fluctuating number of drinking water production locations in the period from 1992 to 2019. This was done using a Restricted Maximum Likelihood (REML) procedure (Payne, 2000). The software programme R was used in the REML model to calculate estimated nitrate concentrations per year (R Core Team, 2019; Pinheiro et al., 2019). In this, the pumping station is what is known as a random effect and the sampling year is a fixed effect. The result is an estimated nitrate concentration for the year that models the effect of whether or not a pumping station was present during that year. This is a method for handling unbalanced data (in this case, data in which the same number of monitoring locations were not sampled in every year).

The drinking water data was used in the chapter on groundwater (Chapter 5, Section 5.4) for the production facilities that use phreatic and Artesian drinking water.

In this report, both the average and the maximum were determined for each drinking water production location, based on the average of the chains. The annual maximum at a location is the highest maximum value of the chains. The annual averages and maximums for the period 1992 to 2019 are based on the supplementary database. The annual averages and maximums have been calculated as mean values and as mean maximums of all locations used for producing drinking water.
Table 2.7 Number of drinking water production locations in the Netherlands during the period 1992 to 2019.

<table>
<thead>
<tr>
<th>Year</th>
<th>Phreatic groundwater</th>
<th>Artesian groundwater</th>
<th>Surface water</th>
<th>Dune infiltration</th>
<th>Riverbank infiltration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>127</td>
<td>86</td>
<td>11</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>1993</td>
<td>126</td>
<td>85</td>
<td>12</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>1994</td>
<td>125</td>
<td>87</td>
<td>12</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>1995</td>
<td>123</td>
<td>86</td>
<td>13</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>1996</td>
<td>123</td>
<td>86</td>
<td>13</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>1997</td>
<td>121</td>
<td>87</td>
<td>12</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>1998</td>
<td>120</td>
<td>86</td>
<td>12</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>1999</td>
<td>117</td>
<td>86</td>
<td>12</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>2000</td>
<td>117</td>
<td>87</td>
<td>12</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>2001</td>
<td>113</td>
<td>82</td>
<td>10</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>2002</td>
<td>105</td>
<td>84</td>
<td>8</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>2003</td>
<td>108</td>
<td>82</td>
<td>8</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>2004</td>
<td>106</td>
<td>81</td>
<td>5</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>2005</td>
<td>102</td>
<td>78</td>
<td>3</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>2006</td>
<td>109</td>
<td>78</td>
<td>5</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>2007</td>
<td>101</td>
<td>78</td>
<td>5</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>2008</td>
<td>94</td>
<td>74</td>
<td>5</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>2009</td>
<td>98</td>
<td>74</td>
<td>5</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>2010</td>
<td>95</td>
<td>74</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>2011</td>
<td>96</td>
<td>72</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>2012</td>
<td>95</td>
<td>72</td>
<td>10</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2013</td>
<td>91</td>
<td>72</td>
<td>10</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2014</td>
<td>92</td>
<td>72</td>
<td>10</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2015</td>
<td>93</td>
<td>70</td>
<td>10</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2016</td>
<td>92</td>
<td>70</td>
<td>10</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2017</td>
<td>90</td>
<td>70</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2018</td>
<td>90</td>
<td>70</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2019</td>
<td>90</td>
<td>69</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

The tables and the maps used to represent the status for each period and the trends over the periods are based on the original database. An average value has been calculated for each drinking water location for each period, based on one to three annual averages or maximums. Only the locations that were monitored during both periods (2012-2015 and 2016-2019) were used for comparison.
2.6 Monitoring status and trends of nutrients in surface waters and their eutrophication status

2.6.1 General
Not all surface waters in the Netherlands are delineated as water bodies for the Water Framework Directive (WFD). In general, only surface waters of a certain size are delineated as water bodies and the numerous ditches, canals and other small surface waters that the Netherlands can boast are not delineated as such. The WFD applies to all waters, however: delineation as a water body is only used to show that reporting about it is required. The WFD objectives therefore apply to all waters and measures must be taken where necessary for all surface waters.

Several monitoring networks for nutrients in surfaces waters are up and running in the Netherlands. In sequence from smaller to larger surfaces waters, these are:
- the Minerals Policy Monitoring Programme (LMM) for ditches on farms (see Section 2.3);
- the Agriculture-Specific Waters Monitoring Network (MNLSO) for regional waters;
- the monitoring networks of the water boards for the regional waters designated under the Water Framework Directive (WFD);
- the monitoring network of the Directorate-General for Public Works and Water Management (RWS) in the national waters designated under the WFD;
- the RWS monitoring network in the transitional and coastal waters designated under the WFD;
- the RWS monitoring network in the open sea.

The networks for monitoring surface waters comprise the monitoring networks for regional and large freshwaters on the one hand, and for transitional waters, coastal waters and the open sea on the other. The division into freshwaters, transitional waters and coastal waters is in line with the WFD. The current report uses the data measured by all WFD monitoring locations in both regional and national waters. This therefore fulfils the desire of the ministries of IenW and LNV for the maximum possible alignment with the water quality reports issued in the context of the WFD. RWS and the water boards are responsible for sampling, analysing and reporting on these WFD monitoring locations in national and regional surface waters respectively. RWS is moreover responsible for water quality monitoring in the open sea.

The regional WFD monitoring locations generally cover a much larger catchment area than any single farm; they differ in this respect from the LMM monitoring locations. These regional WFD monitoring locations are also affected by other anthropogenic nutrient emission sources than agriculture, such as discharges from urban areas.

The Agriculture-Specific Waters Monitoring Network (MNLSO) was therefore set up in 2010-2012 to monitor water quality in terms of nutrients in agriculture-specific waters. Existing monitoring locations with agriculture as the only anthropogenic source of nutrients were selected from all the water boards for this monitoring network.
Additionally, locations were chosen with a minimum influence of seepage and nutrient load due to inlet water. Some of these locations (37) are also WFD monitoring locations. The results from these monitoring locations are therefore reported in both categories. The MNLSO monitoring network is also the water boards’ responsibility.

When the surface waters from the various monitoring networks are compared against one another, the component of the nutrient load due to agriculture decreases relatively in the recipient waters in stages, in this order:
- leaching from the root zones on farms (LMM, see Chapter 4);
- ditch water at farms (LMM, see Chapter 4);
- regional agriculture-specific surface waters (MNLSO, see Chapter 6);
- regional surface waters in the WFD (see Chapter 6);
- national waters in the WFD (see Chapter 6);
- transitional waters in the WFD (see Chapter 7);
- coastal waters in the WFD (see Chapter 7);
- open sea (see Chapter 7).

Because of the increasing distance between the location where the agricultural activities take place and the water quality sampling location, the relationship between the agricultural activity and the water quality measurement will also decrease rapidly along this series. Several factors play a role here. The proportion of agricultural land (genuinely fertilised area) in the catchment area decreases; this is 100% for LMM, lower for MNLSO (79% on average, ranging from 15 to 99%) and even lower in the catchment areas for the WFD monitoring locations (on average close to the national figure of 54%). Biochemical processes have an increasing influence in the progression from the plot level to the sea (uptake, denitrification and sequestration), particularly in the summer. The influence of other sources (sewage treatment plants, discharges) increases for monitoring locations in larger bodies of water, just as the effect of river water from the Rhine and Maas increases from the plot level to the sea.

2.6.2 Data collection for surface waters
To describe the quality of regional surface waters, this report has used the monitoring locations that are also used for checking against the standards for nutrients; these are the WFD monitoring locations. Where present, monitoring data from 1990 onwards was also used (Van Duijnhoven et al., 2019). For the waters that are primarily affected by agriculture, the MNLSO monitoring locations were used, as they were in the previous report (Buijs et al., 2020). These constitute a separate set. Some of the MNLSO monitoring locations (about a quarter of them) are also in the WFD dataset for regional waters. A distinction is made within the WFD waters between national and regional waters.

In line with the EU reporting guidelines (EC, 2020a and 2020b), this report treats nitrate nitrogen as the key variable when representing the effects of agriculture on the quality of surface waters. The eutrophication status is assessed using an evaluation of the biological condition and an evaluation of the nutrient status in the water bodies. The benchmarks
drawn up for this use the average summer values for total nitrogen and total phosphorus, expressed in mg/l as N and mg/l as P respectively.

The separate N components are determined for most of the monitoring locations: Kjeldahl N (sum of nitrogen as NH₄ and organic nitrogen), nitrogen as NO₂, nitrogen as NO₃ and/or the sum of nitrogen as NO₂ and NO₃; total nitrogen can be calculated on that basis. Total nitrogen is measured directly at a number of locations. In cases where nitrate is not determined in a sample, the nitrate concentration is calculated (if possible) from the total nitrogen and the other forms in which nitrogen is present in the water. In saline waters, the dissolved inorganic nitrogen (DIN) concentration and the salinity are also determined. Total phosphorus is measured at almost all locations. For measurements that are below the reporting limit (for all the data presented in Chapter 7 and for calculations of the averages and trends), a figure of half the reporting limit is used.

To allow an assessment to be made of the biological condition, measurements are made at the WFD locations of phytoplankton (in lakes, canals, coastal waters and transitional waters) and phytobenthos or other water plants (in rivers). For phytoplankton, both the abundance (chlorophyll-α concentration) and the species composition are determined.

To allow the data for 2019 to be included in this report as well, all water managers have been asked to provide the data for that year early. Thanks to those extra efforts, it is already possible to give a picture of the status and the trends through to 2019 for the nutrients and for chlorophyll-α.

For determining the eutrophication status, this report directly uses the evaluated assessment as provided by the water managers. Assessment of the eutrophication status is based on average values for a period of three years; in this report, that has been done for the most recent period for which the evaluations are available, namely 2016-2018.

**RWS monitoring locations**
The Directorate-General for Public Works and Water Management (RWS) collects data from 38 observation points in the sea (including the estuaries in Zeeland) and 37 points in large freshwater national waters, such as major rivers, canals and lakes. Seawater samples are taken once a month in the winter and twice a month in the summer. In freshwater bodies, water samples are generally taken every four weeks.

In the previous Nitrate Report, saltwater lakes (code M32) were categorised with the coastal and transitional waters. In this report, those lakes have been placed with the freshwater bodies. Two water bodies are affected: the Veerse Meer and Grevelingenmeer lakes. There are two arguments for doing this:
- These two water bodies have almost no interaction with the marine environment, so their dynamics are more like those of freshwater bodies.
- Given the relationship between sources of nutrients and the quality of the waters plus the measures that are possible (in line
with the DPSIR method: the Driver-Pressure-Status-Impact-Response model), these saltwater lakes fit in better with freshwater bodies than marine ones.

ELECTING TO DO THIS HAS LED TO A SMALL SHIFT BETWEEN THE ‘SALINE’ AND ‘FRESHWATER’ CATEGORIES.

**Regional monitoring networks**

The 21 water boards have their own regional monitoring networks, comprising several thousand monitoring locations in regional fresh surface waters.

A large proportion of the measurements taken are more for specific projects and only cover a limited measurement interval and/or focus on a specific issue; those measurements are therefore not suitable for looking at trends. The report for the Nitrates Directive therefore only uses the data from the WFD and MNLSO observation sites, as submitted by the water boards to the Water Information House (IHW). The sampling frequency varies, but as a general rule measurements are taken once every four weeks at all these locations. The data has been recorded and described in detail in two background documents, KRW-NUTrend (WFD – Nutrient status and trend analysis; Van Duijnhoven et al., 2019) and MNLSO (Status and trends through to 2018; Buijs et al., 2020).

**Regional WFD waters**

Several regions in the Netherlands have finely branched water systems. To obtain a clear picture of these water bodies, the water managers in those regions have chosen to take measurements at multiple locations that they will then aggregate into a single monitoring location. This gives the manager a good overview of developments in water quality in the water bodies, without individual monitoring locations in relatively small waters weighing disproportionately in the water quality picture.

Three of the 21 water boards have multiple monitoring locations in a number of water bodies that they merge to form single monitoring locations. There is a single case for one water board where a monitoring location comprises over 20 monitoring locations, but usually only two or three monitoring locations are combined. Reporting based on the monitoring locations is in line with the reports submitted by the water boards within the context of the WFD.

This report presents data from 818 regional WFD monitoring locations. This is more than twice the number of locations presented in 1990. Taken as a whole, this dataset provides a good and balanced picture of the water quality of the regional WFD water bodies.

**Agriculture-Specific Waters Monitoring Network (MNLSO)**

Over the period 1990-2019, the number of monitoring locations in agriculture-specific surface waters increased from 60 to 168. Since the previous report, data from the MNLSO monitoring locations has been used for presenting developments in agriculture-specific surface waters. This monitoring network provides a good picture of the water quality status in terms of nutrient concentrations in agriculture-specific waters,
i.e. ones where agriculture is the only anthropogenic source of nutrients. Extensive research has been carried out together with the water boards into the characteristics of the catchment areas of the monitoring locations used and the sources that are present in that catchment area. This ensures that the monitoring locations meet the monitoring network’s criteria: that agriculture is the only anthropogenic source and there is very little or no influence from seepage and inlet of water from elsewhere.

The data for those locations is extracted from the IHW water quality portal and included in the MNSLO database.

2.6.3 Data processing for surface waters

Calculating the average values and trends

Annual averages are only calculated for locations where there are at least nine observations in a year. The summer and winter averages and maximums are based on locations for which at least four measurements are available in the season concerned. For saline waters, a winter average (taken from December to February) is calculated if at least two measurements have been taken. The winter and summer averages and maximums for all locations will be calculated respectively as the mean of the winter and summer averages and of the winter maximums of all monitoring locations in surface waters that satisfy the minimum numbers of measurements as stated.

For determining the nitrate trendlines, the only sites included are those for which a monitoring series of at least ten years is available, five of which must be in the period from 2009 onwards with at least five measurements in the winter half-year for fresh surface waters and at least two measurements for saline surface waters. If the measurement series is longer than ten years, the years with fewer than ten measurements per year are also included. About two thirds of the MNLSO monitoring locations (108 of a total of 168 sites) currently have measurement series of more than ten years, which makes it possible to look at trends in nutrient concentrations for those sites as well. This is also the case for over half (60%) of the regional WFD monitoring locations. Trends can be determined for 94% of the monitoring locations for the WFD national waters.

The trendlines for the WFD monitoring network monitoring locations and the MNLSO were calculated using LOWESS (LOcally WEighted Scatterplot Smoothing). This was done by determining a trendline for every monitoring location and then, using the same method, calculating aggregated trendlines (see Buijs et al., 2020). The LOWESS trendline can be used for signalling whether a trend is becoming more or less pronounced over time. These LOWESS trendlines are aggregated for each monitoring location to make a LOWESS trendline for each type of water body – regional or national waters or agriculture-specific. The quartile LOWESS trendlines (25th and 75th percentiles) are also calculated. Together, the LOWESS quartile trendlines give the bandwidth within which 50% of the concentration measurements fall.
**Definition of summer and winter**

A distinction is made between the summer and winter half-years when assessing the quality of water bodies and the effect of agriculture on them. The six summer months of April through to September are the key period for eutrophication. The EU water quality standard of 50 mg/l for nitrate (hereinafter the “EU standard”) is primarily intended for determining the effects of agriculture on water quality. In that respect, the winter months – when leaching plays a major role – are very important. For fresh surface waters, the winter period is defined as the months from October through to March.

The winter period is defined differently for seawater than for freshwaters. There is still biological activity in the seawater during October and November. Those months are therefore not included when calculating the winter averages for transitional, coastal and marine waters. Data measured in the sea also shows that biological growth already starts occurring in March, with nitrogen therefore being sequestered in biomass. The data for March is therefore not suitable for the analysis of nutrient development. The analysis of nutrient concentrations in seawater is therefore based on a winter period from December through February. To measure the evolution of water quality (eutrophication), the nitrogen concentrations in seawater are compared over time. To prevent this creating a distorted picture, the data is analysed for the months during which the biological activity is virtually zero.

This has led to the following definitions and criteria for determining the winter average, summer average and annual average for the various parameters.

**Winter average**

For the winter average in fresh surface waters, the period used runs from October through March. The associated year is taken as that of the months January to March, meaning that October through December belong with the subsequent year (Testing and assessment protocol, RWS, 2020). For example, Winter 2019 covers the months October 2018 through March 2019. A location is included in the report if there are at least 4 measurements for each winter half-year. The winter average for each period is then the mean of the winter averages calculated for the individual years during the period in question. As per the agreements within OSPAR (2013), the winter period for saline waters runs from December through February. The year number used for reporting is that of the January. For calculating a winter average, at least two measurements must be available per location.

**Summer average**

The months April through September are used for calculating the summer average. Similarly, locations are only included in the report as a summer average if at least four measurements are available in the months concerned. The summer average for each period of four years is the mean of the four summer averages for the individual years during the period in question.
Annual average
The annual average is calculated over the months January through December. A precondition for this is that there must be at least nine measurements available for each monitoring location included in any given year.

Differences in salinity
The nutrient concentration in seawater remains more or less steady during the winter period, exhibiting a clear and linear relationship with the salinity: the nutrient concentration increases as the salt concentration decreases. In other words, nutrient concentrations fall as you get further away from the river estuary. As a consequence of differences in river drainage, the salinity also varies at the various locations from one year to the next and so therefore do the concentrations of other substances.

Flow patterns in the sea are of some importance, as they may also cause small differences from other rivers somewhat further away (e.g. the Seine, Somme, Scheldt and Thames), as may atmospheric deposition. The background concentration at sea is determined by the concentrations in the Atlantic, which are assumed to be constant.

To correct for these influences, the nutrient concentrations provided for OSPAR are usually normalised for the salinity (Bovelander & Langenberg, 2004). However, this can only be done at locations in a straight line from the coast, from the estuary to a point offshore where there is no influence from the river, giving a salinity-nutrient correlation for a specific river. This can only be done for a limited number of the points presented in this report. That is why a decision has been taken not to normalise the data in this report for the salinity. The conclusions based on the trends in nutrient concentrations are therefore affected by the annual fluctuations in river drainage (as a consequence of precipitation differences).

The eutrophication characteristic
The eutrophication characteristic is an evaluation of the eutrophication status of the water bodies into three classes (namely non-eutrophic, potentially eutrophic or eutrophic), based on the biological condition and/or the nutrient status of the water bodies. The amounts of nitrogen and phosphorus in the water largely determine how fertile that water is. Phytoplankton and phytobenthos are parameters that are sensitive to how rich in nutrients the water is. Under natural conditions, water type-specific exceedance of standards for these parameters will point to eutrophication. Eutrophication leads to an undesirable disequilibrium between the various organisms present in the water and then to deterioration in water quality. Deviation from the eutrophication status of surface waters without human influences is therefore not desirable.

The majority of surface waters in the Netherlands are however artificial in nature or have been significantly modified. For these water bodies, comparable evaluation systems have been developed that are based on benchmarks for natural surface waters and that take account of the heavily changed characteristics of the water. However, the standards for eutrophication-sensitive parameters vary very little (if at all) from those
for natural surface waters. However, there may be a greater deviation in specific cases, for instance if the increased nutrient concentrations are the result of the significantly modified characteristics of the water body. One example of this is low-lying polders with old marine deposits or peat soils. In these areas, the groundwater table is often kept unnaturally low (a significantly modified characteristic), for example to allow agriculture. As a result of peat degradation, among other things, this leads to nutrient concentrations that are greatly increased. A different nutrient standard then applies in these specific surface waters. All standards and assessments are available and explained for each waterbody, with justifications stated. These are available in the factsheets that are part of the management plans for 2016-2021 for water bodies and river basins within the WFD (IHW, 2020a). The standards defined in the summer of 2019 have been used for the water body assessments in this report.

The previous report included not only the eutrophication indicators chlorophyll-α, phosphorus and nitrogen, but also – for the first time – a eutrophication characteristic in accordance with EU requirements on assessment and classification of eutrophication (Reporting Guide subsection 5.3.2, ‘Eutrophication in freshwater and seawater’; EC, 2020a). Where applicable, these indicators comply with the EU Commission decision on intercalibration (2013/480/EU). The applicable quality elements of the benchmarks for natural surface waters have been adjusted in line with that decision. They are available in ‘References and benchmarks for natural water types 2021-2027 (Van der Molen et al., 2018).

The member states themselves are responsible for deriving standards for nutrients. The EU standard of 50 mg/l NO₃ (winter average) is aimed at protecting the quality of drinking water. Nitrate is just one of the forms in which nitrogen can be present. The figure of 50 mg/l NO₃ is equivalent to 11.3 mg/l N, making it three to five times higher than the standards for achieving a good eutrophication status and therefore not a good benchmark for the ecological water quality within the WFD.

The definition of ‘eutrophic’ or ‘potentially eutrophic’ waters is used for showing that they do not meet the criteria of ‘good’ to ‘very good’ for the parameters mentioned above (see also EC, 2020a).

- Eutrophic: surface waters in which biological quality elements (including phytoplankton and phytobenthos) score below ‘good’ are deemed to be eutrophic, regardless of the score for N or P.
- Potentially eutrophic: surface waters in which the biological quality elements are scored as ‘good’ but N and P both score below ‘good’ are deemed to be potentially eutrophic.
- Non-eutrophic: surface waters in which both the biology and one of the nutrients are scored as ‘good’ are deemed to be non-eutrophic.

The eutrophication level of the surface waters is based fully and exclusively on data and information from all WFD water bodies: freshwater and coastal and transitional waters. The testing is done using standards that are specific to the type of water body, with the various types split into two main groups: the M-types (from the Dutch for “lake”
– non-flowing waters, including ditches and canals) and the R-types (from “rivers” – flowing waters, including smaller streams). The statuses ‘artificial’ and ‘significantly modified’ can be assigned to water bodies belonging to a particular type (e.g. M12) and category (M, R, K or O, whereby the last two are from the Dutch for “coastal” and “transitional”). In the Netherlands, we have opted for separate standard targets for water bodies that have the status ‘artificial’.

The results are reported for each water body.

- For the M-types (“lakes” in the table below), the assessment is based on the summer average concentrations of total N, total P and phytoplankton (with chlorophyll-α as the measure for the abundance and the species composition of the phytoplankton for ‘blooming’). If there is no phytoplankton data, the assessment for “other water flora” is used. In most cases, these are ‘artificial’ or ‘significantly modified’ water bodies.

- For the R-types (“rivers” in the table below), the assessment is based on total N, total P and phytobenthos or “other water flora”.

- For coastal and transitional waters, the assessment is based on the dissolved inorganic nitrogen (DIN) concentration and on phytoplankton. DIN is the sum of nitrogen as nitrite (NO₂), nitrate (NO₃) and ammonia (NH₄). For phytoplankton, chlorophyll-α is measured for the abundance and the species composition is used for ‘blooming’. A review and harmonisation of marine eutrophication parameters are underway as part of OSPAR; this report has done the assessments as per the current protocols.

The assessments of water bodies have been submitted to the IHW by the regional and national water authorities for the WFD reporting. Assessments are based on three-year averages; in this report, that has been done for the most recent period for which the evaluations are available, namely 2016-2018. The previous period being used for comparison is 2012-2014.

As regards coding eutrophication statuses into classes, the new reporting guideline (EC, 2020a, 2020b) states that this can be done in three classes instead of five. This fits in well with the system used in the Netherlands, which distinguishes between non-eutrophic, potentially eutrophic and eutrophic. Table 2.8 below shows the final classes for eutrophication in water bodies based on the biology and nutrient assessments. The specific criteria for each water body can be found on the water quality portal (IHW/Water Information House, 2020b).
Table 2.8 Evaluation matrix for eutrophication in water bodies, based on the assessments of the status in terms of biology and nutrients.

<table>
<thead>
<tr>
<th>Type</th>
<th>Biology</th>
<th>Nutrients</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phyto-plankton</td>
<td>Other water flora</td>
<td>Total P</td>
</tr>
<tr>
<td>M (lakes)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>R (rivers)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>−</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Quality is good
Quality is not good

In the previous report, the figures distinguished between national WFD waters, regional WFD waters and agriculture-specific waters, but the tables only distinguish between KRW surface waters and agriculture-specific surface waters. In this report, we have decided to give as much of the information as possible as figures and maps rather than as tables, each time distinguishing the three categories in those figures. The tables accompanying the figures will be published separately on the RIVM website.

2.7 Sources


3 Agricultural practices

3.1 Introduction
This chapter deals with the development of agricultural policy and regulations (see Section 3.2) and of agriculture in the Netherlands in general, such as developments in land use and livestock (see Section 3.3), as well as what this signifies for nutrient balances (see Section 3.4). It also discusses the development of agricultural practices, addressing manure storage and transport, the actual fertilisation, crop cover in winter, water consumption, ammonia emissions and compliance with fertiliser legislation (see Section 3.5). The changes in agriculture in general and in agricultural practices are the result of the said policies, autonomous developments and informational and demonstration projects involving measures for reducing nitrogen leaching and improving water quality (see Section 3.6). An overview of the benefits for production and for the environment plus the costs of various measures is included in the final section (see Section 3.7).

Because of rounding, individual items may sometimes be higher or lower than the totals shown in the tables presented in this chapter.

3.2 Developments in agricultural policy and regulation

3.2.1 Periods
Dutch fertiliser policy can be divided roughly into four periods, namely 1987-1997, 1998-2005, 2006-2013 and 2014 to date. The first period is about fertiliser policy development, the second covers the MINAS period during which nutrient balances and fertiliser transfer contracts were controlled, and from the third period onwards, animal manure and artificial fertiliser supplies have been used for steering instead of surplus nutrient balances. The fourth period features tighter regulation of manure production and responsible disposal, as well as national regulations being supplemented by local projects involving close cooperation with all parties concerned in order to improve water quality. These projects aim to help achieve the objectives of the Water Framework Directive by 2027. The four periods are not exactly aligned with the periods of the six Action Programmes since 1995 (1995-1999, 1999-2003, 2004-2009, 2010-2013 2014-2017 and 2018-2021).

3.2.2 A sketch of recent developments
The current Nitrate Action Programme (the sixth) covers the period 2018-2021; the effects of this programme on agricultural practices and in particular on water quality are therefore as yet only partially quantifiable. The figures in this report therefore largely show the effects of the previous Action Programme (the fifth), covering the period 2014-2017. The full effects of an Action Programme become visible in rapidly responding water systems about five years after it ends.

From 2012 onwards, there was an increase in nitrogen and phosphate excretion by farm animals as a result of dairy farmers anticipating the abolition of the European milk quota system, which led to a growth in dairy herds (see Subsection 3.3.4). The consequence was that the...
ceilings agreed with the European Commission for total nitrogen and phosphate excretion were exceeded. Measures were taken that made it possible to bring the total phosphate excretion after 2016 back below the phosphate ceiling. However, the emphasis in recent years has shifted to cutting down on nitrogen excretion, as remaining under the nitrogen ceiling is a problem in that regard. The measures taken focused on reducing livestock levels and cutting down on the nitrogen content in feed concentrates.

The nitrogen application standards for animal manure on sandy and loess soils were tightened up in 2014 for derogation farms in the country’s central and southern provinces. Moreover, all derogation farms have been required since 2014 to have at least 80% of their area as grassland instead of 70% as had been required until then. In that same year, the application standards for plant-available nitrogen on grassland were tightened for all soil types (except clay soil), as they also were for various arable crops. Additionally, tighter nitrogen standards applied from 2015 onwards for crops on sand and loess soils in the area Sand South and in the Loess Region than applied for other sandy soil areas. From 2017 onwards, less stringent nitrogen standards have applied for arable farm crops that in previous years yielded larger crops than average. Subsection 3.2.4 gives a more detailed sketch.

Since 2014, artificial phosphate fertiliser may no longer be applied at farms that use a derogation. Phosphate application standards were reduced in 2015 for both grassland and arable land. There were more generous phosphate standards in the period 2017-2019 for arable crops that had produced above-average yields in previous years. This scheme expired in 2020, as phosphate standards from then on have been specified on the basis of the soil phosphate status. There were three different classes until 2020, but five classes have been distinguished from that year onwards (see Subsection 3.2.4).

Over the recent period, various measures have been taken to regulate manure production and manure processing so that manure is used responsibly (see Subsection 3.2.5). Furthermore, the period during which manure may be applied on arable land was reduced by two weeks from 2019 onwards (see Subsection 3.2.6).

Agriculture is the most important source of ammonia emissions in the Netherlands (see Subsection 3.5.5.2). The government also took steps to reduce nitrogen emissions by introducing the Nitrogen Action Programme (hereinafter also “PAS”) in 2015. This was however discontinued in 2019 because of legal issues.

**3.2.3 Nitrate Vulnerable Zones**

The Netherlands always applies each Nitrate Action Programme to its entire territory, but does differentiate between soil types and areas that are more or less susceptible to leaching and run-off into groundwater and surface water. The regulations distinguish between four types of soil: sand, loess, clay and peat (see Map 3.1). For the sandy soils, the regulations differ somewhat between areas. Four sandy soil areas are distinguished, based on the provincial boundaries (see Map 2.1).
3.2.4 Regulating the use of nitrogen and phosphate fertilisers

Even before the Nitrate Directive was introduced in 1991, the Netherlands had adopted legislation to regulate the use of fertiliser. Measures were taken from 1987 onwards to restrict the application of animal manure through fertiliser legislation. To do that, application standards for phosphate (here defined as $P_2O_5$) were drawn up that determined a maximum level for the application of animal manure. These application standards were tightened up after 1990 almost every year (see Table 3.1). This also further limited the amount of nitrogen applied to land via animal manure.

Map 3.1 Map showing the types of soil in the Netherlands and natural watercourses for which a crop-free buffer zone or a no-fertiliser, no-spray grass buffer zone of 5 metres must be allowed.

Source: Alterra (2006)
Table 3.1 Application standards for animal manure in the period 1987-2000, in kg phosphate (as P₂O₅) per hectare.

<table>
<thead>
<tr>
<th>Year</th>
<th>Grassland</th>
<th>Silage maize</th>
<th>Arable land</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987-1990</td>
<td>250</td>
<td>350</td>
<td>125</td>
</tr>
<tr>
<td>1991-1992</td>
<td>250</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>1993</td>
<td>200</td>
<td>200</td>
<td>125</td>
</tr>
<tr>
<td>1994</td>
<td>200</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>1995</td>
<td>150</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>1996-1997</td>
<td>135</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>1998-1999</td>
<td>120</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2000</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
</tbody>
</table>

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

In 1998, the Dutch government introduced a system for declaring the use of minerals (MINAS), which was based on the mineral balances of nitrogen (N) and phosphate (P₂O₅) ‘at the farm gate’, at least for livestock farms. Working with standard elimination figures was permitted for arable farms. For each farm, MINAS defined how high the nitrogen and phosphate surpluses could be (MINAS loss standards). MINAS did not regulate artificial fertiliser and fixation separately, but counted up total mineral flows (including feed, animals, animal products, etc.). Farmers could therefore switch between those various components as long as the total loss standard was not exceeded. The system thereby regulated farms’ nitrogen and phosphate surpluses. Limited nitrogen and phosphate surpluses were considered acceptable and were not subject to levies. The loss standards for nitrogen were gradually tightened over the period 1998-2005 (see Table 3.2). If farmers had surpluses greater than the loss standard, they were required to pay a levy. Those charges were gradually increased between 1998 and 2003. The MINAS system was introduced in phases. When introduced in 1998, it was initially restricted to livestock farms with a high livestock density (> 2.5 livestock units per ha). From 2001 onwards, the system applied to all farms. From that year onwards, lower loss standards were set for arable land on sandy and loess soils, as these are more vulnerable to nitrogen leaching than clay and peat soils (see Map 3.1).

Table 3.2 Nitrogen loss standards in the period 1998-2005 in kg nitrogen (N) per ha for arable and grassland on clay, peat, sand and loess soils.

<table>
<thead>
<tr>
<th>Year</th>
<th>Grassland All</th>
<th>Grassland Sand/loess</th>
<th>Arable land All</th>
<th>Arable land Sand/loess</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998-1999</td>
<td>300</td>
<td>300</td>
<td>175</td>
<td>175</td>
</tr>
<tr>
<td>2000</td>
<td>275</td>
<td>275</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2001</td>
<td>250</td>
<td>250</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2002-2003</td>
<td>220</td>
<td>190</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2004</td>
<td>180</td>
<td>180/160</td>
<td>135</td>
<td>100/80</td>
</tr>
<tr>
<td>2005</td>
<td>180</td>
<td>180/140</td>
<td>125</td>
<td>100/80</td>
</tr>
</tbody>
</table>

1 The lowest standard applies for sand and loess soils that are susceptible to nitrate leaching (see Map 3.3).
Source: LNV (2004, 2001b, 1997a)

As part of the MINAS system, applying nitrogen as fertiliser and nitrogen fixation by leguminous plants (for arable land only) were also included.
As stated earlier, the Netherlands applies each Nitrate Action Programme to its entire territory, but does differentiate between soil types and areas that are more or less susceptible to leaching and run-off into groundwater and surface water. Special lower nitrogen loss standards were introduced in 2002 for farms with sandy soils that are particularly susceptible to nitrate leaching. At the time, a total of 140,000 ha of land was designated where the soil is susceptible to nitrate leaching (see Map 3.2). This information was later used (2006) to introduce use standards for sandy soils, i.e. by an area-weighted method (based on the areas for each type of sandy soil) derived from the application standards for sandy soils that are and are not susceptible to leaching.

Map 3.2 Map showing areas where the soil is prone to nitrate leaching (red areas; 140,000 ha), moderately susceptible (blue; 220,000 ha) or slightly susceptible (green; 240,000 ha).

Source: LNV (2001a)
The system of Manure Transfer Contracts (MAOs) came into effect on 1 January 2002, thereby complying with the application standards for animal manure laid down in the Nitrates Directive. Farms that produced too much manure were obliged to sign MAOs with e.g. arable farms, less intensive livestock farms or manure processing companies. To calculate the exceedance above the permitted manure production level, an application limit of 170 kg nitrogen per hectare was set (introduced in phases). A higher limit of 250 kg/ha applied for grassland. These standards were set so that they were aligned with the notification given by the Netherlands at the time about derogation. Livestock farmers who were unable to sign MAOs to dispose of their excess manure were required to reduce their livestock levels. This policy change was accompanied by extensive advisory campaigns and demonstration projects.

The MINAS system was rejected by the European Court of Justice in October 2003 as an unlawful implementation of the Nitrates Directive, after which the Dutch government decided to abandon MINAS and the manure transfer contracts system. The MAO system was abolished at the beginning of 2005.

The Netherlands introduced a new fertiliser policy in January 2006, based on application standards rather than loss standards (LNV, 2005b). The new fertiliser policy has more restrictions on the application of nitrogen and phosphate, in comparison to MINAS. From 2006 onwards, the Dutch fertiliser policy applied to all manure from animals that are kept for professional purposes and/or for making a profit. This fertiliser policy has a broader scope of applicability than the policy prior to 2006. Manure from horses is also covered in the new legislation, for instance. For grassland, the transition from MINAS to the new system initially meant that more fertiliser could be used.

The system has separate application standards for applying nitrogen from animal manure, plant-available nitrogen and total phosphate. The application standard for nitrogen from animal manure is 170 kg N per ha.

**Derogation**

Grazing livestock farms can use exceptions (known as derogations) to the rule that a maximum of 170 kg/ha of nitrogen from animal manure may be applied as long as they fulfil certain conditions where manure from grazing livestock is concerned. For manure from animals like veal calves, pigs and poultry, these farms cannot use a derogation. The conditions for derogations were tightened up in 2014 and since then, the maximum application standards for animal manure depend on the location of the farm and the soil types present on it (see Table 3.3) (EZ/Ministry of Economic Affairs and Climate Policy, 2014). Farms with at least the prescribed percentage of grassland may adopt an application standard of 230 or 250 kg nitrogen per hectare provided that a fertilisation plan is logged, as per the rules laid down to that end. The phosphate status of the soil must also be determined at least once every four years. Since 2014, phosphate fertiliser may no longer be applied at farms that use a derogation.
Table 3.3 Application standard for animal manure expressed in kg nitrogen (N) per hectare for farms registered for derogations plus the required minimum percentages of grassland in the period 2006-2021 for arable land and grassland in the various areas in the Netherlands.¹

<table>
<thead>
<tr>
<th>Period</th>
<th>Area</th>
<th>Arable land Application standard</th>
<th>Grassland Application standard</th>
<th>% grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-2013</td>
<td>All</td>
<td>170</td>
<td>250</td>
<td>70</td>
</tr>
<tr>
<td>2014-2021</td>
<td>SC, SS, LO¹</td>
<td>170</td>
<td>230</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>170</td>
<td>250</td>
<td>80</td>
</tr>
</tbody>
</table>

¹ These are the sand and loess soil areas in SC (Sand Central = the provinces of Utrecht, Overijssel and Gelderland), SS (Sand South = the provinces of Noord-Brabant and Limburg) and LO (Loess Region).

Source: EZ (2014), EU (2018)

Plant-available nitrogen and availability coefficient

For the application of plant-available nitrogen (the total of plant-available nitrogen from animal manure and artificial fertiliser), different application standards apply per crop and per type of soil, several of which have been tightened up since 2006 (see tables 3.4 and 3.5). For grassland on clay soils, after an earlier stepwise tightening over the period 2007-2009, the application standards were increased in 2014 to the level of 2006 (see Table 3.4). The same happened in 2010 with the application standard for winter wheat on clay soils (see Table 3.5). The full table of nitrogen application standards comprises a number of pages; because of its size, please refer to the RVO website for a complete overview (RVO, 2019a, 2018a, 2017a, 2015a, 2015b, 2011a).

From 2017 onwards, more generous standards apply to arable crops on land with higher yields, with the levels in 2017 depending on the additional yield in the previous year (RVO, 2017b), in 2018 depending on yields in the previous two years (RVO, 2018b) and from 2019 onwards depending on yields in the previous three years (RVO, 2018c).

The efficacy of organic fertiliser is legally defined by means of the nitrogen availability coefficient (NAC), which varies from 10 to 80% of the availability of nitrogen in artificial fertiliser (NAC = 100%). The values for solid animal manure range between 30% and 60%. For slurry, they vary between 45% and 80% (RVO, 2011b). In 2014, the NAC for pig manure, applied on sandy soil in a low-emission process, was increased from 70% to 80%, depending on the application method and grazing (EZ, 2014; RVO, 2014b). This means that when pig manure is applied to sandy soil, less nitrogen may be added from other fertilisers from 2014 onwards than was the case before 2014, thereby remaining within the same nitrogen application standard. The availability coefficients for the period 2018-2021 are the same as those for 2014-2017 (RVO, 2018d, 2018e).
Table 3.4 Nitrogen application standard in kg plant-available nitrogen (N) per hectare in the period¹ 2006-2021 for grassland with and without grazing meadows².

<table>
<thead>
<tr>
<th>Soil type</th>
<th>With grazing meadows</th>
<th>Without grazing meadows</th>
<th>Without grazing meadows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/loess</td>
<td>300</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Clay</td>
<td>345</td>
<td>310</td>
<td>345</td>
</tr>
<tr>
<td>Peat</td>
<td>290</td>
<td>265</td>
<td>265</td>
</tr>
</tbody>
</table>

¹ The application standards were increased step by step between 2006 and 2010.
² Without grazing meadows means that the grassland is only mowed and/or used as meadowland for young cattle (no more than two years of age).

Table 3.5 Nitrogen application standard in kg plant-available nitrogen (N) per hectare in the period¹ 2006-2021 for the main arable crops².

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Clay</th>
<th>Sand and Loess 2006</th>
<th>Sand South and Loess 2015/'21⁵</th>
<th>Other sandy soil areas 2012/'21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes for human consumption³</td>
<td>250-300</td>
<td>225-275</td>
<td>225-275</td>
<td>240-290</td>
</tr>
<tr>
<td>Potatoes for starch</td>
<td>265</td>
<td>220</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>245</td>
<td>220</td>
<td>245</td>
<td>190</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>165</td>
<td>150</td>
<td>150</td>
<td>155</td>
</tr>
<tr>
<td>Maize (derogation)</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>155</td>
</tr>
<tr>
<td>Maize (other)</td>
<td>205</td>
<td>185</td>
<td>185</td>
<td>185</td>
</tr>
</tbody>
</table>

¹ The application standards were increased step by step between 2006 and 2009 (clay soils) and between 2006 and 2012 (sand and loess soils).
² These represent over 80% of the area under cultivation in 2014.
³ The level of the standard depends on the nitrogen requirement of the variety; lower standards apply for new potatoes.
⁴ On loess soils, the standard for potatoes grown for human consumption is 5 kg lower and for winter wheat 30 kg higher.
⁵ The same as ‘Other sandy areas’ for 2014.

There are different phosphate application standards for grassland and arable land, with the application standard since 2010 depending on the soil phosphate status (see Table 3.6a). The application standards are expressed in kg phosphate (as P₂O₅) per hectare. During the period 2010-2014, application standards were tightened, especially for arable land with a neutral or high phosphate status (see Table 3.6a). From 2015 onwards, all phosphate application standards were further reduced by 5 kg, with the exception of those for low-phosphate grassland.

Just as for nitrogen, more generous standards applied for phosphate to arable crops on land with higher yields in the period 2017-2019, with the levels in 2017 depending on the additional yield in the previous year (RVO, 2017c), in 2018 depending on yields in the previous two years (RVO, 2018h) and from 2019 onwards depending on yields in the previous three years (RVO, 2019b). This so-called ‘equivalent measure’ for phosphate lapsed in 2020 (RVO, 2020a).
Since 2020, two phosphate status classes have been added and the phosphate application standards for the phosphate statuses 'neutral' and 'low' are higher (see Table 3.6b). The 'neutral' class from the previous system has been split into the classes 'moderate' and 'neutral' and the 'low' class has been split into 'low' and 'poor'.

Table 3.6a Phosphate application standards in kg phosphate (as P₂O₅) per hectare in the period 2006-2017 for grassland and arable land, for each soil phosphate status¹.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland</td>
<td>Low</td>
<td>110</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>110</td>
<td>100</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>110</td>
<td>100</td>
<td>90</td>
<td>90</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td>Arable land</td>
<td>Low</td>
<td>95</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>80</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>95</td>
<td>85</td>
<td>80</td>
<td>75</td>
<td>70</td>
<td>65</td>
<td>65</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>95</td>
<td>85</td>
<td>75</td>
<td>70</td>
<td>65</td>
<td>55</td>
<td>55</td>
<td>50</td>
</tr>
</tbody>
</table>

¹ The phosphate status for grassland is expressed as a PAL value and for arable land as a Pw value (see footnotes 1 and 2 to Table 3.6b).

Table 3.6b Phosphate application standards in kg phosphate (as P₂O₅) per hectare from 2020 onwards for grassland and arable land, for each soil phosphate status¹.

<table>
<thead>
<tr>
<th>Grassland</th>
<th>PAL¹ Standard</th>
<th>Arable land</th>
<th>Pw² Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td></td>
<td>Class</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>&lt;16</td>
<td>&lt;25</td>
<td>120</td>
</tr>
<tr>
<td>Low</td>
<td>16-26</td>
<td>25-35</td>
<td>80</td>
</tr>
<tr>
<td>Neutral</td>
<td>27-40</td>
<td>36-45</td>
<td>70</td>
</tr>
<tr>
<td>Moderate</td>
<td>41-50</td>
<td>46-55</td>
<td>60</td>
</tr>
<tr>
<td>High</td>
<td>&gt;50</td>
<td>&gt;55</td>
<td>40</td>
</tr>
</tbody>
</table>

¹ PAL: phosphate extraction with ammonium lactate, expressed in mg P₂O₅ per 100 g soil.
² Pw: phosphate extraction with water, expressed in mg P₂O₅ per litre of soil.
Source: RVO (2020a)

3.2.5 Regulation of animal manure production and surpluses
The cornerstones of the Dutch fertiliser policy are regulation of (i) the production of animal manure and (ii) surplus animal manure. Manure production by livestock is regulated by three systems: (a) a system of animal production rights for pig and poultry farms, (b) maximum production levels for nitrogen and phosphate in each sector, with the total production remaining within the ceilings for nitrogen and phosphate at the national level, and (c) phosphate production rights for dairy cattle.

Surplus animal manure is regulated through a system of responsible manure disposal and a system of responsible growth in dairy farming. Both these systems will be explained briefly later.

Since 1987, manure production by pigs, poultry and cattle has been subject to maximum limits in the Fertilisers Act, through the system of manure production rights. That system was extended in 1992 to manure production rights for fur farm animals, ducks, rabbits, sheep and goats. The Pig Production (Restructuring) Act came into effect in 1998,
introducing pig production rights. From 2001 onwards, poultry production rights also applied pursuant to an amendment to the Fertilisers Act. The system of manure production rights was simplified in 2005. As of 1 January 2006, the manure production rights for cattle, fur animals (foxes, mink), ducks, rabbits, sheep and goats were abolished. Manure production by cattle was after all sufficiently restricted (albeit indirectly) by the milk quota system and the amounts from other species of animals were limited. Since 2006, there have only been animal production rights for pig and poultry farms for limiting manure production (Council of State, 2016). On average, a farm may not keep more pigs or chickens in a calendar year than it possesses animal production rights for (RVO, 2020b).

An additional policy included in the third Action Programme 2004-2009 in the Netherlands was that national manure production in terms of nitrogen and phosphate would, from 2006 onwards, not exceed the level of 2002 (LNV, 2005c). This is in line with the obligation under the derogation decision (EU, 2005). This means that the total excretion of manure per year may not exceed 172.9 million kg phosphate and 504.4 million kg nitrogen (including gaseous losses). The reason stated in the Action Programme was that a system of application standards can only function properly when there is an equilibrium between manure production and the scope for manure disposal. Limiting overall manure production is seen as one of the additional measures that Article 5, paragraph 5 of the Nitrates Directive requires member states to take as soon as they prove necessary. In addition, as of 1 January 2020, ceilings have been laid down by law for each sector (LNV, 2019), as included in the sixth Nitrate Action Programme 2018-2021 (LNV, 2017). The European Commission has made defining them a precondition for obtaining a new derogation.

**System of responsible manure disposal**

As of 1 January 2014, a system of responsible manure disposal came into force that obliged companies to process a certain proportion of the phosphate surplus, i.e. take it outside Dutch the agriculture sector (EL&I, 2012). This was that because the Fertilisers Act included the fact that the system of pig and poultry production rights was going to lapse as of 1 January 2015 and the European system of milk quotas would lapse as of 1 April 2015. During the negotiations about the fifth Nitrate Action Programme and the derogation, both covering the period 2014-2017, the European Commission emphasised that any expiry of animal production rights without additional measures to combat nitrate pollution would pose risks to water quality and as a result, animal production rights have not expired.

**System of responsible dairy farming growth**

As of 1 January 2015, a system of responsible dairy farming growth came into effect that was intended to limit dairy farming growth without land growth. The scheme focused exclusively on dairy farms, as dairy farming had grown strongly due to milk quotas being scrapped (EZ, 2015). In the event of growth, it had to be possible to process the additional phosphate production or to apply it entirely on the farm’s own soil. From 1 January 2016, a general order in council (AMvB) came into effect making it no longer possible to only process the extra phosphate
production; that growth had to be partially compensated with extra land. The content of this order in council has been set down since 1 January 2018 in the Dairy Farming (Land-based Growth) Act.

**System of phosphate production rights**

Finally, the system of phosphate production rights for dairy farming was introduced on 1 January 2018 (EZ, 2017a), following the compulsory reduction of the dairy livestock levels in 2017 (Phosphate Reduction Plan; EZ, 2017b). This system is intended to ensure that phosphate production remains below the phosphate ceiling. The production of phosphate in manure is regulated per dairy farm by (tradeable) phosphate rights.

### 3.2.6 Regulating the application of fertiliser

Rules restricting the period during which fertiliser may be spread have been in place since 1988. This period has been reduced thereafter by 1-4 months; from 7-7½ months to 6½-7 months for grassland and from 7-10 months to 6 months for arable land (see Table 3.7).

From the winter of 2005-2006, every farm on which manure is produced has been required to have storage capacity for at least six months. In 2012, when the spreading period was shortened too, the mandatory minimum storage capacity was extended by one month to a minimum of seven months. The evolution of required storage capacity is given in Subsection 3.5.2.

Farms that can demonstrate that manure produced in excess of the actual storage capacity is disposed of or used on the farm in an environmentally harmless way – e.g. by leasing storage space or signing contracts with customers – are exempted from this rule (LNV, 2005d). This could encourage storage at the point of use (arable areas), which has several potential benefits:

- transport is spread more evenly over the year;
- arable farmers have the manure close to the field when they want to apply it;
- arable farmers have more time and therefore more options for composing a good mix of imported manure.
Table 3.7 Periods when slurry application is permitted.¹

<table>
<thead>
<tr>
<th>Years</th>
<th>Soil type</th>
<th>Sand and Loess</th>
<th>Clay and Peat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>grassland</td>
<td>arable land</td>
<td>grassland</td>
</tr>
<tr>
<td>1988-1990</td>
<td>1/1 – 30/9</td>
<td>1/11 – harvest</td>
<td>entire year</td>
</tr>
<tr>
<td>1995-1997</td>
<td>1/2 – 31/8</td>
<td>1/2 – 31/8</td>
<td>1/2 – 31/8</td>
</tr>
<tr>
<td>1998-2004</td>
<td>1/2 – 31/8</td>
<td>1/2 – 31/8</td>
<td>1/2 – 31/8</td>
</tr>
<tr>
<td>2005</td>
<td>-</td>
<td>-</td>
<td>1/2 – 30/11</td>
</tr>
<tr>
<td>2006</td>
<td>-</td>
<td>-</td>
<td>1/2 – 15/10</td>
</tr>
<tr>
<td>2007</td>
<td>-</td>
<td>-</td>
<td>1/2 – 15/10</td>
</tr>
<tr>
<td>2008</td>
<td>-</td>
<td>-</td>
<td>1/2 – 15/10</td>
</tr>
<tr>
<td>2009-2011</td>
<td>-</td>
<td>-</td>
<td>1/2 – 15/9</td>
</tr>
<tr>
<td>2012-2018</td>
<td>16/2 – 31/8</td>
<td>1/2 – 31/7³</td>
<td>16/2 – 31/8</td>
</tr>
<tr>
<td>2019-2021</td>
<td>16/2 – 31/7⁴</td>
<td>-</td>
<td>16/2 – 31/7⁴</td>
</tr>
</tbody>
</table>

¹ Non-standard periods sometimes apply for solid manure.
² '-' means no change with respect to previous years.
³ Slurry may be applied to all soil types until 1 September if a green fertiliser was grown until the latest 31 August of the same year or if a bulb crop is planted in the subsequent autumn.
⁴ From 1 August to 15 September, slurry may only be spread if by 15 September at the latest: a green manure has been sown in the field that remains in the field for at least eight weeks before being destroyed, or if winter oilseed rape has been sown for seed production in the following year, or if flower bulbs have been planted.

3.3 Developments in agriculture

3.3.1 Land use

The Netherlands has a total area of 3.37 million hectares, 1.82 million of which (54%) is cultivated land (CBS Statline, 2020). The area of cultivated land is slowly decreasing. The decreasing trend in cultivated land area is accompanied by an increase in other land uses (including expansion of urban areas and road construction). The area of grassland continues to fall. This is particularly true of permanent grassland, although it can be seen to have been stabilising over the last five years. The arable crop area (excluding maize) had a falling trend between 2000 and 2016, whereas from 2017 onwards it seems to be rising slightly. The area under permanent crops (fruit trees) has stabilised at around 25,000 ha.
### Table 3.8 Land use in the Netherlands (x1000 ha).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland, of which:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>permanent</td>
<td>1,068</td>
<td>998</td>
<td>989</td>
</tr>
<tr>
<td>temporary(^1)</td>
<td>1,032</td>
<td>753</td>
<td>756</td>
</tr>
<tr>
<td>Silage maize</td>
<td>36</td>
<td>245</td>
<td>233</td>
</tr>
<tr>
<td>Other arable crops</td>
<td>223</td>
<td>212</td>
<td>201</td>
</tr>
<tr>
<td>Horticulture(^2)</td>
<td>598</td>
<td>508</td>
<td>518</td>
</tr>
<tr>
<td>Permanent crops</td>
<td>65</td>
<td>73</td>
<td>72</td>
</tr>
<tr>
<td>Fallow</td>
<td>24</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>Total cultivated area</td>
<td>1,989</td>
<td>1,827</td>
<td>1,818</td>
</tr>
</tbody>
</table>

| Nature areas and woodlands\(^3\) | 452 | 415 | 415 |
| Other land use             | 948 | 1,126 | 1,134 |
| **Total land area\(^3\)**  | 3,388 | 3,368 | 3,368 |

\(^1\) Grassland that is converted into another crop after a maximum of 5 years.

\(^2\) Tree nurseries are included in horticulture and are not classed as permanent (non-annual) crops. Horticulture does not cover field-grown vegetables (such as carrots, chicory roots, broad beans and runner bean varieties).

\(^3\) Data is only available for the years 1993, 2008, 2010 and with a provisional status for 2015.

Source: CBS Statline, 2020

#### 3.3.2 Number of farms

The total number of farms fell by 54% over the period 1992-2019 from 117,100 to 54,400 (see Table 3.9). The level of decrease depended on the type of farm: -31% for arable farms, -47% for dairy farms, -66% for horticultural farms and -67% for factory farms. Because the number of farms has fallen much faster than the area of cultivated land (-54% versus -9%), the average farm size has increased over twenty-five years from 17.0 ha to 33.4 ha.

There has been a large drop in the number of farms in the Netherlands since 2016. From that year onwards, Statistics Netherlands has based its records on registrations of companies with the Chamber of Commerce. This has removed many children’s farms, sheep farmers and stables for horses. These are owned by private individuals who work with animals as a hobby and therefore do not have to register with the Chamber of Commerce. Removing them actually has almost no effect on agricultural production, but it does affect average farm sizes, explaining the increase from 17 ha to over 33 ha.
Table 3.9 Number of farms per main farm category (x1000).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable farms</td>
<td>15.8</td>
<td>12.1</td>
<td>10.8</td>
</tr>
<tr>
<td>Horticultural businesses(^1)</td>
<td>20.5</td>
<td>8.7</td>
<td>7.0</td>
</tr>
<tr>
<td>Permanent crop growers</td>
<td>3.0</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Grazing livestock farms</td>
<td>54.0</td>
<td>35.4</td>
<td>27.2</td>
</tr>
<tr>
<td>of which dairy farms</td>
<td>30.0</td>
<td>16.8</td>
<td>15.8</td>
</tr>
<tr>
<td>Factory farms</td>
<td>13.7</td>
<td>5.3</td>
<td>4.6</td>
</tr>
<tr>
<td>Combined farms</td>
<td>10.1</td>
<td>3.2</td>
<td>3.2</td>
</tr>
<tr>
<td>All farm types</td>
<td>117.1</td>
<td>66.4</td>
<td>54.4</td>
</tr>
</tbody>
</table>

\(^1\) Includes greenhouse horticulture; tree nurseries are also seen as horticulture and not as permanent crops.
\(^2\) The figures for 1992-1995 have been corrected to reflect the farm types used for 2008-2011 and 2012-2015.
Source: CBS Statline, 2020

Organic farming does not use artificial fertiliser or chemical crop protection agents. In addition, there are rules about the use of feed concentrates and veterinary medicines and on the possibility for animals to go outside. Approximately 2.8% of all farms are currently organic. That proportion was 1% at the turn of the century. Between 2011 and 2018, the area of organic agriculture grew by 22% (see Figure 3.1, top), the numbers of animals grew by 44% (see Figure 3.1, bottom) and the number of organic farms grew by 22%. That includes farms that are in the process of switching to organic farming. Farms may only officially market their products as organic if they have gone through a transitional period of one to two years and have met the standards of an organic certification agency.

The largest increase in the proportion of organic farming was in greenhouse horticulture, where the share almost tripled (see Figure 3.1). The data from 2015 onwards seems to show a structural break, though, when a different method of recording organic farming was adopted. From 2015, organic farming has been registered through the 'combined declaration' (Agricultural census) and no estimates need to be made. Before 2015, registration was via SKAL and totals were produced and a breakdown by farm type made by Statistics Netherlands. The figures from before 2015 are therefore less reliable. Figures from before 2011 have been left out because of their poor reliability.
3.3.3 Livestock

Numbers of cows and pigs fell by 16% and 15% respectively over the period 1992-2019, whereas the number of chickens rose by 7% (see Table 3.10). Cattle numbers increased from 2012 to 2017 and then decreased again from 2017; the phosphate reduction plan for dairy farming came into force in 2017. From 2017 onwards, many dairy farms were obliged to dispose of dairy cows and heifers if the number exceeded the number on the reference date of 2 July 2015, minus 4%.

Land-based farms were exempted from this reduction. Furthermore, almost 600 of the approximately 16,000 dairy farms announced that they wanted to stop farming and take advantage of the so-called stoppers’ scheme. As a result of this phosphate reduction plan and the introduction of the system of phosphate production rights on 1 January 2018, dairy livestock numbers have shrunk considerably;
between 1 January and 31 December 2017, the number of dairy cows fell by 130,000 as a result of these measures, i.e. a reduction of 8%.

Table 3.10 Number of farm animals (in millions).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>4.8</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Pigs</td>
<td>14.5</td>
<td>12.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Chickens</td>
<td>94</td>
<td>101</td>
<td>101</td>
</tr>
<tr>
<td>Sheep/goats</td>
<td>1.9</td>
<td>1.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Source: CBS Statline, 2020

3.3.4 Excretion of nitrogen and phosphorus in animal manure

Excretion per animal

Over the period 1990 to 2012, annual nitrogen excretion per animal decreased in almost all species. This was primarily due to the combination of lower nitrogen and phosphorus levels in animal feed and more efficient feed conversion. After 2012, nitrogen excretion from dairy cows rose (see Table 3.11) because of higher milk production per animal (higher nitrogen content in the concentrates) and because of expansion of dairy livestock numbers in anticipation of milk quotas being abolished on 1 April 2015. Compared to the period 2012-2015, excretion per dairy cow was 11% higher in the period 2016-2018. For other species, there has been a relative stabilisation in the excretion per animal over the last ten years, although the excretion per broiler chicken decreased significantly by almost 10% in the period 2016-2018 compared to 2012-2015.

An increase in excretion per dairy cow can also be seen in the period 2016-2018. Annual milk production per dairy cow increased from over 8,300 kg in 2016 to 8,850 kg in 2018. Feed consumption per dairy cow also rose. As a result of increasing feed consumption and decreasing acreage areas of silage maize, there has been proportionately more grass and concentrate in cows’ feed in recent years. Grass and concentrates contain up to three times as much nitrogen as silage maize, increasing nitrogen excretion per cow. Additionally, the nitrogen content of grass has also increased in recent years.

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy cows</td>
<td>155.0</td>
<td>126.1</td>
<td>140.4</td>
</tr>
<tr>
<td>Heifers (1-2 years)</td>
<td>95.6</td>
<td>70.8</td>
<td>70.4</td>
</tr>
<tr>
<td>Heifers (0-1 year)</td>
<td>43.7</td>
<td>34.7</td>
<td>34.5</td>
</tr>
<tr>
<td>Pigs (for meat)</td>
<td>14.6</td>
<td>12.0</td>
<td>11.6</td>
</tr>
<tr>
<td>Sows (with piglets)</td>
<td>31.3</td>
<td>29.8</td>
<td>30.0</td>
</tr>
<tr>
<td>Broiler chickens</td>
<td>0.62</td>
<td>0.46</td>
<td>0.41</td>
</tr>
<tr>
<td>Laying hens</td>
<td>0.85</td>
<td>0.76</td>
<td>0.76</td>
</tr>
</tbody>
</table>

¹ The figures are without a deduction for gaseous losses.
Source: CBS Statline, 2020

Phosphorus excretion per category of animals also decreased (see Table 3.12). The phosphate reduction plan led to a drop in dairy cattle numbers and a reduction in the phosphorus concentration in compound feed for dairy cattle. The phosphorus content fell from 4.3 g per kilogram of compound feed in 2016 to 4.1 g per kilogram in 2018, a
drop of over 4%. The phosphorus content of grass and maize, which is important for dairy cattle as well, was lower in 2018 than it had been in previous years.

Table 3.12 Phosphorus excretion per animal per year (kg P per animal per year)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy cows</td>
<td>19.1</td>
<td>17.6</td>
<td>17.7</td>
</tr>
<tr>
<td>Heifers (1-2 years)</td>
<td>10.1</td>
<td>9.9</td>
<td>8.9</td>
</tr>
<tr>
<td>Heifers (0-1 year)</td>
<td>4.5</td>
<td>4.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Pigs (for meat)</td>
<td>2.5</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Sows (with piglets)</td>
<td>7.5</td>
<td>6.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Broiler chickens</td>
<td>0.10</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Laying hens</td>
<td>0.21</td>
<td>0.17</td>
<td>0.18</td>
</tr>
</tbody>
</table>

1 Conversion from phosphorus (P) to phosphate (as P₂O₅) using a factor of 142/62 = 2.29.
Source: CBS Statline, 2020

Excretion by livestock

About 15 years ago, the downward trend in total excretion of nitrogen and phosphate by Dutch livestock slowed down. Since the abolition of the mineral declarations system MINAS in 2005 and the introduction of the system of application standards, annual nitrogen excretion has been between 460 and 512 million kilograms. During the same period, annual phosphate excretions have been between 160 and 180 million kilograms of P₂O₅.

In 2016-2019, total annual nitrogen excretion by cattle was 502 million kilograms (see Table 3.13) and annual phosphorus excretion – expressed as phosphate (P₂O₅) – was 165 million kilograms (see Table 3.14). This meant that nitrogen and phosphorus excretions were then 28% less than in 1992-1995. Two factors play a role in this: the annual nitrogen and phosphorus excretion figures per animal, which are dropping consistently for all animal species (see Table 3.11 and Table 3.12) and the reduced numbers of cattle and pigs (see Table 3.10).

However, an increase has once again become manifest in the total nitrogen excretions during the last five years. This has been caused by a rise in nitrogen excretions per animal for dairy cows (see Table 3.11). For those reasons, the total nitrogen excretion figure over the period 2012-2019 increased, despite livestock numbers going down (see Table 3.13).

The lowest excretion figure over the last ten years was in 2012 for both nitrogen and phosphate. In the years that followed, both nitrogen and phosphate excretion increased (a consequence of the EU milk quota system being abolished). The nitrogen ceiling and phosphate ceiling encompass an agreement made by the Netherlands with the European Commission in 2005 to avoid intensification arising when the requested derogation was applied (EU, 2005). The nitrogen ceiling was set as 504.4 million kilograms of nitrogen. That was exceeded in 2017, and almost so in 2016 and 2018 as well. The phosphate ceiling was set as 172.9 million kilograms of P₂O₅; this ceiling was exceeded in 2015 and 2016.
### Table 3.13 Nitrogen excretions by Dutch livestock (millions of kg N per year).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle excluding veal calves</td>
<td>437</td>
<td>280</td>
<td>306</td>
</tr>
<tr>
<td>Veal calves</td>
<td>8</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Pigs</td>
<td>153</td>
<td>101</td>
<td>96</td>
</tr>
<tr>
<td>Poultry</td>
<td>70</td>
<td>60</td>
<td>58</td>
</tr>
<tr>
<td>Horses and ponies</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>24</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td><strong>All livestock</strong></td>
<td><strong>698</strong></td>
<td><strong>479</strong></td>
<td><strong>502</strong></td>
</tr>
</tbody>
</table>

Source: CBS Statline, 2020

### Table 3.14 Phosphorus excretions by Dutch livestock (millions of kg P per year).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle excluding veal calves</td>
<td>52</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>Veal calves</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pigs</td>
<td>29</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Poultry</td>
<td>15</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Horses and ponies</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>All livestock</strong></td>
<td><strong>100</strong></td>
<td><strong>74</strong></td>
<td><strong>72</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>As phosphorus (P)</td>
<td>230</td>
<td>170</td>
<td>165</td>
</tr>
<tr>
<td>As phosphate (P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;)&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> The conversion from phosphorus to phosphate uses a factor of 142/62 = 2.29.

Source: CBS Statline, 2020

### 3.4 Nutrient balances

#### 3.4.1 Nitrogen and phosphorus balances in agriculture

During the period 2016-2018, an annual average input of 691 million kilograms of nitrogen was supplied to Dutch agricultural land in the form of feed concentrates, artificial fertiliser and other products, in addition to atmospheric deposition (see Figure 3.2). Animal and vegetable agricultural production plus disposal of manure outside agriculture meant an annual average of 375 million kilograms of nitrogen was removed. The surplus disappeared into the soil (231 million kg) and into the air (91 million kg).

The airborne component includes volatile nitrogen compounds (largely ammonia) from stables and manure storage (58 million kg), grazing and manure application (42 million kg) and roughage preservation and ripening crops (9 million kg), minus the fraction of this amount that is later deposited back on farmland (-17 million kg). The soil fraction is partly leached, partly degraded (denitrification) or (temporarily) sequestered.

The difference between inputs (691 million kg) and outputs (697=375+231+91 million kg) of nitrogen corresponds to the change in roughage stocks (5 million kg decrease). Stock level shifts fluctuate around the zero mark: in 2016, they decreased by 4 million kg, in 2017 they rose by 15 million kg, and in 2018 they decreased by 27 million kg. For phosphorus, the average decrease in the roughage stocks was 2 million kg per year.
In the period 2016-2018, an average of 82 million kg of phosphorus per year was provided to Dutch agriculture in the form of concentrates, artificial fertiliser and other products (see Figure 3.3). Animal and vegetable agricultural production plus disposal of manure outside agriculture meant an average of 74 million kilograms of phosphorus was
removed. The excess of 9 million kg (on average) accumulated in the soil on farms.

**Phosphorus average 2016-2018**

Unit: million kg phosphorus per year

Source: CBS

*Figure 3.3 Phosphorus flows: flow diagram for the flows of phosphorus in Dutch agriculture for the period 2016-2018 as the average of the annual figures over the period 2016-2018 (for an explanation, see Inset 3.1, 'Flow diagram explanation').*
Inset 3.1 – Explanation of the flow diagrams for nitrogen and phosphorus

Livestock farming
There are two input flows for livestock farming:
1. use of roughage;
2. use of concentrates.

These two input flows are balanced by three output flows:
1. uptake into animal products;
2. volatilisation (ammonia and other nitrogen compounds) from stalls and manure storage;
3. excretion by livestock, minus what is then volatilised.

Utilised Agricultural Area (UAA)
There are five input flows for Utilised Agricultural Area (UAA):
1. animal manure, excluding manure disposed of outside Dutch agriculture;
2. artificial fertiliser;
3. atmospheric deposition from sources other than agriculture;
4. atmospheric deposition from sources within agriculture;
5. other inputs, comprising inter alia organic nitrogen fixation, composting and sown and seeded crops.

These two input flows are balanced by three output flows:
1. vegetable products;
2. volatilisation (NH₃) during manure application and pasturing;
3. losses into the soil.

Plant products
The ‘plant products’ item can be subdivided into three output flows:
1. outgoing plant products, excluding roughage;
2. harvested roughage;
3. conservation loss to the atmosphere, plus the nitrogen losses from ripening crops and crop residues.

Harvested roughage minus the use of roughage corresponds to the increase in stocks of roughage. However, the exact level of roughage stocks is also affected by the international trade in roughage, but that falls outside the scope of this flow diagram.

3.4.2 Soil balances for nitrogen and phosphorus
There is a downward trend in nutrient losses to the soil. Nitrogen losses have fallen from 417 million kg in 1992-1995 to 231 million kg (see Table 3.15). Phosphorus losses have fallen from 65 million kg to 9 million kg over the most recent period (see Table 3.16). For phosphorus, losses to the soil are approaching the zero line.

The biggest elements adding to the soil balance are animal manure and artificial fertiliser. Over 1992-2018, the inputs of nitrogen through animal manure dropped by 36% and of phosphorus by 43%. For artificial fertiliser, the decrease in nitrogen was 40% and in phosphorus it was 80%. Over 1992-2018, removal in the crops increased for nitrogen by 24% and for phosphorus by 13%.
From 1986 onwards, for both phosphorus and nitrogen, the surplus from Dutch agriculture decreased (see Figure 3.4). For phosphorus, that excess is equal to the losses to the soil. For nitrogen, losses to the atmosphere have to be added (‘Total losses’ in Figure 3.2). If volatilisation from stables, storage and grazing is not taken into account, this decreasing trend is hardly affected. For phosphorus, this trend is approaching the zero line.

However, that falling curve has stagnated over recent years for nitrogen in particular. One year that is particularly striking is 2018, which showed increases in the surpluses of both nitrogen and phosphorus. Because of the dry summer, less nitrogen and phosphorus were taken up into plant products. On top of that, a lot of stocked roughage was used.

Table 3.15 The nitrogen balance of Utilised Agricultural Area (UAA).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input as:</strong></td>
<td>in millions of kg N per year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal manure</td>
<td>572</td>
<td>345</td>
<td>367</td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>372</td>
<td>218</td>
<td>222</td>
</tr>
<tr>
<td>Other(^1)</td>
<td>15</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Atmospheric deposition</td>
<td>70</td>
<td>42</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total inputs</strong></td>
<td>1,030</td>
<td>621</td>
<td>645</td>
</tr>
<tr>
<td><strong>Total outputs (crops)</strong></td>
<td>491</td>
<td>367</td>
<td>373</td>
</tr>
<tr>
<td>Nitrogen volatilisation</td>
<td>121</td>
<td>39</td>
<td>42</td>
</tr>
<tr>
<td>Losses into the soil</td>
<td>417</td>
<td>215</td>
<td>231</td>
</tr>
<tr>
<td>Use of minerals on cultivated land (%)</td>
<td>48</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td><strong>Losses into the soil losses in kg N per ha</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>211</td>
<td>112</td>
<td>128</td>
</tr>
</tbody>
</table>

\(^1\) Includes biological nitrogen fixation, compost, sown and seeded crops.
Source: CBS Statline, 2020
Table 3.16 The phosphate balance of cultivated ground.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Input (in millions of kg P per year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal manure</td>
<td>94</td>
<td>56</td>
<td>54</td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>29</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Atmospheric deposition</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other(^1)</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total inputs</strong></td>
<td>127</td>
<td>64</td>
<td>63</td>
</tr>
<tr>
<td>Total outputs (crops)</td>
<td>62</td>
<td>57</td>
<td>54</td>
</tr>
<tr>
<td>Losses into the soil</td>
<td>65</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Use of minerals on cultivated land (%)</td>
<td>49</td>
<td>90</td>
<td>85</td>
</tr>
</tbody>
</table>

| Losses into the soil | 33 | 4 | 5 |
| *losses in kg P per ha* |

\(^1\) Includes compost and sown and seeded crops.

Source: CBS Statline, 2020

Year-on-year fluctuations in surpluses from 1986 onwards are associated with yield differences due to the weather conditions, which change every year. Such fluctuations are not visible before 1986 because the surpluses were not calculated annually at that time.

![Nutrient surplus in agriculture (1970 = 100)](image)

Figure 3.4 Trend line for the nitrogen and phosphorus surpluses in Dutch agriculture. The value for 1970 is indexed as 100. Annual measurements since 1986.

Source: CBS Statline, 2020
3.5 Developments in agricultural practices

3.5.1 Manure transport and manure processing

The recent tightening of the phosphate application standards means that ever larger quantities of manure have to be transported from farms with a nitrogen surplus or phosphate surplus to farms with sufficient scope to apply that fertiliser. The manure has to be transported over greater and greater distances, largely from areas that have a lot of intensive livestock farming and therefore a regional surplus.

Map 3.3 Transport balance for animal manure (expressed in kg nitrogen per hectare) for the periods 2012-2014 and 2016-2019, to and from farms

Source: Statistics Netherlands, customised work
For the period 2016-2019, it appears that farms are removing slightly less manure on balance (expressed as nitrogen per hectare) than in the previous period. The Sand Central and Sand South areas have the largest net outflows, as there are numerous intensive pig and poultry farms there that are not land-based. Manure transport for these two areas has been manifesting a strong net outflow for twenty years now, but it shrank from 2016 to 2019.

The total disposal of animal manure to destinations outside Dutch agriculture, as shown in the flow chart in Figure 3.2, has increased in recent years. This represents a doubling over the last twenty years (for nitrogen see Table 3.17 and for phosphorus see Table 3.18). More than half the nitrogen that has to be disposed of outside Dutch agriculture is now exported abroad. In 2019 (provisional data), 45% of the nitrogen exported went to Germany, 30% to France and 21% to Belgium (RVO, 2020d). Over the last five years, exports to Germany have fallen and exports to France have risen.

Table 3.17 Nitrogen disposal in fertiliser to destinations outside Dutch agriculture (million kg N per year).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure exports</td>
<td>25</td>
<td>23</td>
<td>41</td>
<td>49</td>
</tr>
<tr>
<td>Other manure processing¹</td>
<td>3</td>
<td>4</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Non-agricultural use ²</td>
<td>12</td>
<td>12</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Total disposals outside agriculture</td>
<td>40</td>
<td>39</td>
<td>78</td>
<td>82</td>
</tr>
</tbody>
</table>

¹ This refers to processing activities in which the final product is no longer used as fertiliser in Dutch agriculture (except for export), such as manure incineration and nitrogen that escapes to the atmosphere during aerobic slurry purification.

² Use at hobby farms, by private individuals and in nature areas.

* The status for the reporting year 2019 is provisional. Earlier years are finalised figures.

Source: Statistics Netherlands, customised work

Table 3.18 Phosphorus disposal in fertiliser to destinations outside Dutch agriculture (million kg P per year).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure exports</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Other manure processing¹</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Non-agricultural use ²</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Total export outside agriculture</td>
<td>8</td>
<td>9</td>
<td>18</td>
<td>19</td>
</tr>
</tbody>
</table>

¹ This refers to processing activities in which the final product is no longer used as fertiliser in Dutch agriculture (except for export), such as manure incineration.

² Use at hobby farms, by private individuals and in nature areas.

* The status for the reporting year 2019 is provisional. Earlier years are finalised figures.

Source: Statistics Netherlands, customised work
3.5.2 Manure storage capacity
Because of the ban on spreading in the autumn and winter, livestock farms must have sufficient storage capacity for animal manure; from 2012 onwards, that means seven months. This does not apply to farms that can show that the surplus is being removed or applied responsibly (see Subsection 3.2.6). This is a particular issue for pig farms and veal calf farms. In 2014, 97% of dairy farms, 96% of pig farms and 88% of veal calf farms had facilities for storing all the manure they produce for at least six months (see Figure 3.5). Between 2014 and 2018, the number of farms with a storage capacity of at least seven months rose to about 91% for dairy farms, 93% for pig farms and 82% for veal calf farms.

Various manure policy measures and a tightening of application standards are behind the rise in manure storage capacity. A ban on spreading in the autumn and winter came into effect in 2006 (see Subsection 3.2.6). In the following years as well, stricter rules were introduced on manure spreading plus a further reduction in the length of the spreading period. The spreading period was temporarily extended in some years due to extreme weather conditions. This has recently been the case in 2018 because of the hot and dry summer that year.

![Figure 3.5 Trends in available storage capacity (slurry) for various types of species livestock farms.](source)

Source: Statistics Netherlands, customised work

3.5.3 Fertilisation practices
3.5.3.1 Period and method of fertilisation
Since 1992, both the fertilisation period (see Table 3.7) and the fertilisation methods have been regulated further, step by step. This complies with the requirements of the Nitrates Directive for banning the application of fertilisers during inappropriate periods (Nitrates Directive, Appendix III, point 1 sub 1) and taking measures to limit nutrient leaching into groundwater and runoff into surface waters (Nitrates Directive, Appendix II, point A sub 2-6 and Appendix III, point 1 sub 3). The rules for fertilisation methods are aimed at limiting releases of ammonia into the atmosphere (see Subsection 3.5.6), as well as helping to limit runoff (see next section). From 2012 onwards, fertilising grassland is only allowed from 15 February to 1 September and arable
land from 1 February to 1 August (see Table 3.2). The manure must be applied using a low-emission process. The rules for low-emission application were tightened up for arable land as of 2008. From that year onwards, spreading onto the ground surface followed by turning it below the surface (a two-stage process) is no longer allowed; spreading has to be done either in a one-stage process or using a recognised low-emission technique (LNV, 2005a). The application of phosphate fertiliser has been banned since 2014 on farms that are registered for derogations (EZ, 2014; EU, 2014).

On top of the requirements described above for the fertilisation period, fertilisation of soil that is partly or completely covered with snow has been prohibited in the Netherlands since 1994 (LNV, 1995; as per the Nitrates Directive, Appendix II, point A sub 3). This ban was extended in 1998 to include a ban on fertilising totally or partially frozen soil as well (LNV, 1997b; as per the Nitrates Directive, Appendix II, point A, sub 3), although this was rare in practice anyway because of the obligation for the manure to be turned below the ground surface, which is more difficult for frosty soil.

3.5.3.2 Fertilisation near watercourses

Several measures help prevent fertilisers from ending up directly or indirectly in surface waters that are alongside agricultural plots. These are low-emission manure spreading, the ban on fertilisation during the winter and the ban on fertilising the strip directly along the edges of designated water bodies (see Map 3.1).

The requirement to spread manure using low-emission techniques (see Subsection 3.5.6) leads not only to lower ammonia emissions and a corresponding decrease in nitrogen deposition but also to improved surface water quality. By using techniques that restrict ammonia emissions, the manure is spread more evenly and taken up in or below the turf (as per the Nitrates Directive, Appendix II, point A, sub 6). This prevents the manure from draining off and ending up directly in watercourses.

The ban on winter fertilisation (see Subsection 3.2.6) prevents manure from being spread in the wettest period of the year (as per the Nitrates Directive, Appendix II, point A, sub 1). This reduces the risk of nitrogen getting into watercourses as a result of runoff and leaching.

Since 2006, an uncultivated buffer zone of at least 5 metres has to be observed along natural watercourses, as indicated in the Fertilisers Act Implementation Decree (see Map 3.1) (LNV, 2005a). There have been rules in place since 2000 on how to fertilise (distance and method) near watercourses (as per the Nitrates Directive, Appendix II, point A, sub 4) to protect surface waters against pollution (Decree on Discharges from Open Cultivation and Livestock Farming, VenW/Ministry of Transport, Public Works and Water Management, 2000). From 2013 onwards, the rules in question have been included in the Environmental Management Activity Decree (IenM, 2012). Where there is cultivation near watercourses, the strip alongside the water may not be fertilised. The width of this buffer strip, as it is known, varies for many crops between 0.5 metres and 1.5 metres and mostly corresponds to the width of the
strip on which crop protection agents may not be used. To protect adjacent water bodies better, the width of the buffer strip for grain crops and grasses was increased from 0.25 m to 0.50 m as of 1 January 2018 (IenM, 2017). Moreover, there is an obligation to use an edge spreader attachment along the buffer strip when using certain types of fertiliser.

3.5.4 Crop cover during the winter period

In the Netherlands, over half the cultivated acreage is grassed over and therefore covered during the winter. Growing winter cereals on arable land is a suitable method for preventing nitrate leaching. These winter grain crops are sown in the autumn and fertilised in the spring. The proportion of winter crops in the overall Utilised Agricultural Area (UAA) is stable at about 60% (see Table 3.19).

Table 3.19 Area\(^1\) of Utilised Agricultural Area (UAA) (x1000 ha) in the Netherlands covered by crops during the winter period (not fertilised).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Areas (x1000 ha)</th>
<th>Fraction of total Utilised Agricultural Area (AEE) (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grassland(^2)</td>
<td>1,068</td>
<td>998</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>110</td>
<td>128</td>
</tr>
<tr>
<td>Winter barley</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Green manure</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>1,196</td>
<td>1,141</td>
</tr>
</tbody>
</table>

1 Based on what is recorded as the main crop in the Agricultural Census (reference date: 15 May).

2 Both permanent and temporary grassland (see Table 3.8).

* The status for the reporting year 2019 is provisional. Earlier years are finalised figures.

Source: CBS Statline, 2020

Since 2006, it has been mandatory to sow a catch crop on sandy and loess soils after growing silage maize (LNV, 2005a). This implements the option given in the Nitrates Directive of ensuring that there is a minimum amount of vegetation during rainy periods (Nitrates Directive, Appendix II, point B, sub 8). The study by Hilhorst & Verloop (2009) showed that nitrogen fixation by catch crops can vary considerably, depending on the catch crop used and the extent to which the main crop was fertilised. There were 187,000 hectares of silage maize in 2019 (provisional figures). About 230,000 hectares of catch crops were planted after silage maize, registered in the Agricultural Census as ‘succession planting’, comprising 105,000 ha green manure, 100,000 ha grassland and 20,000 ha winter cereals. The area of catch crops grown after maize is greater than the area of maize as the main crop because there can also be a second or even a third round of follow-on cultivation in some cases. Winter barley has been very much on the rise in recent years, for instance because of new variants with higher yields, lower growing costs than winter wheat, and better harvest timing (winter barley is 2 to 3 weeks earlier than winter wheat).

Catch crops are also grown for other main crops than silage maize. In 2019, the total acreage of catch crops was about 400,000 ha: 210,000 ha green manure, 140,000 ha grassland and 50,000 ha winter
cereals. The areas of green manure and grassland based on follow-on crops are substantially higher than what is recorded in the Agricultural Census as the main crop (see Table 3.19). Taking account of that, it is reasonable to reckon that around three quarters of the total cultivated acreage has crop cover during the winter. This is more than the figure of 60% stated earlier, which is based on the main crops (grassland and winter cereals).

3.5.5 Water consumption

Agriculture uses about 110 million m$^3$ groundwater and surface water annually for irrigation (71 million m$^3$) and watering livestock (37 million m$^3$). Additionally, about 46 million m$^3$ of drinking water is used for watering livestock and cleaning stalls. The quantity of water used for irrigation depends heavily on the weather and has varied over the period 2001-2018 between 23 million m$^3$ (2012) and 265 million m$^3$ (2018) (Van der Meer, 2020; averages for the period 2001-2018).

A limited proportion of the agricultural land area in the Netherlands, generally between 4% and 8%, is irrigated at least once a year (see Figure 3.6). This only increases significantly in years with a dry spring and a dry summer, as far as 16% of the area or more, as in 2018. In that year, most fields were also irrigated more often.

Figure 3.6 Dutch agricultural land area (x1000 ha) that was irrigated one or more times a year during the period 2004-2018. If a field was irrigated more than once in a year, its area is included multiple times in the ‘total area irrigated’.

3.5.6 Ammonia emissions

Agriculture is the most important source of ammonia emissions in the Netherlands. The lion’s share of these emissions ultimately ends up in the soil, the vegetation and the water via atmospheric deposition. Measures for limiting emissions have ensured that volatilisation of ammonia has decreased.

Over the period 1992-2018, ammonia emissions from animal manure and artificial fertiliser have fallen by 58% (see Table 3.20). The key causes of this decrease are reduced nitrogen excretion from livestock, increased use of low-emission stalls and the obligation to apply using low-emission techniques. Above all, the requirement for low-emission manure application ensured a large drop in emissions in the early 1990s. From 2008 onwards, spreading slurry on arable land and then working it into the soil in a two-stage process has not been allowed. This measure means that the proportion of manure injection has increased sharply (Van Bruggen et al., 2019).

Table 3.20 Ammonia emissions from animal manure and artificial fertiliser (in millions of kg NH3).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock manure</td>
<td>242</td>
<td>95</td>
<td>97</td>
</tr>
<tr>
<td>stalls and storage</td>
<td>101</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>application</td>
<td>124</td>
<td>37</td>
<td>40</td>
</tr>
<tr>
<td>grazing</td>
<td>17</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>13</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total emissions</strong></td>
<td><strong>256</strong></td>
<td><strong>105</strong></td>
<td><strong>107</strong></td>
</tr>
</tbody>
</table>

1 The nitrogen losses from stalls and storage in Figure 3.2 include not only losses as NH3 but also volatilisation of other nitrogen compounds.
2 Refers only to ammonia emissions from Dutch agriculture, excluding emissions from hobby farms, from animals held by private individuals and from nature areas.

Source: Emissieregistratie, 2019

There has been no further reduction since 2013. Recent studies have shown that low-emission stalls may possibly be less effective than was thought and that the ammonia emissions from stored manure are in practice probably higher than previously calculated (Van Bruggen & Geertjes, 2019). In that study, nitrogen losses were calculated from the difference between the ratios of nitrogen and phosphate upon excretion and when the manure was disposed of. The most likely explanation for the difference with the previously published nitrogen loss figures is an underestimate of the emission factors for losses in gaseous form.

3.5.7 Compliance with fertiliser legislation

The number of factually checked items relating to compliance with the fertiliser legislation has increased since 2017 (see Figure 3.7). A single inspection allows multiple items to be fact-checked. The effort put in by the NVWA (Netherlands Food and Consumer Product Safety Authority) and the RVO rose from about 56,000 hours in 2017 to over
99,000 hours in 2018. This largely involved extra efforts for the derogation and the start of area-based enforcement in 2018 (RVO & NVWA, 2019a, 2019b). This had been made a precondition by the European Commission for obtaining derogation for 2018 and 2019. The number of factual items found to be non-compliant increased. This may possibly be linked to the risk-oriented approach that was introduced in 2018. The farm types at which the majority of non-compliances were observed varied from one year to the next (see Figure 3.8). The current distribution (2018-2019) of non-compliances among farm types can be seen as a reflection of the estimated risk of non-compliance.

![Figure 3.7 Number of items checked and number of compliant and non-compliant outcomes over the period 2015-2019.](image)

**Figure 3.7** Number of items checked and number of compliant and non-compliant outcomes over the period 2015-2019.

![Figure 3.8 Number of non-compliant items observed per farm type over the period 2015-2019.](image)

**Figure 3.8** Number of non-compliant items observed per farm type over the period 2015-2019.
The penalty sums imposed in each year increased over the period 2015-2019 (see Figure 3.9). The very high figure in 2018 is because cases involving the separation of manure were handled.

![Figure 3.9 Penalty sums imposed in each year over the period 2015-2019 (in thousands of euros).](image)

3.6 Knowledge development and dissemination, communication and supporting policy

3.6.1 Knowledge development and dissemination

For the development and dissemination of knowledge about improvements to agricultural practices, various pilot projects were carried out during the lifetimes of the completed Action Programmes. Existing and new projects were encouraged through the policy for the key sectors, by means of public-private partnerships.

Five projects have been completed or are ongoing. These are the ‘Nutrient Concentrates’ project for obtaining high-quality fertilisers from animal manure; regional pilot projects such as ‘Achterhoek without Artificial Fertiliser’ and the ‘Smart Fertilising’ project in the Loess Region; the ‘Nitrate Guide’ pilot focusing on plot-oriented and farm-oriented nitrogen or nitrate measurement; and the ‘Awareness in arable farming and open field vegetable growing’ pilot. The experiences gained from the pilots are included as part of the knowledge dissemination project within the DAW (Delta Plan for Agricultural Water Management) (see Subsection 3.6.3). In that programme, links are made for a large group of arable farmers between knowledge and the options for taking action. The text of the programme can be found as a whole (in Dutch) on [https://zoek.officielebekendmakingen.nl/kst-33037-367.html](https://zoek.officielebekendmakingen.nl/kst-33037-367.html).

Furthermore, there are three key sector projects involving public-private partnerships (PPP). These are the ‘Cows and Opportunities’ project, which is another of the projects under the DAW umbrella (more about that shortly), the ‘Better Soil Management’ project and the ‘Roughage, Soil and Closed-Cycle Agriculture’ project.
Those eight projects are discussed briefly below.

a) Nutrient Concentrates pilot
During the period covering the fourth and fifth Action Programmes, the Netherlands built up experience with processing animal manure at ten pilot farms. That pilot study was continued in the sixth Nitrate Action Programme. The pilot led to reduced spreading of traditional artificial fertilisers and offers an opportunity to utilise nutrients that are locally available in animal manure effectively and efficiently.

There are currently 10 products/cooperative ventures in the Nutrient Concentrates pilot, with a total of 18 functioning systems. The producers supplied nutrient concentrates in 2018 and 2019 to 1,466 different farms. The amount of product that is spread by a customer can vary widely; some farms only fertilise partly with nutrient concentrates, or only do so for part of the year. Others use nutrient concentrates for fertilisation of all the land and throughout the year. A total of 2 million kilograms of nitrogen were applied by farmers as nutrient concentrates in 2018.

Preconditions for the Nutrient Concentrates pilot
The following preconditions apply for the Nutrient Concentrates pilot. It covers a maximum of 10 production farms and a maximum of 20,000 ha that are fertilised using nutrient concentrates at above the application standard for nitrogen from animal manure but within that for nitrogen. The producers are recognised through the Fertilisers Act implementing regulation as producers and their production uses a process that involves reverse osmosis technology. The users of a nutrient concentrate are registered with the RVO.

As a product, the nutrient concentrate meets the following quality criteria:
- the nitrogen contained in the product is at least 90% in mineral form;
- the nitrogen-phosphate ratio is at least 15;
- the electrical conductivity is at least 50 mS/cm.

Research 2018-2019
During the period 2018-2019, tests were carried out within the Nutrient Concentrates pilot to improve the stability of the production process. The purpose of this approach is preparing for an intended permanent provision in the Nitrates Directive for the application of high-quality fertilisers from animal manure. The European Commission has announced the launch of a two-year study by the Joint Research Centre (JRC) into criteria for using processed manure products in the context of the Nitrates Directive. In the European context, the Nutrient Concentrates pilot is a unique project that is testing out a system of manure processing at a practical scale, as well as being one in which the commercial sector and research are working closely together. Five farms have supplied samples to the JRC as part of the pilot.
Moreover, a monitoring programme has looked at the quality of the product, also studying the contaminants such as heavy metals and pathogens. There have also been investigations at the production farms that discharge into surface waters looking for emissions of pathogens and veterinary medicine residues in the permeated water. This data will
be used by the water boards for defining the best available technology for manure processing in line with the decree about water discharges.

The results of this pilot and the additional studies have been delayed by the Covid-19 crisis and will be reported upon in a report that is expected to appear at the end of 2020.

b) Achterhoek without Artificial Fertiliser pilot
The Achterhoek without Artificial Fertiliser pilot takes pig manure from the Achterhoek region in the eastern part of the province of Gelderland and processes it sustainably to make valuable fertilisers, energy and clean water. The company Groot Zevert Vergisting ferments about 130,000 tons of products per year, of which about 90,000 to 100,000 tons are pig manure. Biogas from fermentation of the manure and from co-products is used as an energy source for the Friesland Campina dairy factory. The digestate is processed further in what is known as a Green Minerals Plant (Groene Mineralen Centrale/GMC) to produce valuable fertiliser products. Clean water (40-65%) and a concentrated liquid fraction that is used as fertiliser in the region are produced from the digestate. The thicker fraction is made hygienic and then exported. In the ‘Added Value from Manure and Minerals’ public-private research programme (that the Achterhoek without Artificial Fertiliser pilot is part of), a method has been developed to extract low-phosphate organic matter and a concentrated phosphate fertiliser (struvite or calcium phosphate). The GMC also produces two types of fertiliser (nitrogen/potassium and nitrogen/sulphur) that are spread on grassland and maize crops in the region. Fertilisation advice for specific crops is given in cooperation with the company ForFarmers. That fertilisation advice is then put into effect using the fertilisers that the GMC has available.

There was an increase in 2019 in the number of farms taking part in the Achterhoek without Artificial Fertiliser pilot (from 10 in 2018 to 57 in 2019). This pilot aimed to show that artificial fertiliser can be replaced in this region by locally reclaimed nutrients. On instructions from LNV, Wageningen University & Research (WUR) carried out research into the agricultural and environmental effectiveness of the reclaimed fertilisers compared to a mineral fertiliser. A field trial was also started in 2019 with silage maize, looking at leaching effects and the nitrogen replacement value. The results from the demonstration plots in 2018 were recently published (Ehlert & Van der Lippe, 2020). Based on those results, there seem to be almost no differences between fertilisation using substances reclaimed from manure and artificial fertiliser. The report on the demonstration plots of 2019 and on the field trials is being prepared and will be published at the end of 2020 or beginning of 2021. These results are also important for the Netherlands for making the case to the European Commission that manure processing products should no longer retain the status of animal manure within the Nitrates Directive. The farmers taking part in the pilot are overwhelmingly positive. They see the reclaimed fertiliser as a fully-fledged replacement for artificial fertiliser and the majority of those taking part have registered for 2020 again. Further field trials (with grass and maize) and monitoring were carried out in 2020, as well as risk analyses that are intended to yield a
protocol for producing, mixing, transporting and applying these circular fertiliser products.

c) Smart Fertilising pilot
The soils in the Loess Region are susceptible to nitrate leaching. The nitrate concentrations in this region are above the EU standard of 50 mg/l. In this pilot, 25 agricultural businesses in the Loess Region are attempting to keep the crop yields and quality up to scratch through a precise farm management and mineral management programme while at the same time achieving the objectives of the Nitrates Directive in terms of water quality. The latter aspect means that they are aiming to reduce nitrate leaching into groundwater and surface water and to achieve lower ammonia emissions through agriculture-related actions. The pilot is intended to create a simple-to-use management model that is widely applicable in the Loess Region. The participants in the pilot are dairy farmers – including some with derogations – and arable farmers. These farmers have exemptions for applying artificial nitrogen fertilisers under certain circumstances to above the nitrogen application standard. The farms receive close supervision from farm business advisors. In addition to LNV, various other parties from Limburg are involved, as is WUR; this is under the auspices of the LLTB (Limburg Agriculture and Horticultural Association). After an initial period of three years, the pilot was extended for a further two years on request from the LLTB and it ran until the end of 2020.

d) Nitrate Guide Pilot
This comprises a study that was carried out in 2019 to give an indicator at the level of the farm or plot of land for estimating the nitrate concentration in the upper groundwater layer. That research could then be used for accountability and justification at the farm level. The researchers from WUR concluded that the best indicator was the nitrate residue (NR) in the layer 0-90 cm below ground level when measured in the autumn (Noij & Ten Berge, 2019). The NR indicator was defined based on a literature study of previous research (including indicators in the Netherlands and elsewhere), nitrate policy in Flanders and Baden-Württemberg, plus several sub-aspects and trials in the Netherlands. The NR can be determined on an agricultural plot for just limited costs; determining an average NR value for a plot is a factor 15 to 40 cheaper than determining an average value for the groundwater nitrate concentration for a plot. The NR responds relatively quickly to measures: the farmer gets feedback on their actions in terms of NR measurements later in the same growing year.

For the areas studied in Flanders and Baden-Württemberg, the NR is seen as an instrument for checking whether farms are applying fertilisation measures properly. Both those regions have complex systems of measures that are put in place if a certain NR threshold value is exceeded. The threshold values used vary widely between the two regions. Using the NR has not helped develop a simple farm-specific or plot-specific target policy in either Flanders or Baden-Württemberg. It has however led to complex regulations including a large number of prescribed materials with little freedom of action in the areas at risk. The approach has resulted in drops in both regions in both the NR and
the nitrate concentration in groundwater and surface water, although
the fall in Flanders has levelled out in recent years.

The relationship between NR and the nitrate concentration in
groundwater and how it is affected by local factors is insufficiently
understood for an NR measurement on a plot to be used for determining
whether the nitrate standard of 50 mg/l in the upper groundwater on
that plot and the nitrate standard for surface waters are being
exceeded. The bandwidth for this is several tens of mg/l, for instance
because of annual variations in the weather. This is also the case in
Flanders and Baden-Württemberg. The relationship between NR and
nitrate is therefore not explicitly used in Flanders and Baden-
Württenberg. Instead of that, the NR is used for determining what
measures need to be taken. Using the NR in the soil instead of nitrate in
the groundwater is not recommended in the Netherlands for monitoring
and reporting on the effectiveness of the generic fertiliser policy,
according to the researchers (Noij & Ten Berge, 2019). It could lead to a
structural break in terms of the long-term time series for nitrate in
leachates that has already been built up as part of the Minerals Policy
Monitoring Programme. The researchers do however believe that the NR
is very valuable for steering and for awareness among agricultural
businesses. The indicator gives the farmers feedback relatively quickly
about their actions, offering the option of self-assessment with respect
to the group; it could also act as the basis for a learning system. For
that reason, using the NR as a tool for steering and awareness may be
elaborated upon further in 2020 to produce a proposal for public-private
cooperation to achieve the desired results of the administrative
agreements for the 34 groundwater protection areas (see elsewhere).

e) Awareness in Arable Farming and Open Field Vegetable
Growing pilot
At the end of 2018, as part of the sixth Nitrate Action Programme, a
behavioural intervention was developed that was aimed at arable
farmers and open field vegetable growers on sandy soils and loess soils
in the Sand South area and the Loess Regions. This was triggered by the
Fertilisers Act Evaluation 2016 summary report, which stated that the
average nitrate concentration in groundwater below arable farming
areas in the Sand Region in the period 2011 to 2014 was around
80 mg/l and that the average concentration for open field vegetable
growing was even higher than that, suggesting that the nutrient levels
in that sector needed to improve and that attention was needed for
which crops could be grown in which soils.

Looking closely at the stimuli that affect farmers’ behaviour and using
understandings gleaned from behavioural science, an approach was
developed that focuses on what is known as the ‘nitrate app’: an app
that is used along with measuring strips to give farmers an easily
accessible way of determining the nitrate levels on their own land and
giving them insights into the consequences of their own actions. Making
clear in communications and at meetings that increasing numbers of
farmers are getting down to taking measures against nitrate leaching
can create a new social norm. This working method gives arable farmers
and open field vegetable growers a way of taking control for themselves.
Preliminary research also showed that the effectiveness of behavioural interventions is greatest when the farmers were given individualised training in how to use the nitrate app. Two ‘measuring days’ were therefore started up at which arable farmers and open field vegetable growers were invited to come and measure nitrate levels under the supervision of an expert at a fellow arable farmer’s farm. There was then an opportunity for discussions with experts and colleagues about known and new measures to combat runoff and leaching. A total of around thirty farmers took part. At the Agricultural Days in Someren (the largest agricultural trade fair in the south of the Netherlands, with an estimated 12,000 visitors), demonstrations were then arranged for the nitrates app and nitrate strips were handed out to encourage measurements at home. These demonstrations reached about 200 farmers.

To show that the approach has broad enough support, which will strengthen the message, cooperative links have been sought with organisations involved such as Brabant Bewust, Delphy and Meststoffen Nederland. Additionally, RVO, NVWA, Deltares, Cumela, Nederlands Agrarisch Jongeren Kontakt and the province of Noord-Brabant also joined in.

f) The ‘Cows and Opportunities’ PPP

The Cows and Opportunities project (also known as ‘K&K’) has been running since 1999 with the primary aim of implementing anticipated environmental legislation in agricultural practices. In K&K, a group of sixteen highly motivated dairy farmers are looking with researchers at the options for sustainable and socially accepted dairy farming. By applying specific measures, they are obtaining a picture of the environmental, technical and economic consequences at the farm level. Additionally, these participants are acquiring experience of using these measures that is valuable for the sector as a whole. These pilot farms are also providing evidence for the effectiveness of the legislation.

K&K is making a significant contribution to developing an economically healthy dairy farming sector that operates within the environmental preconditions that have been set. This can also help improve the social acceptance of the sector further. The project yielded the following results:

- insights in the economic, ecological, sociocultural consequences of implementing future environmental legislation on dairy farms in the Netherlands;
- building blocks for implementing future environmental legislation;
- dissemination of knowledge within the sector by sharing experiences with colleagues;
- refinements to the application and excretion standards (flexibility and scope for business decisions).

To obtain an understanding of the water situation on the farm and of the associated risks for the farm and the environment, K&K developed the Farm Water Guide (BedrijfsWaterWijzer/BWW). The BWW uses seven modules. These are the modules Farm Premises, Drought, Flooding, Leaching, Run-off, Drinking Water and Ditch Management. See also (in
The supervisory committee and steering group decide each year which elements require specific attention. Over recent years, studies have also been carried out within this project looking at farms’ own nitrogen fertilisation using animal manure (BES) and farms’ own nitrogen standards (BEN) for aligning artificial fertiliser dosing to the yield capacity. A number of K&K farms took part in these pilots. The BEN pilot stopped in 2020.

The BES pilot is being extended, which means that all K&K farms with normal business operations will take part in the BES. For more information (in Dutch), see [https://www.koeienenkansen.nl](https://www.koeienenkansen.nl).

g) Better Soil Management PPP
The Better Soil Management PPP is a research programme by the Ministry of Agriculture, Nature and Food Quality (LNV) and a consortium of various parties from the vegetable products chains, under the auspices of the arable farming sector organisation. The PPP is part of the ‘Agri & Food’ key sector and runs for the period 2017-2020. The Better Soil Management PPP aims to use an integrated approach to extend knowledge about the soil and soil processes, aiming to increase yields and/or yield stability in both the shorter and longer term, to reduce undesirable emissions into the environment and to strengthen social soil services such as biodiversity and water management.

The work done over recent years has included a manual on green manure, research into non-inversion tillage and a report on classifying organic fertilisers. Work has also been done on a soil quality plan. More information is available (in Dutch) through [https://www.beterbodembeheer.nl/](https://www.beterbodembeheer.nl/).

h) The Roughage, Soil and Closed-Cycle Agriculture PPP
The Roughage, Soil and Closed-Cycle Agriculture PPP is running from 2020 to 2023. It is a follow-up to the Roughage Production and Soil Management PPP that ran from 2015 to 2019.

A broad consortium is working on making the production of grass and food crops more sustainable. The focus is on care for the soil, aiming for closed cycles, climate-friendly and climate-proof crop production, biodiversity and agroecology plus optimisation of crop yields and crop management. The PPP will help achieve the targets set in the LNV’s vision of closed-cycle agriculture, the Climate Agreement, the ‘On the Way to Planet Proof’ quality mark and elsewhere. New targets for optimising roughage production and soil management have been added with respect to the previous programme; attention is now also paid explicitly to reducing the emissions/losses of carbon, nutrients and pesticides to the atmosphere and to water. For more information (in Dutch), see [https://www.wur.nl/nl/Onderzoek-Resultaten/Projecten/PPS-Ruwvoer-Bodem-en-Kringlooplandbouw.htm](https://www.wur.nl/nl/Onderzoek-Resultaten/Projecten/PPS-Ruwvoer-Bodem-en-Kringlooplandbouw.htm).

3.6.2 Communication
Dutch fertiliser policy is an interpretation of the European Nitrates Directive. The purpose of the fertiliser policy is to improve the quality of
groundwater and surface waters by reducing the amounts of nutrients from agriculture. The IenW and LNV ministries acknowledge that many people seem to have lost sight of that objective and are also insufficiently aware that water quality in the Netherlands is under pressure. They see fertiliser policy not as a way of making improvements in that regard but as a goal in its own right, embodied in complex and ever-changing regulations. To promote awareness and understanding of the quality of groundwater and surface waters in the country and about how the fertiliser policy makes a positive contribution to it, the sixth Action Programme includes a statement that communication is to be used as a policy instrument.

To that end, cooperation on communication between the fertiliser policy team and the communications department at LNV, and the implementing organisations RVO and NVWA has been strengthened. A joint ‘fertiliser communications policy’ has been developed with the aim of drawing attention more actively and more clearly to fertiliser policy as an environmental policy that is socially important.

Various specific actions have been taken in the meantime that should help this, such as:

- a pilot in the arable farming and open field vegetable growing sectors to encourage greater awareness of the environmental effects of farmers’ actions (see point e in Subsection 3.6.1);
- more interaction between farmers and policy, for instance including more direct contacts between policymakers and farmers’ groups;
- providing more background information about the reasons underlying certain measures through the ‘Meer over mest’ (More about Manure) newsletter on rvo.nl;
- more attention to the results of the policy through wider reporting (for instance using social media) about the Derogation Monitor, the more rigorous fertiliser enforcement strategy and the quadrennial report on the results of the Nitrates Directive implementation.

Ultimately, these actions must not only get the objectives of the fertiliser policy into the spotlights better but must also improve the compliance and the results. The LNV’s aim is to have research carried out among farmers to see whether the actions are bearing fruit and where additional activities are still needed.

3.6.3 Supporting policy

**Delta Action Programme on Water Quality and Freshwater**

At the end of 2016, IenW brought the parties together that have been most closely involved in good water quality and who are responsible for achieving it in the programme called the Delta Action Programme on Water Quality and Freshwater. The objective is to see the activities of various governmental bodies and social organisations as a cohesive whole and to get them supporting each other so that results can be achieved. This is all focused on achieving chemically clean and ecologically healthy waters by 2027, the target for the EU Water Framework Directive (WFD). At the end of 2018, it was decided to concentrate the efforts by setting up several ‘accelerator forums’, as
they are called, for two years; these are based on the key challenges in reducing the loads on groundwater and surface water. One of the Accelerator Forums focuses on nutrients and crop protection agents; this is the Agriculture Accelerator Forum. The participants in this forum are managers of the Agriculture and Horticulture organisation, the Union of Water Boards, the Interprovincial Forum, Nefyto, the Royal General Bulb Growers’ Association (KAVB), Glastuinbouw Nederland (greenhouse horticulture) and the managers responsible for policy at the LNV and IenW ministries. The case has been made, among other things, for a simplified executive structure during the new phase of the Common Agricultural Policy, and support has been offered to provide an extra impulse for the DAW (Delta Plan for Agricultural Water Management).

Another important element in the Delta Action Programme is reinforcing the underlying level of knowledge. This covers not only new understandings that are being developed and disseminating them but also bundling existing knowledge, making sure it is applicable in practice and then doing so. This is known in short as the Water Quality Knowledge Impulse (or KIWK in Dutch).

The DAW and KIWK mentioned above and the Administrative Agreement are discussed briefly below.

**The Delta Plan for Agricultural Water Management (DAW)**
LTO Nederland (the Dutch Federation of Agriculture and Horticulture) took the initiative in 2013 to play its part in resolving what are referred to as the ‘water issues’, along with strengthening agriculture and horticulture. This DAW initiative is being put into effect with the assistance of the water boards, the provincial authorities and the drinking water sector; it also involves the IenW and LNV ministries (DAW, 2020). The project is intended to have resolved both the water quality issues by 2027 and to have achieved sustainable water supplies for agriculture. This is therefore not only about improving water quality but also about counteracting the damage done by drought and flooding. The implementation will be done at four levels of scale, ranging from the farm level to the national. At the beginning of 2020, about 340 projects were brought together under the DAW umbrella. These are both new and existing projects (see Map 3.4; the DAW website also gives an overview in Dutch – [https://agrarischwaterbeheer.nl/](https://agrarischwaterbeheer.nl/)). The themes addressed are business operations, fertilisation, soil, crop protection, drought and water table elevation, and mineral utilisation.

An example of a DAW project is VKA (Fertile Recycling in the Achterhoek and Liemers Regions), which was started up in 2014. There are currently 285 dairy farmers in the project, working on improving the fertility of their soil, who are being encouraged and supervised in making more efficient use of the minerals on their farms (VKA, 2020). As well as the projects, the DAW website offers options for viewing a list of possible measures for each sector, soil type and theme, along with the pros and cons plus a global indication of the costs (DAW, 2020). Moreover, there are initiatives by the provinces and the drinking water companies. The Province of Overijssel, together with the drinking water company Vitens and agricultural advisers and farmers, has for instance been attempting since 2012 through the ‘Farmers for Drinking Water’ project to reduce the nitrate load in five vulnerable drinking water
extraction areas. Waterleiding Maatschappij Limburg (WML/Limburg Water Company) has been working since 1997 with farmers who have land holdings in groundwater protection areas. This is being done in the Sustainable Clean Groundwater project, which is aiming to reduce leaching of both nitrogen and crop protection agents. Projects such as Farmers for Drinking Water have resulted in a ‘Management Agreement for Groundwater Protection Areas’ being defined.

![Map 3.4 The number of projects being carried out as part of the Delta Plan for Agricultural Water Management.](image)
Source: DAW, 2020

To sharpen the focus on achieving the water-related objectives, the ‘Impulse for Agricultural Water Management’ was defined. Agricultural businesses are practically oriented: they have their own opinions about the remaining water-related tasks and are asking questions such as what the task is, what their contribution to it is and what others are doing, and what is in it for them if they take measures. As part of the impulse provided by the DAW, the residual tasks for agricultural water management are therefore being described for each water board (in consultation with the groundwater and surface water managers) in the ‘Regional Tasks for Agricultural Water Management’. This phase will be completed by the end of 2020 and used as input for the second stage, namely setting up implementation programmes with the measures needed for each area if the water-related objectives are to be achieved. This is voluntary, first and foremost, but not without obligations. If sufficient results are not obtained, additional measures will be considered that will be more obligatory in nature. Additionally, methods
are being considered for dealing with measures that have already proved useful in agricultural practice but that are not yet being implemented throughout the sector.

The approach sketched out for the cooperation between research and the agricultural sector is part of a long tradition. Examples include the ‘Sustainable Dairy Farm Management’ project, carried out during the period 1991-1995 at 16 farms spread across all the regions in the Netherlands (Beldman, 1993); the Bioveem project, carried out in two phases from 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 ‘Telen met toekomst’ (Growing with a Future) network, carried out in two phases over the period 2000-2010. The setup and the numbers of participants in the phases of Growing with a Future differed. During the first phase (2000-2003), there were 34 practising farms from the arable farming, open field vegetable growing, tree nursery and bulb growing sectors (De Ruijter & Smit, 2003). During the second phase (2004-2010), the participants came from all plant growers in the Netherlands, involving about 400 participants working in 35 groups (Van Geel & Brinks, 2011; Drent, 2010).

Management Agreement for Groundwater Protection Areas
For the supplementary approach to nitrate leaching from agricultural activities in specific groundwater protection areas, a management agreement was signed between the Dutch Federation of Agriculture and Horticulture (LTO), the Association of Water Companies in the Netherlands (Vewin), the Interprovincial Forum (IPO) and the IenW and LNV ministries (see Appendix 7a in LNV, 2017).

For implementing the management agreement, RIVM had identified 40 groundwater protection areas as being susceptible to nitrate leaching (Claessens et al., 2017). The provincial authorities and water companies have used regional information to assess whether these are indeed the areas where leaching from agriculture and horticulture is a determining factor. Based on this regional analysis, some areas were dropped (11) and others were added (5). Areas were for example dropped where agricultural land use is very limited because most of the land is either natural or urban.

For the remaining 34 areas (see Map 3.5), the provincial authorities, the drinking water companies and the agricultural and horticultural organisation organised implementation meetings in accordance with the administrative agreement, setting out agreements for the regional approach.

As part of the DAW, the regional branches of the Dutch Federation of Agriculture and Horticulture went into the areas to recruit participants, which was done by approaching agricultural land users in person. The efforts that had to be put into this personal approach meant results could be achieved faster in smaller areas than in larger ones. In some cases, there was a drop-off in participation due to discussions about compensation for land dehydration between the agricultural land users and the drinking water company in question. Recruitment of participants
is ongoing. Further information is available (in Dutch) from https://agrarischwaterbeheer.nl/thema/grondwaterbescherming

Map 3.5 Locations of the 34 groundwater protection areas for which agreements have been made about a regional approach as part of the Administrative Agreement on a ‘Supplementary approach to nitrate leaching from agricultural activities in specific groundwater protection areas’.
Source: Land Registry, customised work

A specific monitoring programme has been developed for monitoring the effects of this administrative agreement on water quality, in line with the Minerals Policy Monitoring Programme (LMM). The results of the baseline measurement will be made available after the summer of 2020.

To illustrate what the target range means (achieving less than 50 mg/l nitrate on average in the water leaching from the root zone of plots on farms), an ex-ante evaluation was carried out in 2020 at the request of all parties participating in the administrative agreement (Van den Brink et al., 2020). Based on that, the parties involved expect the objective of the administrative agreement to be achievable in 11 of the 34 areas by better mineral management on the part of the participating farmers. For 23 areas, this is not going to be straightforward. For 12 of those 23
areas, the parties involved have said that the target range is within sight but that additional voluntary efforts are needed, such as a greater acreage taking part. For the remaining 11 areas, it is expected that the target range is not going to be realistic within the given context and scope of the administrative agreement. For these 11 areas, more far-reaching measures will need to be worked out, given their susceptibility to nitrate leaching resulting from the combination of soil type, low groundwater tables and land use. Based on a further analysis, the parties to the administrative agreement will determine by no later than 2021 what additional measures are needed and whether they should then be imposed by legislation and regulations. Taylor-made solutions are clearly needed for each area as the tasks differ from one area to the next, meaning that the effectiveness, feasibility and efficiency of measures must be weighed up for each.

Water Quality Knowledge Impulse
In the Water Quality Knowledge Impulse, the national and provincial authorities, water boards, water companies and knowledge institutes are working to gain a clearer understanding of the quality of groundwater and surface water and the factors that influence that quality. This will allow water managers and others to take the right measures for improving water quality and increasing biodiversity in water bodies. In the programme, parties bring together existing and new knowledge, and make it applicable (or more applicable) in practice. The programme runs until the end of 2021. The Knowledge Impulse is financed by IenW, the water boards as a whole, STOWA (Foundation for Applied Water Research), IPO (the Interprovincial Forum) and the drinking water companies. The Knowledge Impulse is being put into effect by the KWR Watercycle Research Institute, Deltares, Wageningen Environmental Research and RIVM. More information (in Dutch) can be found at https://www.kennisimpulswaterkwaliteit.nl.

3.7 Cost-effectiveness
Within the DAW mentioned above (see Subsection 3.6.3) a list of 99 agricultural measures was defined in 2017 in the BOOT (Administrative Forum for Outdoor Cultivation and the livestock sector) to reduce emissions of nutrients and crop protection agents into the waters (DAW, 2020). For 24 of these measures, fact sheets were drawn up estimating the production benefits, the environmental benefits and the costs (Verloop et al., 2018; see Table 3.21).
Table 3.21 Effects and costs of a selection of measures from the BOOT list.1

<table>
<thead>
<tr>
<th>Factsheet</th>
<th>Planning</th>
<th>Effect</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Production benefit</td>
<td>Environmental benefit</td>
</tr>
<tr>
<td>1</td>
<td>Factsheets manual2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Get a picture of your water management2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Know your soil2</td>
<td></td>
<td>+/+ + +3</td>
</tr>
<tr>
<td>4</td>
<td>Plan your fertilisation ahead</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>5</td>
<td>Find the optimum land use for grass and maize</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Extend the lifespan of grassland</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>Dry buffer strips</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>8</td>
<td>Wet buffer strips</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>9A</td>
<td>Removing nitrate from drained water</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>9B</td>
<td>Removing phosphate from drained water</td>
<td>0</td>
<td>+(+</td>
</tr>
<tr>
<td>10</td>
<td>Postpone spreading animal manure on grassland until mid-March</td>
<td>- -</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>Get the optimum nitrogen effect from your fertiliser</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>Apply mineral nitrogen fertilisers that are less liable to leaching</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>13</td>
<td>Adjust the fertilisation to the nitrogen mineralisation</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>14</td>
<td>Apply barriers in ridge cultivation</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>15</td>
<td>Use a dredging pump for clearing silt effectively from ditches</td>
<td>-/0</td>
<td>++</td>
</tr>
<tr>
<td>16</td>
<td>Cultivate the soil along contour lines</td>
<td>0</td>
<td>++</td>
</tr>
<tr>
<td>17</td>
<td>Make grassland deeper-rooted</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>18</td>
<td>Use deep-rooting crops and “resting crops” (e.g. cereals and legumes)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>19</td>
<td>Increase organic material in the soil on dairy farms (in systems with crop rotation)</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>20</td>
<td>Use of compost and organic fertiliser</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>21</td>
<td>Sow a good catch crop</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>22</td>
<td>Soil cover</td>
<td>-/+</td>
<td>++</td>
</tr>
<tr>
<td>23</td>
<td>Save manure on maize on ploughed grassland</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>24</td>
<td>Dilute slurry when spreading</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

1 Meanings of the production benefit and environmental benefit codes: -- = very negative, - = negative, 0 = neutral, + = positive, ++ = very positive. Meanings of the cost codes: 0 = none, + = limited, ++ = considerable, +++ = high.

2 These are measures that create the conditions: the effects depend on subsequent actions.

3 Dependent on the type of study – a soil science study or a soil status check.

Source: Verloop et al. (2018)

Verloop et al. (2018) note that the study and its execution show that many of the measures need their empirical underpinnings to be strengthened. They also conclude that the effectiveness of these
measures on the ultimate water quality objectives needs to be quantified. A number of measures relate to changes in soil parameters (such as the soil’s organic matter content) without the relationship of these targets to the water quality being elaborated upon sufficiently.

3.8 Source


EU (2005) Uitvoeringsbesluit van de Commissie van 8 december 2005 tot verlening van een door Nederland gevraagde derogatie op grond van Richtlijn 91/676/EEG van de Raad inzake de bescherming van water tegen verontreiniging door nitraat uit agrarische bronnen, Publicatieblad van de Europese Unie, L 324, 89-93.


Van den Brink, C., Strulik, A., Pape, J.J. (2020) Verkenning effectiviteit van verschillende vormen van agrarische bedrijfsvoering in het kader van de Bestuursovereenkomst 'Aanvullende aanpak nitrautuispoelings uit agrarische bedrijfsvoering in specifieke grondwaterbeschermingsgebieden'. Amersfoort, Royal HaskoningDHV, rapport BH2977WATRP2006091139WM.


4  Effects of Action Programmes on agricultural practices and nitrate concentrations in the water on farms

4.1  Introduction

This chapter gives an overview of the status and trends in agricultural practices and in the nitrate concentrations measured in water leaching from the root zones of fields and in ditch water on farms for each of the main soil type regions in the Netherlands: the Sand, Loess, Clay and Peat regions. Additionally, it reports on the nitrate concentrations in the three key sandy soil areas within the Sand Region (see Figure 3.2). The bulk of agricultural land is in the Sand Region and the Clay Region. About 47% of Dutch agricultural land by area is in the Sand Region, 42.5% in the Clay Region, 9% in the Peat Region and 1.5% in the Loess Region.

Arable farming and dairy farming are the main land users in the Netherlands (over 65% of the acreage in each region) (see Table 4.1). Dairy farming is the main land user in the Peat and Sand regions. In the Clay and Loess regions, both arable farming and dairy farming are important land users. The acreage covered within the Minerals Policy Monitoring Programme (LMM) in the various regions has ranged from 76% in the 1990s to 86% from 2016 onwards.

Table 4.1 Overview of the agricultural land area represented in the LMM in 2018 per farm type and region (as a percentage of all agricultural land).

<table>
<thead>
<tr>
<th></th>
<th>Arable farming</th>
<th>Dairy farming</th>
<th>Factory farming</th>
<th>Other¹</th>
<th>Non-LMM²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Region</td>
<td>18%</td>
<td>48%</td>
<td>8%</td>
<td>13%</td>
<td>13%</td>
</tr>
<tr>
<td>Loess Region</td>
<td>40%</td>
<td>28%</td>
<td>-</td>
<td>19%</td>
<td>13%</td>
</tr>
<tr>
<td>Clay Region</td>
<td>39%</td>
<td>38%</td>
<td>-</td>
<td>9%</td>
<td>14%</td>
</tr>
<tr>
<td>Peat Region</td>
<td>-</td>
<td>81%</td>
<td>-</td>
<td>-</td>
<td>19%</td>
</tr>
</tbody>
</table>

¹ The category ‘Other’ refers to other farms with livestock (see Subsection 2.3.2).
² ‘Non-LMM’ comprises both farm types that are not part of the LMM and farms that do not meet the LMM criteria in terms of acreage and/or commercial scale. This report does not cover such farms.

Section 4.2 gives an overview of agricultural practices for the farm types that are represented in the LMM. Section 4.3 presents the nitrate concentrations as measured in water leaching from the root zones of fields on LMM farms and in ditches next to those fields. As in the chapters on the water quality of groundwater and surface waters, the nitrate concentrations are compared against the EU standard of 50 mg/l. Strictly speaking, this standard does not apply to soil moisture, i.e. not to the water present in unsaturated soil. Almost all measurements of water leaching from the root zone in the Loess Region and a limited number of measurements in the Sand region apply to nitrate concentrations in soil moisture. This is because the groundwater (i.e. the water-saturated zone) at these locations is found at great depths, often tens of metres below surface level. This groundwater is therefore not representative of the water leaching from the root zone.
The report on the LMM data shows a difference of one year between the reporting periods for agricultural practices on the one hand and the nitrate concentrations in the water leaching from the root zone on the other. In other words, the farm data from 1991-1994 is compared against the quality of the water on farms during the period 1992-1995 (see also Subsection 2.3.2). It has been assumed that the quality of the water on farms in Year X is above all affected by agricultural practices in Year X-1. The relationship between changes in agricultural practices and the nitrate concentrations in water on farms is discussed in Section 4.4.

4.2 Agricultural practices

4.2.1 General

This section details the general characteristics of agricultural practices at farms within the LMM sample population in the FADN (see Subsection 2.2.3). The data presented here is intended as background information for clarifying the trends in water quality (see Section 4.3) on those farms. The developments in agricultural practices for the Netherlands as a whole have been described in Chapter 3.

The figures for surpluses in this chapter are based on the LMM sample and have been stated for each farm type (arable and dairy farms) and for each region (Sand, Clay, Peat and Loess). The nutrient surplus in kg N per hectare on the agricultural soil balance for the whole of the Netherlands (see Subsection 2.2.3), as calculated by Statistics Netherlands and shown in Table 3.15, matches the nitrogen surplus on the soil balance (see Subsection 2.3.2) of the arable and dairy farms in the LMM sample in terms of both the order of magnitude and the trend (see tables 4.2 and 4.3). The figures for surpluses from Statistics Netherlands in the previous chapter refer to the nitrogen losses to both the atmosphere and the soil for the entire Dutch agricultural and horticultural sector.

The general tendency among the LMM sample population is that the farms are increasing in size, that the livestock density (calculated using phosphate excretion) has increased somewhat over recent years and that application of nitrogen from both animal manure and artificial fertiliser is decreasing, albeit by very little if at all in recent years.

4.2.2 Arable farming

Arable farms in the Clay Region are on average the largest in the LMM (approximately 63 ha in the period 2015-2018) (see Table 4.2). The arable farms in the Sand Region and Loess Region are distinctly smaller in area (approx. 55 and 42 ha respectively). The arable farms in the Sand Region and Clay Region have grown in area by about 30% with respect to the initial period (1991-1994 for the Sand Region and 1995-1998 for the Clay Region), but the average farm size in the Sand Region has decreased by about 5 ha over the period 2011-2014 and only increased by a mere 3 ha in the Clay Region. Farm sizes have remained stable in the Loess Region. The proportions of potatoes and sugar beet in the growing plans has fallen and the proportion of cereals has risen compared to the 1990s.

Use of nitrogen from animal manure on arable farms has fallen with respect to the 1990s, particularly in the Clay Region. This stronger drop
in the Clay Region may possibly be a result of the ban on manure spreading in the autumn since about 2009. In the Sand Region and Loess Region, animal manure is generally spread in the spring, so the autumn restrictions have little influence there. Use of animal manure has been fairly stable over recent years. Less nitrogen fertiliser has been applied since the initial period, but usage has not changed much since the period 2007-2010. An increase can be seen in the use of nitrogen from other organic fertilisers, though this is generally less than the decrease in artificial fertiliser. The nitrogen surplus in the soil balance has been reasonably stable over the two most recent periods. The surplus in the Loess Region is an exception: the number of arable farms in the LMM in that region is relatively small (18 to 20 – see Table 2.2) and so outliers affect the averages more. The surpluses in all the regions were higher in 2018 than 2017, at least partly because the figures for 2017 were relatively low (see figures 4.1 to 4.3). Fairly stable fertilisation and probably also reasonably stable crop yields explain the stability of the soil surpluses for nitrogen on arable farms.

4.2.3 Dairy farming

Dairy farms in the LMM in the Sand Region and Clay Region are smaller in area than arable farms but are still growing in acreage; this includes the years 2015-2018 compared to the years 2011-2014 (see Table 4.3). The growing plans have remained fairly stable, albeit with a small increase in the proportion of grassland in the Sand Region and Loess Region at the expense of the proportion of maize. This may have been the consequence of the derogation condition requiring at least 80% grassland, which came into force in 2014. The proportion declined slightly in the Clay Region and Peat Region, where the grassland percentage was already above the required 80%. The livestock headcount fell up to the fifth period (2007-2010), but rose again after that due to the almost annual increase in the milk quota of 1–2% from 2008 and abolition of the quota in 2015. The manure storage capacity has increased over the last few periods, except in the Clay Region.

Figure 4.1 Development in the nitrogen soil surplus (kg/ha) in arable farms in the Sand Region (mean and 10th to 90th percentile range per annum). The figures for 2018 are provisional.
Compared to the first period (1991-1994), the use of both nitrogen from animal manure and nitrogen from artificial fertiliser fell up to and including the fifth period. However, there is almost no change between the fifth and seventh periods (2007-2018) in dairy farms in all regions. Nitrogen soil surpluses did fall slightly between the fifth and sixth periods; a decline in the nitrogen in animal feed played a role here. This decline continued in the Sand Region and Peat Region. However, there was a slight increase in the Clay Region and the nitrogen soil surplus in the Loess Region was distinctly higher in the period 2015–2018 compared with previous years. This is largely due to a combination of more feed purchases and fewer removals of plant products in 2015 and 2016. Furthermore, one of the dairy farms in the Loess Region changed its structure. Surpluses were higher in 2018 than in 2017 in all regions, probably partly because of lower volumes of crops being removed due to the drought (see Figures 4.4 to 4.7).
Figure 4.4 Change in the nitrogen surplus on dairy farms in the Sand Region (mean and 10th to 90th percentile range per annum).

Figure 4.5 Change in the nitrogen surplus on dairy farms in the Loess Region (mean and 10th to 90th percentile range per annum).

Figure 4.6 Change in the nitrogen surplus on dairy farms in the Clay Region (mean and 10th to 90th percentile range per annum).
4.2.4 Other livestock farms

The LMM group ‘other livestock farms’ can only be shown for the Sand Region and Clay Region as there are not enough farms available per annum in the Loess Region. As regards developments in the acreage, these farms show a similar pattern to the arable farms (stable in the last two periods) (see Table 4.4). As regards the other results such as crops and nitrogen surplus, the changes on ‘other livestock farms’ are more in line with the dairy farms.
<table>
<thead>
<tr>
<th>Arable farms</th>
<th>Sand Region</th>
<th>Clay Region</th>
<th>Loess Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>'91-'94</td>
<td>'11-'14</td>
<td>'15-'18</td>
</tr>
<tr>
<td>Acreage (hectares)</td>
<td>46</td>
<td>58</td>
<td>55</td>
</tr>
<tr>
<td>Potatoes (%)</td>
<td>44</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Sugar beet (%)</td>
<td>19</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Cereals (%)</td>
<td>17</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Other crops (%)</td>
<td>20</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>N from animal manure (kg/ha)</td>
<td>124</td>
<td>112</td>
<td>117</td>
</tr>
<tr>
<td>N from artificial fertiliser (kg/ha)</td>
<td>114</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>N from other organic fertilisers (kg/ha)</td>
<td>0</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>N surplus for soil surface balance (kg/ha)</td>
<td>158</td>
<td>100</td>
<td>101</td>
</tr>
</tbody>
</table>

1 Arable farming is rare in the Peat Region; the Clay Region and Peat Region have been in the LMM since 1996 and the Loess Region since 2002.
Table 4.3 Dairy farms in the Netherlands that are part of the LMM sample group; key features of agricultural practices on farms in the Sand, Clay, Peat and Loess regions\(^1\) for various reporting periods.

<table>
<thead>
<tr>
<th>Dairy farms</th>
<th>Sand Region '91-'94</th>
<th>'15-'18</th>
<th>Clay Region '95-'98</th>
<th>'11-'14</th>
<th>'15-'18</th>
<th>Peat Region '95-'98</th>
<th>'11-'14</th>
<th>'15-'18</th>
<th>Loess Region '07-'10</th>
<th>'11-'14</th>
<th>'15-'18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acreage (hectares)</td>
<td>28</td>
<td>45</td>
<td>49</td>
<td>35</td>
<td>55</td>
<td>60</td>
<td>34</td>
<td>51</td>
<td>55</td>
<td>45</td>
<td>49</td>
</tr>
<tr>
<td>Grassland (%)</td>
<td>77</td>
<td>77</td>
<td>80</td>
<td>90</td>
<td>86</td>
<td>88</td>
<td>96</td>
<td>92</td>
<td>93</td>
<td>66</td>
<td>65</td>
</tr>
<tr>
<td>Maize (%)</td>
<td>20</td>
<td>20</td>
<td>17</td>
<td>8</td>
<td>11</td>
<td>9</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Other crops (%)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Livestock (phosphate LSU per hectare)(^2)</td>
<td>2.8</td>
<td>2.4</td>
<td>2.4</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>1.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Manure storage (%)(^3)</td>
<td>94</td>
<td>146</td>
<td>154</td>
<td>108</td>
<td>168</td>
<td>166</td>
<td>102</td>
<td>158</td>
<td>170</td>
<td>150</td>
<td>144</td>
</tr>
<tr>
<td>N from animal manure (kg/ha)</td>
<td>362</td>
<td>229</td>
<td>227</td>
<td>301</td>
<td>231</td>
<td>237</td>
<td>293</td>
<td>230</td>
<td>238</td>
<td>221</td>
<td>219</td>
</tr>
<tr>
<td>N from artificial fertiliser (kg/ha)</td>
<td>245</td>
<td>108</td>
<td>110</td>
<td>279</td>
<td>140</td>
<td>149</td>
<td>252</td>
<td>108</td>
<td>107</td>
<td>97</td>
<td>106</td>
</tr>
<tr>
<td>N from other organic fertilisers (kg/ha)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>N surplus for soil surface balance (kg/ha)</td>
<td>331</td>
<td>145</td>
<td>132</td>
<td>328</td>
<td>161</td>
<td>164</td>
<td>415</td>
<td>220</td>
<td>202</td>
<td>130</td>
<td>126</td>
</tr>
</tbody>
</table>

\(^1\) The Clay Region and Peat Region have been in the LMM since 1996 and the Loess Region since 2002.

\(^2\) Phosphate LSU is the number of livestock units calculated based on their phosphate excretion; 41 kg phosphate per annum is equivalent to 1 dairy cow.

\(^3\) Percentage of the total volume of manure produced that can be stored on the farm for six months.
### Table 4.4 Other livestock farms in the Netherlands that are part of the LMM sample group; key features of agricultural practices on farms in the Sand Region and Clay Region\(^1\) for each reporting period.

<table>
<thead>
<tr>
<th>Other livestock farms</th>
<th>Sand Region</th>
<th>Clay Region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>'91-'94</td>
<td>'11-'14</td>
</tr>
<tr>
<td>Acreage (hectares)</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>% grassland</td>
<td>49</td>
<td>64</td>
</tr>
<tr>
<td>% maize</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>% potato, sugar beet, grain</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>% other crops</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Livestock (phosphate LSU per hectare)(^2)</td>
<td>4.3</td>
<td>1.7</td>
</tr>
<tr>
<td>% manure storage (^3)</td>
<td>105</td>
<td>226</td>
</tr>
<tr>
<td>Nitrogen from animal manure (kg/ha)</td>
<td>306</td>
<td>195</td>
</tr>
<tr>
<td>Nitrogen from artificial fertiliser (kg/ha)</td>
<td>159</td>
<td>87</td>
</tr>
<tr>
<td>Nitrogen from other organic fertilisers (kg/ha)</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>N surplus for soil surface balance (kg/ha)</td>
<td>281</td>
<td>167</td>
</tr>
</tbody>
</table>

\(^1\) The Clay Region has been included in the LMM since 1996. There are hardly any 'other livestock farms' in the LMM sample in the Peat and Loess Regions.

\(^2\) Phosphate LSU is the number of livestock units calculated based on their phosphate excretion; 41 kg phosphate per annum is equivalent to 1 dairy cow.

\(^3\) Percentage of the total volume of manure produced that can be stored on the farm for six months.

#### 4.3 Nitrate concentrations

#### 4.3.1 Overview at the national level

Nitrate is the main form of nitrogen in the water that leaches from the root zone of agricultural land (leachates) (> 80%; see Figure 4.8). Nitrate is also the main nitrogen component in ditch water on farms in the Sand Region (approx. 80%) and the Clay Region (approx. 70%). Nitrate is far less important in the leachates and ditch water of the Peat Region (< 25%). In the Peat Region, ammonium is the main form of nitrogen in leachates (approx. 45%) and organic nitrogen is the main form in ditch water (approx. 45%). Ammonium concentrations in groundwater in the Peat Region increase with the groundwater depth (Van der Grift, 2003). This has been ascribed to the mineralisation of the organic material (Meinardi, 2005).

Average nitrate concentrations in leachates vary between the regions. The concentration is lowest in the Peat Region, higher in the Clay Region and highest in the Sand and Loess Regions (see Figure 4.8). In the winter, nitrate concentrations in ditch water are lower than in leachates.
In the period 2016–2019, the nitrate concentration in the leachates in the Sand and Loess regions was lower on average than in all previous periods, but still at or above the standard of 50 mg/l (see Table 4.5a). In the Clay Region, the concentration was higher than in the previous period; at an average of 30 mg/l, it is roughly equal to the concentration in the period 2008–2011. In the Peat Region, the concentration is permanently low (average < 10 mg/l), without a clear trend.

All regions have some farms that fail to achieve the standard (see Table 4.5b). The percentage of farms that achieve the standard has increased in the Sand and Loess regions: almost half of the farms in the Loess Region and over half the farms in the Sand Region have concentrations of less than 50 mg/l. In the Clay Region, a smaller proportion of farms now achieve the standard compared to the previous period (82% now and 90% in the previous period). Nearly all farms in the Peat Region are still below the standard (> 95%).

Figure 4.8 Dissolved nitrogen concentration (as N in mg/l) in water that leaches from the root zone (left) and in ditch water (right) on farms in the Sand and Loess regions (no ditches), the Clay Region and the Peat Region in the Netherlands. Average concentration in the period 2016–2019 weighted by acreage.
Table 4.5a Nitrate concentrations (mg/l as NO₃) in water that leaches from the root zone. Averages per period¹, measured (M) and standardised (S).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>M</td>
<td>145</td>
<td>116</td>
<td>64</td>
<td>75</td>
<td>62</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>145</td>
<td>107</td>
<td>84</td>
<td>68</td>
<td>55</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>Clay</td>
<td>M</td>
<td>39</td>
<td>35</td>
<td>47</td>
<td>29</td>
<td>23</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>55</td>
<td>46</td>
<td>36</td>
<td>29</td>
<td>25</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Loess</td>
<td>M</td>
<td>89</td>
<td>90</td>
<td>74</td>
<td>68</td>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peat</td>
<td>M</td>
<td>9</td>
<td>3</td>
<td>13</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

¹ Average weighted by acreage of the farm averages per period.
² M = measured, S = standardised (see Subsection 2.3.3, 'Statistical analyses and effects observed').

Although the average nitrate concentrations for the period were lower in the Sand and Loess regions in the period 2016–2019 than in the previous period, they started to rise again from 2017, as they did in the Clay Region (see Figure 4.9). The percentage of farms that do not meet the standard of 50 mg/l also increased after 2017 (see Figure 4.10). The increase is attributed to a combination of factors that mainly seem to be related to the dry conditions of recent years (see Inset 4.1). The dry conditions can lead to increased nitrate concentrations in the leached water in various ways:

a. Drought can make crops’ uptake of nitrogen decline, with lower crop yields as a result. The nitrogen soil surplus will increase as a consequence, resulting in more leaching in the winter.

b. Furthermore, less nitrate may be broken down (denitrification) and more nitrate can therefore leach into the groundwater and surface water in the winter.

c. An evaporation effect, as it is known, may also occur: if the soil becomes severely dehydrated, the soil moisture in which the nitrate is dissolved evaporates, which means that the concentrations increase.

Table 4.5b Percentage of farms with nitrate concentrations greater than 50 mg/l (as NO₃) in water that leaches from the root zone. Averages weighted by acreage, per period¹, measured (M) and standardised (S).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>M</td>
<td>89</td>
<td>81</td>
<td>55</td>
<td>65</td>
<td>54</td>
<td>47</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>94</td>
<td>86</td>
<td>75</td>
<td>66</td>
<td>55</td>
<td>48</td>
<td>45</td>
</tr>
<tr>
<td>Clay</td>
<td>M</td>
<td>26</td>
<td>26</td>
<td>37</td>
<td>19</td>
<td>10</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>36</td>
<td>32</td>
<td>22</td>
<td>15</td>
<td>11</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Loess</td>
<td>M</td>
<td>89</td>
<td>82</td>
<td>63</td>
<td>54</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peat</td>
<td>M</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Average weighted by acreage of the farm averages per period.
² M = measured, S = standardised (see Subsection 2.3.3, 'Statistical analyses and effects observed').
**Inset 4.1 – Dry conditions and the effect on leachates**

Increases in nitrate concentrations in leachates and ditch water on farms have been attributed to the dry conditions of recent years. The effect of the dry conditions can be seen clearly in the increasingly low groundwater levels in the Sand Region in the summer and in the increased formation time for the top metre of groundwater (see Figure I-4.1). The formation time denotes the time that is needed to fill the soil column containing the uppermost metre of groundwater with water that leaches from the root zone in the plot.

Since 2017, groundwater levels have been lower than in all the previous years since 1992, the first year of measurements. Usually, a lower groundwater table means less breakdown of nitrate by denitrification. The organic matter content in the soil decreases as the depth increases. Organic matter is needed as a source of energy for the breakdown of the nitrate (Scientific Committee on Nutrient Management Policy (CDM, 2017).

The formation time has increased since 2016 and it was equal to 1992 in 2019, the former being considered to be an exceptionally dry year. A high value for the formation time means that after the harvest, relatively little water was leaching the nitrate in the root zone away into the groundwater; as a result, the nitrate concentration in the uppermost metre of groundwater is usually high (Boumans & Fraters, 2017). A low value means that a relatively large amount of water was leaching the nitrate away and the concentration is then usually low. In wet areas with high groundwater tables, this rapidly leads to higher concentrations in the uppermost metre of the groundwater and in the water that is discharged via drainage pipes. In drier areas, it can take a little longer before nitrate concentrations rise in the uppermost metre of the groundwater because of the transit time.

![Figure I-4.1 – Groundwater table in metres below ground level (left) and formation time for the uppermost metre of groundwater in years per cubic metre (right).](image-url)
Effect of external conditions on nitrate concentration

The average nitrate concentration has always varied considerably from year to year. These fluctuations are largely caused by external circumstances. The main factors are differences between years in the precipitation surplus and changes in the group of farms taking part. The variation in the precipitation surplus leads to differences between years in the degree of dilution and the depth of the groundwater table (Boumans et al., 2001, 1997) (see Inset 4.1). An increase in the
precipitation surplus leads to dilution of the leachates and consequently to lower concentrations. What is more, a rise in the groundwater table leads to greater denitrification.

The composition of the group of farms that is monitored has changed during the period of twenty-five years plus during which measurements have been made. In the period between 1996 and 2006, the LMM was a 'peripatetic' monitoring network (see Subsection 2.3.2), which meant there were greater differences between years than in the periods before 1996 and after 2006. The LMM became a fixed monitoring network after 2006, as it did between 1992 and 1995, but some farms ceased to operate and were therefore replaced. Moreover, farms buy and/or sell land or exchange plots of land. These changes can lead to differences between years in the proportions of the various soil types within the LMM. Any increase over time in the proportion of peat soils on farms in the Sand Region would lead to a reduction in the measured nitrate concentrations even if the nitrogen surplus remained unchanged.

To better quantify the actual effects of the fertiliser policy, the changes in the nitrate concentration have been estimated excluding the effect of external conditions. A statistical model was used for this (Boumans & Fraters, 2016; see Subsection 2.2.3). The result is what is termed the standardised nitrate concentration.

This standardised nitrate concentration in the leachates on farms in the Sand Region decreased clearly from 145 mg/l in the period 1992-1995 to 45 mg/l in the period 2016-2019 (see Figure 4.11 and Table 4.5a). The standardised nitrate concentration in the Clay Region also declined, from 55 mg/l in the late 1990s to 25 mg/l in the period 2011-2018. The standardised concentration increased slightly in 2019, but by much less than the measured concentration. This suggests that all the effects of the dry conditions mentioned above probably affected the nitrate concentrations as measured.

Not only did the average standardised nitrate concentration decrease, so did the standardised percentage of farms that exceeded the EU standard in the Sand and Clay regions (see Figure 4.12).
Figure 4.11 Nitrate concentrations (as NO₃ in mg/l) in water leaching from the root zones on farms in the Sand and Clay regions in the period 1992–2019. Annual average for measured and standardised concentrations, weighted by acreage.

Figure 4.12 Percentage of farms that exceed the EU standard of 50 mg/l nitrate in water leaching from the root zones on farmland in the Sand and Clay regions in the period 1992–2019. Exceedance above the standard, based on measured and standardised concentrations.

The average nitrate concentration in winter in the ditch water varies between regions, as is the case for leaching. The concentration is lowest in the Peat Region, higher in the Clay Region and highest in the Sand Region (see Figure 4.13 and Table 4.6). There are virtually no ditches on farms in the Loess Region. The average nitrate concentration and
exceedances of the standards were higher in the period 2016–2019 than in the previous period. This is mainly due to the large increase in nitrate concentrations in the winter of 2018-2019 (see Figure 4.13). The average nitrate concentration was below 40 mg/l in all regions for the past four years. In the Peat Region, farms that exceed the 50 mg/l standard are very rare (see Figure 4.14). In the Sand and Clay Regions, the percentage of farms that exceeded the average concentration in winter of 50 mg/l rose considerably in the winter of 2018-2019, which made the average for the period of 2016-2019 higher than the average for the previous period (see Table 4.6).

Table 4.6 Nitrate concentrations (mg/l as NO₃) and the percentage of farms with a concentration above 50 mg/l in ditch water (in brackets). Averages per period.¹

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>35 (22%)</td>
<td>27 (22%)</td>
<td>35 (22%)</td>
<td>27 (22%)</td>
<td>35 (22%)</td>
<td>35 (22%)</td>
</tr>
<tr>
<td>Clay</td>
<td>47 (37%)</td>
<td>47 (37%)</td>
<td>35 (22%)</td>
<td>27 (18%)</td>
<td>21 (8%)</td>
<td>21 (8%)</td>
</tr>
<tr>
<td>Peat</td>
<td>4 (0%)</td>
<td>3 (0%)</td>
<td>5 (1%)</td>
<td>3 (0%)</td>
<td>4 (0%)</td>
<td>5 (0%)</td>
</tr>
</tbody>
</table>

¹ Average weighted by acreage of the farm averages per period.

Source: RIVM, LUM

Figure 4.13 Nitrate concentrations (acreage-weighted average for winter, as NO₃ in mg/l) measured in the ditch water on farms in each region in the period 1992–2019.
Figure 4.14 Percentage of farms that exceed the EU standard of 50 mg/l nitrate measured in the ditch water in each region in the period 1992–2019. Acreage-weighted exceedance based on measured concentrations in winter

Inset 4.2 – Explanation of the cumulative distribution graphs
The following sections contain information about each region, in part in the form of cumulative distribution graphs. This inset explains how to interpret such graphs, using Figure 4.15 as an example. The graph shows that in the period 2016–2019, 38% of the monitored arable farms had average nitrate concentrations below the EU standard of 50 mg/l, and 20% of the farms had concentrations greater than 93 mg/l. Follow the horizontal 50 mg/l line (the solid red line showing the EU standard) from the y-axis until it meets the solid purple line giving the period 2016-2019. Then drop a vertical from the 50 mg/l line straight down onto the x-axis. This shows the percentage of farms that have a measured nitrate concentration in the water that is lower than 50 mg/l. It is also possible to see that 80% of the arable farms had an average concentration in this period of less than 93 mg/l – and therefore 20% had a higher concentration. Draw a vertical line up from the x-axis from 80% until it meets the solid purple line that gives the cumulative distribution for the period 2016–2019. Then draw a horizontal line perpendicular to it through to the y-axis. The concentration that is not exceeded can then be read off from the y-axis (in this case, 93 mg/l).

4.3.2 Sand Region
The average nitrate concentrations for the period on arable farms in the Sand Region are lower in the period 2016-2019 compared with the previous period 2012-2015 (see Figure 4.15); the percentage of farms satisfying the standard increased from around 30% to nearly 40%. However, in both periods around 10% of farms had high concentrations (> 125 mg/l).

For dairy farms, where nitrate concentrations have been lower than arable farms since the period 2000-2003, there was a decrease in the nitrate concentration between 2016-2019 and the previous period (see
Figure 4.16, but not as big a decline as in earlier periods. Over 70% of farms had concentrations below the EU standard, compared to 65% in the previous period.

There was a slight improvement in the nitrate concentrations for ‘other livestock farms’ as well (see Figure 4.17), with the percentage of farms satisfying the standard going up from 39% to 43%.
Nitrate concentrations differ between the three main sandy soil areas within the Sand Region: they are higher in Sand South than in Sand Central and Sand North (see Figure 4.18). There is hardly any arable farming or dairy farming in Sand West (see Map 2.1). The number of LMM farms is therefore too small to present any data. Nitrate concentrations in all three sandy soil areas have declined since 1992 but an increase has been seen in all three areas since 2017. In Sand Central, concentrations fell between 1992-1995 and 2012-2015 by nearly 70%. The average nitrate concentration in Sand North and Sand South fell by nearly 60% in the same period. The concentration in 2016-2019 fell compared with the period 2012-2015 by nearly 10% in Sand Central, by nearly 20% in Sand North and by nearly 5% in Sand South, despite the rise in the last two years of the later period.

The differences in nitrate concentrations between the sandy soil areas, as evident from Figure 4.18, can largely be explained by differences between these areas in the nitrogen surplus, soil use, farm types, precipitation surplus and the distribution of the groundwater level ranges and soil types (Schoumans et al., 2012).
4.3.3 Loess Region

In the Loess Region, the percentage of arable farms with a nitrate concentration below the standard in the period 2016-2018 was comparable to the previous period, at about 20%. Among arable farms with concentrations above the standard, there was a clear reduction in those concentrations. Over the period 2012-2015, some 40% of farms had concentrations of more than 100 mg/l. During the most recent period, this was the case for just 20% of arable farms in the Loess Region.

The distribution of nitrate concentrations on dairy farms has hardly changed since the period 2008-2011. Nearly 70% of dairy farms have a concentration below 50 mg/l.
4.3.4 Clay Region

In the Clay Region, an increase is seen on both arable farms and dairy farms in the nitrate concentrations when the periods 2012-2015 and 2016-2019 are compared (see Figure 4.21). In arable farming, the percentage of farms with nitrate concentrations of under 50 mg/l has fallen from 84% to 68%. Nearly 95% of the dairy farms had concentrations below the EU standard in both periods, despite the increase in concentrations (see Figure 4.22).
4.3.5 Peat Region
Nitrate concentrations in the Peat Region are low (see Figure 4.23); 95% of dairy farms have concentrations of under 35 mg/l. The differences between periods are small.
4.4 Consideration of trends in nitrogen surplus and nitrate concentration

This section briefly summarises all the information about the changes in the nitrogen surplus and nitrate concentration in the leachates. For each of the three main land-using agricultural sectors (arable, dairy and other livestock farming), the development is shown for each region in figures giving the averages for the seven four-year reporting periods since 1992. The four-year period for the nitrogen surplus starts one year earlier (1991) because the measured nitrate concentrations respond to changes in the nitrogen surplus with a lag of at least one year.
**Arable farming**
The nitrogen surplus on arable farms has increased slightly in the Clay Region and Loess Region compared with the previous period, and stayed more or less the same in the Sand Region (see Figure 4.24a). In the Clay Region, which also already had a slightly higher nitrogen surplus in the period 2011-2014 compared with the period 2007-2010, the nitrate concentrations in leachates were higher in the period 2016-2019 than in the previous period (see Figure 4.24b). The Sand and Loess Regions once again experienced a decrease in nitrate concentrations compared with the previous period. This may partly be the result of the decline in the nitrogen surpluses in earlier periods.

**Dairy farming**
As on arable farms, the nitrogen surplus on dairy farms increased slightly in the Clay and Loess Regions while a further decrease was seen in the Peat and Sand Regions (see Figure 4.25a). Nitrate concentrations on dairy farms in the Clay Region are also higher than in the previous period; however, nitrate concentrations in the Loess Region, which also had higher nitrogen surpluses, were actually slightly lower in the period 2016-2019 (see Figure 4.25b). In the Sand Region, nitrate concentrations declined relative to the previous period for the third period in a row.

The effect of the decline in the nitrogen surplus on the nitrate concentration in the Peat Region is not clear. This is mainly because the nitrate concentrations are low anyway due to the soil type (peat) and the hydrological characteristics of the soil (high groundwater levels and poor flows), which lead to relatively high levels of nitrate breakdown (denitrification). In this region, nitrogen in groundwater and surface water is mainly found in the form of ammonium and organic nitrogen (see Figure 4.8).

**Other livestock farms**
The nitrogen surplus on other livestock farms in the Clay Region has increased slightly, as it has on arable farms and dairy farms in this region (see Figure 4.26a). In the Sand Region, the surpluses fluctuate a great deal between periods but they seem to be slowly increasing since the period 1999-2002. It was not possible to obtain a reliable calculation of the nitrogen surplus for enough farms in the Loess Region. In the ‘other farms’ category too, it can be seen that the nitrate concentration in the Clay Region is higher than in the previous period while the concentration still seems to be decreasing slightly in the Sand and Loess Regions (see Figure 4.26b).
Figure 4.24a Average nitrogen surplus in the soil balance of arable farms in each region and period (calculated using the Wageningen Economic Research method; see Subsection 2.3.3). For details, see figures 4.1 to 4.3.

Figure 4.24b Nitrate concentrations (as NO₃ in mg/l) in water leaching from the root zones of arable farms in each region and period. Area-weighted average measured concentrations for the period. For details, see figures 4.15, 4.19 and 4.21.
Figure 4.25a Average nitrogen surplus in the soil balance of dairy farms in each region and period (calculated using the Wageningen Economic Research method; see Subsection 2.3.3). For details, see figures 4.4 to 4.6.

Figure 4.25b Nitrate concentrations (as NO₃ in mg/l) in water leaching from the root zones of dairy farms in each region and period. Area-weighted average measured concentrations for the period. For details, see figures 4.16, 4.20, 4.22 and 4.23.
Figure 4.26a Average nitrogen surplus in the soil balance of other livestock farms in each region and period (calculated using the Wageningen Economic Research method; see Subsection 2.3.3).

Figure 4.26b Nitrate concentrations (as NO₃ in mg/l) in water leaching from the root zones of other livestock farms in each region and period. Area-weighted average measured concentrations for the period. For the Sand Region details, see Figure 4.17.
Discussion and summary
In the Clay Region, we see slightly higher nitrate concentrations in all farm types in the period 2016-2019 compared with the previous period 2012-2015; this seems to be a logical consequence of the slightly higher nitrogen surpluses. However, nitrate concentrations in the other regions are the same or lower, despite the somewhat higher nitrogen surpluses (compared with the previous period) in arable farming in the Sand and Loess Regions and on dairy farms in the Loess Region.

The higher nitrate concentrations in the Clay Region in the period 2016-2019 compared with the period 2012–2015 are almost entirely due to the high nitrate concentration in 2019 (see Figure 4.9). A relatively large increase was seen in nitrate concentrations in the Clay Region in 2019 compared with the other regions.

The increase in the nitrate concentration in 2019, and also in 2018 in the Sand and Loess Regions, can largely be attributed to the effect of dry conditions on the concentration (more evaporation and less breakdown) combined with higher nitrogen surpluses in 2018 (see figures 4.4 to 4.7) due to the lower yields caused by the dry conditions.

4.5 Source
5 Groundwater quality

5.1 Introduction
Nitrate concentrations in groundwater in the Netherlands vary a great deal, both from one location to the next and with the depth. The variation between locations is partly caused by the variation in land use and differences in nitrogen emissions. Other causes of this are variations in net precipitation, the type of soil and the geohydrological characteristics of the aquifers (see also Chapter 4).

The variations can also be large within areas that have the same type and use of soil. The average nitrate concentration in the groundwater is determined by the small numbers of monitoring locations with relatively high concentrations, whereas the concentration is low at a large number of monitoring locations. Variations in the average nitrate concentration can be caused by variations at a single point or at several. For that reason, we do not solely state the average concentrations (e.g. Figure 5.1) but also the distribution across the various nitrate classes (e.g. Figure 5.3).

On average, nitrate concentrations are lower in the groundwater beneath peat soils, relatively high beneath sandy soils and intermediate beneath clay soils (Van Vliet et al., 2010, Reijnders et al., 2004). Agriculture is a key source of nitrogen emissions into the groundwater; nitrate concentrations beneath agricultural land are therefore higher than beneath land that is used for other purposes. As a rule, the nitrate concentration is lower as measurements are taken at greater depths in the groundwater. This is caused by the breakdown of nitrate as it is transported (denitrification), the mixing with water of various ages and groundwater from other locations due to horizontal transport of groundwater because of poorly permeable strata that partially or completely block vertical water flows.

This chapter consists of three parts. Each section considers the results of the measurements at one of the three depths used when monitoring groundwater in the Netherlands: 5-15 metres, 15-30 metres and greater than 30 metres. For the first two depths, both the groundwater as a whole (as for the WFD) and groundwater specifically beneath agricultural land are examined. This is not possible for the deepest groundwater (> 30 metres) because this concerns information about drinking water extraction in areas where the land use is mixed.

5.2 Nitrate in groundwater at depths of 5 to 15 metres
Nitrate concentrations in the groundwater at depths of 5 to 15 metres are generally highest in agricultural areas (see Figure 5.1). The nitrate concentration increased until 1996. The maximum value was measured in 1996, which is nine years after the peak in the nitrogen surplus of the national nitrogen balance in 1987 (see Figure 3.4). Nitrate concentrations fell after 1996; the lowest concentration in the entire series was measured in 2019.
Nitrate concentrations in nature areas exhibit a similar pattern, though at values much lower than in agricultural areas and with a later peak; the maximum value in the series was measured in 1999. The reduction is associated with a decrease of almost 60% that was seen in ammonia emissions from animal manure and artificial fertiliser since the early 1990s (see Subsection 3.5.6).

The progression of nitrate concentrations over time in areas with other types of land use (including orchards and urban areas) has a fluctuating pattern, but the nitrate concentrations in the majority of years are higher than in nature areas but lower than in agricultural areas. The rise in nitrate concentrations between 2001 and 2014 is almost entirely due to a single monitoring location at which the nitrate concentration rose from under 30 mg/l before 2001 to over 800 mg/l in 2013.

![Figure 5.1 Average annual nitrate concentration (mg/l) in groundwater in the Netherlands at depths of 5 to 15 metres below ground level as a function of land use.](image)

The nitrate concentrations in the groundwater in agricultural areas are highest in the Sand Region (see Figure 5.2). Nitrate concentrations in the Clay Region are just a little higher than in the Peat Region. The situation in the Clay and Peat regions often involves no infiltration and excess precipitation is removed using drains and ditches. The water that is sampled at depths of 5 to 15 metres is probably older. In the Sand Region, infiltration often does take place to greater depths and the water that is sampled is generally water that infiltrated about a decade earlier.

During the period 2016-2019, the EU standard of 50 mg/l for nitrate was exceeded at 11% of the groundwater monitoring locations at depths of between 5 and 15 metres (see Figure 5.3). This figure was 12% for agricultural areas. There were small differences from one year to the next (see Figure 5.4).
Figure 5.2 Average annual nitrate concentration (mg/l) in groundwater in agricultural areas at depths of 5 to 15 metres below ground level for each region.

Figure 5.3 Percentage of groundwater monitoring locations at depths of 5 to 15 metres for each nitrate concentration class during the various reporting periods.
Figure 5.4 Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at depths of 5 to 15 metres below ground level as a function of land use.

The percentage of monitoring locations at which the EU standard of 50 mg/l is exceeded for agricultural areas in the Sand Region fluctuates at around 20% (see Figure 5.5) but – unlike the concentrations – does not show a falling trend (see Figure 5.2). The drop in nitrate concentrations can above all be ascribed to a drop in the concentrations at a small number of points that had very high nitrate concentrations. The result of this is that the trend in the average nitrate concentration and the trend in the number of cases exceeding the limit appear to be independent of one another. From 2008 onwards, there was only a single exceedance of the EU standard in agricultural areas in the Clay Region and there were none in the Peat Region.

The majority of monitoring locations (about 75%) showed no change in the nitrate concentration between the two most recent reporting periods (2012-2015 and 2016-2019) (see Figure 5.6). The percentage of monitoring locations at which the concentration fell is roughly equal to the percentage of monitoring locations with increases between the two most recent periods.

Of the three sandy soil areas (North, Central and South), the nitrate concentration is clearly highest in Sand South (see Figure 5.7). Concentrations are lower in Sand Central and lowest in Sand North. For Sand North and Sand Central, only small amounts of nitrate are found at the bulk of the monitoring locations (see Table 5.1). The concentration in these areas is determined by a small number of points with elevated nitrate concentrations. In Sand South, there are roughly as many monitoring locations with low concentrations (< 1 mg/l) as with nitrate concentrations above 10 mg/l.
Figure 5.5 Exceedance of the EU standard of 50 mg/l for nitrate in groundwater in agricultural areas at depths of 5 to 15 metres below ground level for each region.

Other types of soils do also occur in the sandy soil areas. If only the monitoring locations in sandy soils are selected, the nitrate
concentrations are a little higher. Sand South also has the highest number of points at which the EU standard is exceeded (see Figure 5.8).

Table 5.1 Number of monitoring locations for each nitrate concentration class for agricultural land in the Sand Region (for each subarea) at depths of 5 to 15 metres during the period 2016-2019.

<table>
<thead>
<tr>
<th>Nitrate class (NO$_3$ in mg/l)</th>
<th>Sand North</th>
<th>Sand Central</th>
<th>Sand South</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 mg/l</td>
<td>33</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>1 to 10 mg/l</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 10 mg/l</td>
<td>6</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>Total number of wells</td>
<td>42</td>
<td>37</td>
<td>37</td>
</tr>
</tbody>
</table>

Figure 5.7 Nitrate in groundwater below agricultural land at depths of 5 to 15 metres below ground level for each sandy soil area.
Figure 5.8 Exceedance of the EU standard of 50 mg/l for nitrate in groundwater beneath agricultural land at depths of 5 to 15 metres below ground level for each sandy soil area.

The monitoring locations can be subdivided into those with older groundwater (> 25 years) and younger (< 25 years) (see Map 5.1). The points with older groundwater generally have water from Artesian aquifers with lower nitrate concentrations as a result (< 15 mg/l), whereas those with younger groundwater have phreatic layers that are affected by activities above ground level. High nitrate concentrations (> 50 mg/l) are found in young groundwater in the Sand Region and Loess Region (in the east and south of the Netherlands). These high nitrate concentrations largely occur at monitoring locations with young groundwater. It is striking that there is one such point at Weert where the water is more than 25 years old yet still has a high nitrate concentration. The concentration of nitrate here was already above 200 mg/l back in 1984.

The largest numbers of changes also occur in the Sand Region and Loess Region (see Map 5.2). Both increases and decreases in nitrate concentrations have been observed.
Map 5.1 average nitrate concentration (mg/l) in the groundwater at depths of 5 to 15 metres for the period 2012-2019. The change is given as the difference between the averages for the period 2012-2015 and the period 2016-2019.

Map 5.2 Changes in average nitrate concentration (mg/l) in the groundwater at depths of 5 to 15 metres for the period 2012-2019. The change is given as the difference between the averages for the period 2012-2015 and the period 2016-2019.
5.3 Nitrate in groundwater at depths of 15 to 30 metres

The nitrate concentrations encountered in monitoring locations at depths between 15 and 30 metres below ground level are much lower than in the shallow-lying monitoring locations (see Figure 5.9). This is because the deeper water is older and infiltrated down before the intensification of agriculture. Additionally, nitrate still breaks down to some extent between the shallower and deeper monitoring locations.

The nitrate concentrations for monitoring locations in agricultural areas are higher than for nature areas. The average nitrate concentrations have been extremely stable over recent years in both cases. The average nitrate concentrations for the monitoring locations in the other areas vary widely. This variation is caused by a single monitoring location. If that point is not included, the nitrate concentration for other land use lies between those for agriculture and nature areas, as was the case in the period through to 1999.

The nitrate concentrations in deeper groundwater in agricultural areas are highest in the Sand Region and lowest in the Peat Region (see Figure 5.10). This is consistent with the picture for shallower groundwater. Rainwater infiltrates to greater depths in the Sand Region, whereas a lot of water in the Clay and Peat regions is carried away as shallower water via ditches. There is a seepage situation in many cases in these regions, averaging that the water at greater depths has not come from agricultural plots of land but instead flows towards them. No trend can be seen in the nitrate concentration; the figures have been stable over recent years.
Figure 5.10 Average annual nitrate concentration (mg/l) in groundwater in agricultural areas at depths of 15 to 30 metres below ground level for each region.

The number of cases of the EU standard of 50 mg/l being exceeded is stable in both agriculture and nature areas (see Figure 5.11). The number of such monitoring locations in the other areas has increased from 5% to 10% in recent years (from 3 to 6). Those three monitoring locations were previously all just below the EU standard but just above it for the last four years. This is therefore not visible as an increase in the average concentration (see Figure 5.10).

Figure 5.11 Exceedance of the EU standard of 50 mg/l for nitrate in groundwater at depths of 15 to 30 metres below ground level as a function of land use.
The greatest number of exceedances of the EU standard in agricultural areas was in the Sand Region (see Figure 5.12). There were no exceedances of the standard in the Clay Region and Peat Region during the last two years.

Figure 5.12 Exceedance of the EU standard of 50 mg/l for nitrate in groundwater beneath agricultural areas at depths of 15 to 30 metres below ground level for each region.

The stability of nitrate concentrations in the monitoring wells at depths of 15 to 30 metres below ground level can also be seen in the number of monitoring locations for each concentration class (see Figure 5.13). This is not changing considerably over time. The number of points where it is increasing is low and roughly equal to the number where it is decreasing (see Figure 5.14).

Looking at the sandy soil areas Sand North, Sand Central and Sand South, the nitrate concentration in the deeper groundwater is highest in Sand Central (see Figure 5.15), in contrast to the monitoring results for groundwater at depths of 5 to 15 metres below ground level. The average nitrate concentration at depths of 15 to 30 metres in the sandy soil areas is determined entirely by a limited number of monitoring locations with high nitrate concentrations (see Table 5.6), meaning that e.g. the selection of the points can play an important role. Even so, the difference between the shallower and deeper monitoring locations in Sand South is striking, given that almost half the shallower points have nitrate concentrations above 10 mg/l. Among the deeper monitoring locations in Sand South, this only applies in a single case. The percentage of monitoring locations with concentrations about the EU standard of 50 mg/l in the groundwater at depths of 15-30 metres is highest in Sand Central (see Figure 5.16). That percentage is only a fraction lower than for the groundwater at depths of 5-15 metres (see Figure 5.8). The decrease in the number of exceedances is much greater for Sand South; in the shallower well screens, about a third of the points
were above the EU standard but there were no cases among the deeper monitoring locations.

Figure 5.13 Percentage of groundwater monitoring locations at depths of 15-30 metres for each nitrate concentration class during the various reporting periods.

Figure 5.14 Percentage of groundwater monitoring locations at depths of 15-30 metres with increasing or decreasing nitrate concentrations during the various reporting periods.
Van Vliet et al. (2010) had also observed that the number of exceedances of the EU standard was small for deeper groundwater in Sand South. The report by Van Loon & Fraters (2016) also shows that the problems with fertiliser-induced pollution in drinking water sources arise primarily in Sand Central and not in Sand South. Map 5.7 shows that high maximum nitrate concentrations in groundwater at deeper than 30 metres in sandy soils are mostly measured in Gelderland and Overijssel and to a lesser extend in Noord-Brabant. According to Broers (2002), oxidation of pyrite and reduction of nitrate are the most likely explanations of the low nitrate concentrations in deeper groundwater in Noord-Brabant. Broers (2002) has demonstrated that there is more pyrite in the subsoil in Noord-Brabant than in Drenthe. It is suspected that pyrite concentrations in the subsoil in Sand Central are also lower than in Sand South.

Table 5.2 Number of monitoring locations for each nitrate concentration class for agricultural land in the Sand Region (for each sandy soil area) at depths of 15 to 30 metres during the period 2016-2019.

<table>
<thead>
<tr>
<th>Nitrate class (NO₃ in mg/l)</th>
<th>Sand North</th>
<th>Sand Central</th>
<th>Sand South</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 mg/l</td>
<td>38</td>
<td>32</td>
<td>35</td>
</tr>
<tr>
<td>1 to 10 mg/l</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 10 mg/l</td>
<td>3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Total number of wells</td>
<td>42</td>
<td>37</td>
<td>36</td>
</tr>
</tbody>
</table>

Figure 5.15 Nitrate in groundwater beneath agricultural land at depths of 15-30 metres below ground level for each sandy soil area.
Figure 5.16 Exceedance of the EU standard of 50 mg/l for nitrate in groundwater beneath agricultural land at depths of 15 to 30 metres below ground level for each sandy soil area.
Map 5.3 Average nitrate concentration (mg/l) in the groundwater in the Netherlands at depths of 15 to 30 metres for the period 2016-2019.

‘Young’ groundwater is less than 25 years old; ‘old’ is above that figure.

Map 5.4 Changes in average nitrate concentration (mg/l) in the groundwater at depths of 15 to 30 metres for the period 2012-2019. The change is given as the difference between the averages for the period 2012-2015 and the period 2016-2019.
5.4 Nitrate in groundwater at depths of over 30 metres

Nitrate concentrations in raw water from phreatic groundwater showed a slight increasing trend until 2003 followed by a slight decrease (see Figure 5.17). Nitrate concentrations between 2006 and 2012 were stable.

Between 2010 and 2011, the nitrate concentration in the Artesian groundwater increased by 1 mg/l. It is not clear what caused that increase. The increase, which is of about 1 mg/l, has occurred at the majority of monitoring locations (drinking water production sites).

The percentage of monitoring locations at which the average nitrate concentration in the untreated water was above 50 mg/l was below 2% (see Figure 5.18 and Figure 5.19; note that the total percentage in these and other bar charts may sometimes differ slightly from 100 because of rounding).

Between the last two periods, the nitrate concentrations at almost 89% of the monitoring locations were stable; this applies for 81% of monitoring locations in phreatic groundwater (see Figure 5.20). It is striking that the monitoring locations with increases are more numerous than those with decreases.

The EU standard of 50 mg/l was not exceeded in the drinking water supplied. In 2019, none of the 166 monitoring locations had nitrate concentrations of over 50 mg/l. It should be noted here that wells for extracting drinking water are often closed or that the water from those extraction wells is mixed so that the concentration in that raw water remains below 50 mg/l on average.

The highest nitrate concentrations occur in the Loess Region (see Map 5.5) but there was a large decrease at one of the monitoring locations (see Map 5.6). The most changes in nitrate concentration occur in Sand Central; these are mainly small decreases (see Map 5.6).
Figure 5.17 Average annual nitrate concentration (mg/l) in the groundwater at drinking water production sites in phreatic and Artesian groundwater.

Figure 5.18 Exceedance of the EU standard of 50 mg/l for the average nitrate concentration in groundwater at drinking water production sites for phreatic and Artesian groundwater. Exceedance is shown as the percentage of all monitoring locations.
Figure 5.19 Percentage of drinking water production sites (monitoring locations) for each nitrate concentration class during the various reporting periods.

Figure 5.20 Percentage of drinking water production sites (monitoring locations) with increasing or decreasing nitrate concentrations during the various reporting periods.
Maximum concentrations
During the most recent period, the average maximum nitrate concentration for the monitoring locations remained stable in both the phreatic and the Artesian sources (see Figure 5.21). The nitrate standard was not exceeded for the Artesian sources; there was one single phreatic source at which the maximum concentration is higher than the nitrate standard (see figures 5.22 and 5.23).

Figure 5.21 Maximum nitrate concentration (mg/l) in the groundwater at drinking water production sites using phreatic and Artesian groundwater.

Figure 5.22 Exceedance of the EU standard of 50 mg/l for the maximum nitrate concentration in groundwater at drinking water production sites for phreatic and Artesian groundwater. Exceedance is shown as the percentage of all monitoring locations.
The majority of monitoring locations (over 80%) have had stable nitrate concentrations. The number of monitoring locations with increases over the periods 2012-2015 and 2016-2019 is roughly equal to the number of points with decreases (see Figure 5.24).

**Figure 5.23** Percentage of drinking water production sites (monitoring locations) for each nitrate concentration class (maximums) during the various reporting periods.

**Figure 5.24** Percentage of drinking water production sites (monitoring locations) with increasing or decreasing maximum nitrate concentrations during the various reporting periods.
The highest maximum nitrate concentrations occur in the Loess Region and the east of the Netherlands (see Map 5.7). Several small increases in the maximum nitrate concentrations occurred in Sand North (see Map 5.8) whereas there were both large and small increases and decreases in Sand Central. There were no changes in Sand South.

5.5 Discussion of the trends in agricultural practices and nitrates in groundwater

The nitrate concentration in the deeper groundwater is a reflection of the concentrations in the upper groundwater. The key source of nitrogen in the upper groundwater is agriculture. The nitrate concentrations measured beneath agricultural areas are therefore higher than under nature areas and other zones. Furthermore, the nitrate concentration depends on the capacity of the soil to break nitrate down. Nitrate is broken down to a lesser extent beneath sandy soils than beneath clay and peat soils. Nitrate concentrations are therefore also highest beneath sandy soils.

The nitrate concentration beneath agricultural land in the Sand Region at monitoring locations in shallow groundwater (5 to 15 metres below ground level) reached its highest concentration in 1996, about nine years after the peak in the soil surplus (which was in 1987 – see Figure 3.4). The nitrate concentration in groundwater at this depth has been decreasing since then. The nitrate concentration in medium-deep groundwater (15-30 metres down) is lower than in shallow groundwater. This is a result of mixing and breakdown during the time downward transport takes place. The nitrate concentrations in agricultural areas are higher than in nature areas because of the effects of that agriculture. The average nitrate concentration in deeper groundwater has been stable over recent years.

The average value for the nitrate concentration is driven by a small number of monitoring locations with relatively high nitrate levels and a large number with almost no nitrate. The year-on-year fluctuations are therefore driven by a small number of monitoring locations, as can also be seen on Map 5.2 and Map 5.4. The nitrate concentration at the majority of monitoring locations is stable and the number at which the trend is upwards is comparable to the number where it is downwards.

A trend analysis has been carried out for the Water Framework Directive (WFD) looking at the chemical quality of groundwater (Steinweg, 2020). The WFD monitoring network is a subset of the monitoring locations of the PMG (Provincial Groundwater Quality Monitoring Network) and the LMG (National Groundwater Quality Monitoring Network). That trend analysis has examined the individual points to see if the trend is downward, upward or reversing. A selection was made for this that contains points where the concentration is at least 75% of the standard. For nitrate, fewer than 20% of the points selected have shown an increase. It should be noted at this point that the analysis was carried out using a different selection of monitoring data than those used for this report.
Map 5.5 average nitrate concentration (mg/l) in the groundwater that was used for producing drinking water during the period 2016-2019.

Map 5.6 Change in the average nitrate concentration (mg/l) in the groundwater that was used for producing drinking water during the period 2012-2019. The change is given as the difference between the averages for the period 2012-2015 and the period 2016-2019.
There are large regional differences in the transport of nitrate from shallow to deeper-lying groundwater. There is a reduction in nitrate concentration with depth in Sand Central, from an average of 20 mg/l in the shallow groundwater to 15 mg/l in the medium-deep. The concentration in Sand South decreases much more rapidly with depth, from 70 mg/l to 1 mg/l, and in Sand North it falls from 15 mg/l to 3 mg/l. It is suspected that a great deal more nitrate is broken down in the subsoil (denitrification) in Sand South than in Sand Central.

The nitrate concentration in deep groundwater (> 30 metres) at drinking water production sites is higher at those with phreatic groundwater than at the sites with Artesian groundwater. The soil layers confining the aquifers from above provide protection against nitrate pollution in the case of Artesian groundwater. In phreatic groundwater, where these confining soil layers are not present, nitrate can penetrate to greater depths. There are no production locations where the EU standard is exceeded, but there are several phreatic sites in Sand Central and the Loess Region where the concentration is between 15 and 40 mg/l. There are no instances of elevated nitrate concentrations in Sand South. This is in line with the idea of higher nitrate breakdown rates in Sand South.

The nitrate concentrations for the drinking water production sites come from the REWAB database (Drinking Water Company Declarations Register), which contains annual average information about the mixed groundwater that is pumped up for each chain of wells at the location (see Section 2.5), rather than for the individual extraction wells in each chain. This means that high nitrate concentrations are averaged out and this dataset therefore underestimates the actual fertiliser-related water quality issues at production locations (Wuijts et al., 2010). The analysis by Van Loon & Fraters (2016), which looked at the individual extraction wells, showed for instance that there were 89 groundwater extraction points in the period 2000-2015 at which one or more raw water standard indicators for the effect of fertilisers were exceeded for individual pumping wells. In the majority of cases, fertilisation plays a major role in such exceedances of the standards. Some cases are related above all to the groundwater table falling and natural causes (Van Loon & Fraters, 2016). Standards being exceeded in individual wells is seen as problematic because the drinking water companies then have to blend various raw water flows if the quality norms are to be met. This increases the costs of monitoring and impacts the flexibility.

5.6 Source


6 Freshwater quality

6.1 Introduction

A clear decrease in nutrient concentrations has occurred in Dutch surface waters since 1991. The introduction of the Fertilisers Act in 1986 and the European Nitrates Directive coming into effect have both contributed to this. This chapter describes the current situation and the changes that have occurred since the previous reporting period.

The chapter starts with an overview of the nutrient load of the surface waters in the Netherlands (see Section 6.2). Both nitrogen and phosphorus affect the degree of eutrophication.

The status and the trends in the concentrations of nitrate, total nitrogen and total phosphorus and the eutrophication status of the surface water bodies in the Netherlands are tracked for various types of water bodies. In sequence from smaller to larger bodies of water, these are:

- Ditches at farms (the results for this have been given in Chapter 4); the direct influence of agriculture is most clearly visible at these locations.
- Agriculture-specific surface waters; these are regional surface waters for which agriculture is the only anthropogenic source of nutrients.
- Regional surface waters that have been designated under the Water Framework Directive (WFD); these are larger water systems that can be affected not only by agriculture but also by seepage and by discharges from industry and from urban areas.
- National surface waters that have been designated for the WFD; the load in these waters comes largely from abroad and from discharge from regional waters.

The effect of agriculture on these waters decreases from agricultural ditches to agriculture-specific waters, regional WFD waters and finally national WFD waters.

In line with the EU reporting guidelines (EC, 2020), this report considers nitrogen from nitrate (NO$_3^-$ nitrogen) to be the key variable when representing the effects of agriculture on the quality of surface waters. Section 6.3 therefore looks in depth at the status and trends for nitrate concentrations in the various surface water types.

An important aim of the Nitrates Directive is limiting the occurrence of eutrophication in surface waters. The key factors that play a role in eutrophication are discussed in Section 6.4, namely chlorophyll-α, total nitrogen and total phosphorus. Van Duijnoven et al. (2019) give a detailed description of the status and trends for total nitrogen and total phosphorus in WFD water bodies. In comparison with the previous reports, in this report the eutrophication characteristic has also been included, in line with the methodology used within the WFD. Along with the presentation of data for chlorophyll-α, details are given about the eutrophication status of the surface waters.
A distinction is made in this assessment between lakes, rivers, coastal and transitional waters. This chapter contains the results for the lakes and rivers. Chapter 7 discusses the situation in the open sea as well as the situation for coastal and transitional waters.

6.2 Nutrient load in fresh surface waters

The Netherlands is a delta. The bulk of the river basin district of the large, cross-border rivers is abroad. As a result, nutrient concentrations in national surface waters, such as the major rivers, the IJsselmeer lake and the coastal waters, are largely determined by conditions abroad. The influx of nitrogen and phosphorus from abroad in the rivers coming into the Netherlands is roughly the same as the outflow to the seas; the vast bulk of these loads leaves the Netherlands again quickly via the Maas and the Rhine into the North Sea (Van Gaalen et al., 2020 and 2016). There are also several cross-border stream systems in the south and east of the country where the influx of nutrients from abroad plays a role. For the other regional waters, the load from abroad generally only plays a modest part. During the summer however, it can make a contribution by inlet of water from the Rhine and the Maas into regional water systems. Additionally, the load of phosphate and ammonium via seepage can be substantial in the low-lying polders in the west of the Netherlands. The largest sources for the regional waters are generally leaching and run-off in rural areas, effluents from sewage treatment plants and atmospheric deposition (see Inset 6.1).

Inset 6.1 – Atmospheric deposition

The contribution made by atmospheric deposition to the nitrogen load is limited for many surface waters. It does however play a part for lakes, ponds and waters with a large surface area where the residence time of the water within the system is high. This was shown by a study by Van Duijnhooven & Thiange (2013), showing that the contribution of deposition to the nitrogen load was about 10% for the Volkerak-Zoommeer lake and that it is even as much as approximately 30% for the Markermeer lake. Because of the shorter residence time of water in the IJsselmeer lake, the effect of deposition there is limited, at only 4%. For the marine waters (see Chapter 7), the contribution from atmospheric deposition becomes greater the further you get from the coast, i.e. as the contribution from rivers decreases.

The figures below give the nationwide picture of the contributions from various sources in 2018, the most recent year for which that information is available from the National Emissions Register. Figures 6.1 and 6.3 show the contributions from the various sources in terms of percentage. Figures 6.2 and 6.4 give representations of the distribution of the various sources over time.
Figure 6.1 Shares of various sources (%) in the nitrogen load in surface waters in 2018 (RWZI = sewage treatment plant).
Source: Emissieregistratie, 2020

Figure 6.2 Evolution of the nitrogen load in surface waters from national sources (in million kg nitrogen) from 1990 to 2018.
(1) Atmospheric deposition = deposition onto fresh surface waters.
(2) Sewage water not via sewage treatment plants = overflows, rainwater sewers, discharges via individual wastewater treatment, untreated sewers and households not connected to the system.
(3) Direct agricultural = greenhouse horticulture, farmyard run-off and unintended fertilisation of ditches.
Source: Emissieregistratie, 2020
Figure 6.3 Shares of various sources (%) in the phosphorus load in surface waters in 2018 (RWZI = sewage treatment plant).
Source: Emissieregistratie, 2020

Figure 6.4 Evolution of the phosphorus load in surface water bodies from domestic sources (in million kg phosphorus) from 1990 to 2018.
(1) Sewage water not via sewage treatment plants = overflows, rainwater sewers, discharges via individual wastewater treatment, untreated sewers and households not connected to the system.
(2) Direct agricultural = greenhouse horticulture, farmyard run-off and unintended fertilisation of ditches.
Source: Emissieregistratie, 2020
This report has for the first time adopted a different method of aggregation for the data to that used in previous reports, allowing better attribution of the load in freshwater and saltwater. Due to this, the discharges from a major source of phosphorus – industrial discharge from an artificial fertiliser factory in the Rijnmond area (a transitional waterway) – are now assigned to the load in saltwater, for instance. As a result, the total phosphorus load in freshwater is much lower in the new data for the period 1992-1995 than was stated in earlier reports. The factory has been closed since 2005; the differences for the more recent periods with respect to previous reports are therefore small or zero.

The biggest source of nitrogen is the diffuse load of leaching and run-off from the soil in rural areas (59%), followed by sewage treatment plants (19%) and atmospheric deposition onto regional waters (12%) (see Figure 6.1). The overall nitrogen load for water bodies has decreased by about 50% since 1990 (see Figure 6.2). The main contributors to this reduction are sewage treatment plants, industry and the leaching and run-off of nitrogen in rural areas, with the last of these sources in particular showing a big decrease in the period 2000-2010. The direct load of point sources in agriculture has decreased clearly since 1990. The nitrogen load from the various sources has hardly decreased at all since 2010. For nitrogen, the relative contribution of leaching and run-off in rural areas has fluctuated since 1995 between 60 and 70%. Calculated values for the leaching and run-off are showing a small increase again since 2015, after decreases between 2000 and 2010.

Leaching and run-off from the soil in rural areas are also the biggest source for phosphorus (59%), followed by sewage treatment plants (25%) and point sources from agriculture and (untreated) discharges of rainwater and sewer water (6% to 8%) (see Figure 6.3). The overall phosphorus load in surface waters has decreased by about 50% since 1990 (see Figure 6.4). A large proportion of this reduction has been achieved by cutting down the load from sewage treatment plants. No major change has occurred since 2015 in terms of the nitrogen and phosphorus loads discharged by sewage treatment plants into surface waters. Emissions of phosphorus are still decreasing slightly; those of nitrogen from sewage treatment plants seem to be stabilising. The removal efficiency figures for sewage treatment plants have fluctuated around 84% and 87% for nitrogen and phosphorus respectively over the last three years (including 2018; see CBS Statline (2020) for data up to 2017).

The relative contributions of leaching and run-off have increased over that time frame for phosphorus from 30 to 60%, largely because the contributions from other sources (including agricultural point sources such as fertiliser going into ditches, drainage from property and greenhouse horticulture) have decreased more rapidly.

On average throughout the country, the phosphorus surplus has almost completely disappeared (see Figure 3.4). The surplus for nitrogen has been greatly reduced, certainly when compared to the peak years at the end of the 1980s, but it is still significant. The reduced nitrogen surplus has also led to a decrease in the leaching and run-off. The phosphorus
The load resulting from leaching and run-off has however only decreased to a limited extent. One cause of this is that the amount of phosphorus accumulated in the soil in the past is still causing leaching from agricultural land.

As a consequence of the differing percentage reductions for nitrogen and phosphorus, the ratios of the concentrations for these substances have also changed in various water bodies. The potential effects of this are not fully understood but may include a shift in the species composition of algae.

**Inset 6.1 leaching and run-off in rural areas: sources and pathways**

The load resulting from leaching and run-off in rural areas goes via several pathways. Figure 1-6.1 below shows this for phosphorus and nitrogen, by splitting the leaching and run-off (all the orange and red colour) further into leaching from nature areas (dark red), leaching as a result of current fertilisation (yellow), delayed release from the soil e.g. as the result of fertilisation in the past (orange/red), among others. Other sources not related to leaching are shown in blue, e.g. sewage treatment plants, direct atmospheric deposition onto the surface waters and direct point loads from agriculture.

Leaching from nature areas is about 12% (nitrogen) to 14% (phosphorus) of the total leaching and run-off. For both these nutrients, around 60% of the load from leaching and run-off in agricultural areas can be seen to be the result of current fertiliser use. About a quarter is related to the other sources, such as delayed release from the soil and nutrient seepage.

<table>
<thead>
<tr>
<th>Phosphorus</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not leaching or run-off</td>
<td>64%</td>
</tr>
<tr>
<td>Fertilisation</td>
<td>2%</td>
</tr>
<tr>
<td>Supply from soil</td>
<td>0%</td>
</tr>
<tr>
<td>Deposition indirectly</td>
<td>11%</td>
</tr>
<tr>
<td>Upward seepage/ infiltration</td>
<td>11%</td>
</tr>
<tr>
<td>Nature</td>
<td>8%</td>
</tr>
</tbody>
</table>

*Figure 1-6.1 Shares of various sources (%) in the phosphorus (left) and nitrogen (right) loads of surface waters via leaching and run-off in the period 2012-2014. Source: Fraters et al. (2017) – see figures based on data from Groenendijk et al. (2014)*

The Emissions Register does not distinguish between agricultural land and nature areas for the leaching and run-off in rural areas. A study by Groenendijk et al. (2014) has shown that the contribution from leaching and run-off from agricultural land to the total phosphorus load in surface water during the period 2012-2014 was 48%. For nitrogen this was 52%. The load resulting from leaching and run-off in rural areas goes via several pathways (see Inset 6.1). This is the picture
nationwide; the share due to sources of leaching and run-off can vary widely between the regions.

6.3 Nitrate concentration in freshwater

This section describes the developments in the nitrate concentration in fresh surface waters, distinguishing between national WFD waters, regional WFD waters and agriculture-specific waters. The nitrate concentrations in the section are given in mg/l NO₃. For comparison: 10 mg/l NO₃ is equivalent to 2.3 mg/l nitrogen from NO₃.

In waterways that are susceptible to eutrophication, nitrate disappears to varying degrees because algae absorb and/or break down nitrate in the summer period (denitrification), which can yield a distorted picture in the monitoring results. The greater the degree of eutrophication in a body of water, the greater the reduction in nitrate concentration will be in the summer. Moreover, the Dutch situation can be affected in the summer by seepage and drainage of water into polders from other areas, which can influence the water quality measured there. The winter average (October to March) therefore gives a more representative picture of the load in surface waters than the summer or annual averages do. The winter period is moreover the time when leaching and run-off processes play an important role. This section therefore states not only the annual average concentrations for nitrate but also the winter average and the winter maximum. A topographical picture is given in the maps at the end of this chapter (see maps 6.1 to 6.4).

6.3.1 Winter average nitrate concentration

The average winter nitrate concentration is a good indicator of the load of that nutrient in surface waters. For fresh surface waters, the winter average is the average of the months October through to March (e.g. winter 2018 consists of the months October 2017 to March 2018). This is the season when the nitrate load resulting from leaching and drainage is greatest and there is little sequestration by plants or breakdown.

Since the Fertilisers Act was introduced in 1986 and the European Nitrates Directive coming into effect, there has been a clear reduction in nitrate concentrations in the three types of surface waters (agriculture-specific, regional WFD and national WFD). A large proportion of that reduction took place in the previous reporting periods. The average winter concentration has decreased since 1990 for agriculture-specific waters from 25 to 15 mg/l NO₃. A decrease can be seen in the regional waters from 21 to 12 mg/l and in national waters from 16 to 10 mg/l. The rate of decrease has been less steep since 2003 and seems to have stagnated since 2012 (see Figure 6.6). The highest concentrations are still found in agriculture-specific waters; the national average concentrations for the regional WFD waters and the national waters have been similar to each other in recent years.

Compared to the previous reporting period, the average winter nitrate concentration in all types of waters has decreased slightly (see Figure 6.5a). This can also be seen from the statistically derived trend lines for these datasets (see Section 6.5). Although there were
Improvements in the previous periods for almost all surface waters, the quality deteriorated during the current reporting period in approximately 20% of the waters.

In about 22 to 28% of the monitoring locations (for national/regional WFD waters and agriculture-specific waters respectively), decreases in concentration can be seen with respect to the previous reporting period. That is offset by the fact that there is a comparable number of monitoring locations (from 20% for regional waters to 27% for agriculture-specific waters) with slight increases in concentration (1 to 5 mg/l) or even large ones (more than 5 mg/l – the case in 3 to 5% of monitoring locations) measured with respect to the previous reporting period (see Figure 6.5b). Map 6.1 and Map 6.2 at the end of this chapter give a picture of the topographical distribution of the average winter nitrate concentrations and of the sites where the concentrations are rising or falling. The greatest increases were observed in the south of the Netherlands.

The EU water quality standard of 50 mg/l NO₃, used in this chapter as the benchmark for nitrate, was exceeded during the most recent period (2016-2019) in 1.5% of the monitoring locations in WFD water bodies (see Figure 6.3); the number for agriculture-specific waters is 2.4%. The figure of 50 mg/l NO₃ is equivalent to 11.3 mg/l N, making it much higher than the standards for achieving a good eutrophication status, which are at around 2.5 mg/l N; this is therefore not a good benchmark for the ecological water quality. Assessing the nutrient concentrations against the ecological standards is described in Section 6.4.

**Figure 6.5a Winter average nitrate concentration. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters for each nitrate concentration class (in mg/l NO₃) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.**
Figure 6.5b Winter average nitrate concentration. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters with increasing or decreasing nitrate concentrations (in mg/l NO₃); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.

Figure 6.6 Average winter nitrate concentration (in mg/l NO₃) in surface freshwaters in the period 1990-2019, distinguishing between agriculture-specific waters, regional WFD waters and national waters.

### 6.3.2 Winter maximum nitrate concentration

The winter maximum nitrate concentrations decreased during the period 1992-2019, just as the average concentrations did (see Figure 6.7a).
Although the maximum nitrate concentrations in the winter are still decreasing for some of the regional waters, the proportion of surface waters with increasing concentrations is growing rapidly with respect to the previous reporting periods (see Figure 6.7b). In the national surface waters, slight increases were seen at 42% of the locations, with locally large increases of more than 5 ml/l nitrate. In the regional WFD waters, increasing concentrations were noted at a total of 47% of locations, 27% of which were sharp rises. In the agriculture-specific waters, the winter maximum increased at more than half of the locations and rose strongly at 44% of them.

The maximum winter concentrations exceeded the value of 50 mg/l NO₃ at 23% of the agriculture-specific waters (see Figure 6.7a). For the regional WFD waters, such exceedance occurred in 12% of the locations. There were occasional cases of concentrations of over 100 mg/l nitrate being measured.

Figure 6.7a Winter maximum nitrate concentration. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters for each nitrate concentration class (in mg/l NO₃) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.
6.3.3 Nitrate concentration – annual average

Annual average nitrate concentrations above the EU standard of 50 mg/l were still being measured for a few regional WFD waters during the current reporting period (2016-2019). The number of agriculture-specific waters in the highest nitrate class has however increased somewhat since the previous period, from 1.3% to 1.8% (see Figure 6.8). The greatest improvements occurred for all types of surface waters during the previous reporting periods.

Figure 6.7b Winter maximum nitrate concentration. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters with increasing or decreasing nitrate concentrations (in mg/l NO₃); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.
6.4 The eutrophication of fresh surface waters

6.4.1 General status

To give a picture of the ecological water quality and the eutrophication status, various quality elements specific for each type of water body were used for assessing the status, in accordance with the WFD methodology. This involved looking not only at nutrients but also at biological quality elements in the water bodies such as phytoplankton and phytobenthos. The assessment for lakes is based on total N, total P and phytoplankton. For rivers, the assessment is based on total N, total P and phytobenthos. If phytoplankton or phytobenthos data is not available, an evaluation of other water flora is used. In most cases, this occurs in artificial or significantly modified water bodies. All tests were carried out using targets that have been specifically determined for the water bodies concerned by the managers and that have been reported nationally.

The eutrophication status of a water body is determined using a three-year average of the parameters. Three classes are distinguished for the status descriptions: eutrophic, potentially eutrophic and non-eutrophic. ‘Eutrophic’ indicates that eutrophication effects can be observed in the biology. The biological quality elements are then scoring less than ‘good’. Assignments to this classification are made independently of the scores for the nutrients. ‘Potentially eutrophic’ indicates that no eutrophication effects can be observed in the biology but the nutrient concentrations are sufficiently high that they could cause such effects. A detailed explanation of the assessment method has been given in Chapter 2 (Subsection 2.6.3).
This yields the following picture for WFD freshwater bodies as a whole (both regional and national):

- 59% of all water bodies were assessed as eutrophic for the most recent assessment period (2016-2018). This is an improvement with respect to the previous period, during which 64% were in this class. 10% were assessed as potentially eutrophic and 32% were assessed as non-eutrophic (see Table 6.1);
- the biggest improvements occurred in the regional water bodies, for which the number of bodies with a ‘good’ status (non-eutrophic) rose from 23% to 30%;
- within the regional water bodies, the categorisation into eutrophication classes was almost identical for the two main types of water body (lakes and rivers).

<table>
<thead>
<tr>
<th>Table 6.1 Eutrophication characteristic of freshwater bodies in the periods 2012-2014 and 2016-2018 (% of water bodies).</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFD water bodies (2012-2014)</td>
</tr>
<tr>
<td>National water bodies</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Non-eutrophic</td>
</tr>
<tr>
<td>Potentially eutrophic</td>
</tr>
<tr>
<td>Eutrophic</td>
</tr>
<tr>
<td>Number</td>
</tr>
</tbody>
</table>

Note: rounding may mean that the total percentages do not always add up exactly to 100%.

Van Duijnhoven et al. (2019) reported on the assessments for the individual parameters that determine the eutrophication status. This shows that the nutrients in almost half the water bodies comply with the standards for those bodies. Maps 6.6 and 6.7 at the end of this chapter show these assessments for each water body.

6.4.2 Chlorophyll-α

Concentrations of chlorophyll-α have been measured since the early 1990s in both WFD waters and a proportion of the agriculture-specific waters. Chlorophyll-α is a parameter that is primarily determined for the main surface water type 'M' (lakes). The standards for chlorophyll-α have been derived separately for each type of water body. The WFD standard for the average summer chlorophyll-α concentration for shallow (moderately large) buffered ponds (WFD type M14) is for instance 10.8 μg/l and for weakly buffered (regional) ditches (WFD type M24) it is 23 μg/l (Bijkerk, 2014). The limits for the classes shown in Figure 6.9a have been adjusted with respect to the previous report so that they fall better within the specific standards for these surface water types.

The largest improvements were seen in the previous periods. The number of monitoring locations where an average summer chlorophyll-α concentration of less than 23 μg/l was measured has increased since 1992 from 42% to 51% for agriculture-specific waters and it rose from 28% to 47% for regional WFD waters and from 55% to 91% for national...
waters (see Figure 6.9a). When the two most recent periods are compared, stabilisation can be noted in the three distinct groups of surface waters, with in fact a very small increase in chlorophyll concentrations in the agriculture-specific waters. Although there are surface waters in which the chlorophyll concentrations are still decreasing, increases were observed in 22% to 26% of the water bodies water (see Figure 6.9b). There are relatively large year-on-year fluctuations in the agriculture-specific waters (see Figure 6.10). One explanation for this may be the small number of waters in this category for which chlorophyll data was available for the earlier reports.

Figure 6.9a Chlorophyll-α-concentration, summer average. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters for each chlorophyll-α concentration class (in µg/l) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.
Figure 6.9b Chlorophyll-α concentration, summer average. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters with increasing or decreasing chlorophyll-α concentrations (in µg/l); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.

Figure 6.10 Chlorophyll-α (average summer concentration in µg/l) in freshwaters in the period 1990-2019.
6.4.3 Nitrogen and phosphorus

The eutrophication status is assessed using a biological evaluation and an evaluation of the nutrient status in the water bodies. The benchmarks drawn up for this use the average summer values for total nitrogen and total phosphorus, expressed in mg N/l and mg P/l respectively. The months April to September have been used for the average summer concentrations.

The WFD standard for water types that are susceptible to eutrophication such as shallow (moderately buffered) ponds (type M14) is 1.3 mg/l as the summer average for total nitrogen and 0.09 mg/l for total phosphorus. For weakly buffered regional and other ditches (type M4), the summer average standard for total nitrogen is 2.8 mg/l; for total phosphorus, it is 0.15 mg/l. The assessments for total N and total P for each water body are shown in maps 6.6 and 6.7 at the end of this chapter.

Total N

Average summer total nitrogen concentrations have fallen since 1992 (see Figure 6.11a). The biggest changes were in the period up to 2005. There have only been limited improvements over recent years for both the regional WFD waters and agriculture-specific waters. In both types of surface water, there is still a higher percentage with decreasing total N concentrations than with an increase (see Figure 6.11b). In almost half of both types of waters, the total nitrogen concentration has fallen; this drop has even been large in 34% of agriculture-specific waters. Over the most recent period, however, up to about 10% of the monitoring locations in regional WFD waters and up to 15% of agriculture-specific waters showed large increases in concentration that have virtually cancelled out the effect on the national average of the improvements that have occurred in other water types (see Figure 6.12). Map 6.6 at the end of this chapter gives a picture of the topographical distribution of the nitrogen concentrations and of the monitoring locations where the concentrations are rising or falling. The greatest increases were observed in the south of the Netherlands.

The total nitrogen concentration in national surface waters is stable in the majority of those bodies (see Figure 6.11b). The percentages of water bodies with improvements or deterioration are relatively small compared to the figures for regional waters. The average concentration in national surface waters is now comparable to the average concentration in the regional WFD waters (2.5 mg/l total nitrogen) (see Figure 6.12). Higher concentrations are encountered in agriculture-specific waters, with concentrations during the past three years of around 3.2 mg/l.
Figure 6.11a Total nitrogen, summer average. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters for each total nitrogen concentration class (in mg/l as N) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.

Figure 6.11b Total nitrogen, summer average. Percentage of monitoring locations in agriculture-specific waters, regional WFD water and national waters with increasing or decreasing total nitrogen concentrations (in mg/l as N); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.
Inset 6.2 – The effect of weather conditions

Weather conditions have a major influence on the nutrient concentrations in surface waters (and on the testing against the standards). The influence of precipitation quantities in particular on the nutrient concentrations in water bodies differs from the influence on root zone leaching water (see Inset 4.1). In wet years, the total N concentrations in surface waters are generally higher than in drier years, whereas those in root zone leaching water are conversely lower. The higher concentration in surface waters is also caused in part by a greater contribution from relatively nutrient-rich shallow pathways to the composition of surface water in wet situations (Rozemeijer & Broers, 2007; Rozemeijer et al. 2010). In wet and mild winters, a relatively large amount of run-off into surface waters occurs via shallower pathways (upper groundwater layer, tile drainage, run-off). Additionally, cracking occurs in the soil in dry periods, particularly in clay and peat soils, which results in preferential transport of nitrate (and indeed phosphate) into surface waters during rainfall after a dry period. Even though the concentrations in leachates are lower in wet years than in dry years, they are still much higher than in deeper-lying groundwater. In dry situations, the deeper and less fertiliser-contaminated groundwater in fact makes a relatively large contribution to the composition of the surface waters. Weather variation can therefore cause major differences in nutrient concentrations and nutrient loads, both between the seasons and when comparing wet and dry years. The higher concentration in 1998 is one example of a year that was highly unfavourable for the water quality, with the total N concentrations about twice as high as in other years. This was the result of three relatively dry years (1995-1997) with little leaching followed by an extremely wet year (1998) in which the accumulated nutrients leached out quickly (see Figure 6.12). That is why the elevation could be seen at all locations, both WFD and MNLSO (see Figure 6.6). The advisory report by the CDM (2020) about drought and fertilisation discusses these effects in greater depth.

Figure 6.1 Total nitrogen concentration (summer average as N in mg/l) in freshwaters during the period 1990-2019.
Total phosphorus
The fall in total phosphorus concentration since the beginning of the 1990s is largest in national surface waters and only limited in agriculture-specific waters. This reflects the strong reduction of the load in surface waters from sources such as sewage treatment plants and industry, which are not present in agriculture-specific waters.

The total phosphorus concentration decreased slightly for all three types of surface waters, when compared against the previous period (see figures 6.13a and 6.14). The summer average total phosphorus concentration has been decreasing slowly in WFD waters since the early 1990s (see Figure 6.14). A clear decrease to 0.10 mg/l can also be seen after 2010 in the national waters. In the regional WFD waters, the phosphorus concentration fell rapidly until 2005 but stabilised in the years that followed at a phosphorus concentration of about 0.25 mg/l. In agriculture-specific waters, the phosphorus concentration began by increasing until the end of the 1990s and then decreased again to about 0.4 mg/l. The phosphorus concentration in these surface waters can vary widely from year to year as a result of outliers, particularly in the early years when the number of monitoring locations was still limited.

Figure 6.13a Total phosphorus, summer average. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters for each total phosphorus concentration class (in mg/l as P) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.

The percentage of monitoring locations with a total phosphorus concentration in the higher phosphorus classes (above 0.18 mg/l) has decreased in the regional WFD waters from 65% in 1992-1995 to 41% in 2016-2019 (see Figure 6.13b). In agriculture-specific waters, the decrease between the first and last periods is smaller (from 62% to 49%). When comparing the final reporting period against the previous one, the total phosphorus concentration in the WFD waters and
agriculture-specific waters appears to be stable and there is on average little increase or decrease in the concentration.

Figure 6.13b Total phosphorus, summer average. Percentage of monitoring locations in agriculture-specific waters, regional WFD waters and national waters with increasing or decreasing phosphorus concentrations (in mg/l as P); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.

Figure 6.14 Total phosphorus concentration (summer average) in freshwaters in the period 1990-2019: agriculture-specific, regional WFD and national waters.
6.5 **Discussion of the trends in agricultural practices and quality of fresh surface waters**

The sections above show a clear fall in the concentrations of nitrate, total nitrogen and total phosphorus since 1992 both in regional agriculture-specific waters and in regional and national WFD waters.

The average winter nitrate concentration is a good indicator of the effect of the agricultural emission on surface water quality. Viewed over a longer period, the winter average nitrate concentration over the periods 1992-1995 to 2012-2015 decreased in all agriculture-specific waters and in about 90% of all regional and national WFD waters. The concentration only increased at a small number of monitoring locations in regional WFD waters. This decrease can be seen to be stagnating when the changes between the two most recent periods are examined. Between 2012-2015 and 2016-2019, the number of locations at which the concentration is decreasing further has been roughly equal to the number of locations where concentrations are rising. An increase in the average winter nitrate level can be seen at about 20% of all monitoring locations for all water types, with an increase of more than 5 mg/l nitrate at 3 to 5% of the locations.

Despite the fact that a clear improvement in nutrient concentrations can be seen over the period as a whole, nearly 60% of WFD freshwater bodies were still eutrophic in the period 2016-2018. That is the same percentage as in the previous period. Over a quarter (32%) of these water bodies are non-eutrophic and a small proportion (10%) are potentially eutrophic.

The trend for nitrate has also been made clear by using LOWESS (LOcally WEighted Scatterplot Smoothing) to determine a trend line for each monitoring location and then using the same method to calculate aggregated trend lines (see Klein & Rozemeijer, 2015). Using this method gives a clear picture of whether a trend is accelerating or fading out over time. Together, the quartiles give the bandwidth within which 50% of the concentration measurements fall. A more detailed description of this calculation method has been given in Subsection 2.6.3. The results are shown below.

The calculation shows a downward trend for winter nitrate concentrations for agriculture-specific waters, regional WFD waters and national waters (see figures 6.15a to 6.15c). For agriculture-specific waters, this downward trend for the nitrate concentrations has continued in recent years (see Figure 6.15a), whereas it has flattened out for the WFD waters in 2003-2005 (see figures 6.15a to 6.15c).

When the nitrate trend as calculated based on LOWESS (see figures 6.15 to 6.15c) is compared against the one produced by averaging the measurements (see Figure 6.6, average winter nitrate concentrations), the trend calculated for nitrate in agriculture-specific waters is seen to be substantially lower than the line for average concentrations measured in the winter. One explanation for this is the greater effect of a few outliers in the nitrate concentrations on the average measured values than on the calculation of the trend lines; average concentrations are...
pulled upwards a lot by outliers, whereas the LOWESS trend lines are not sensitive to outliers. Furthermore, an outlier has relatively more effect when calculating the average for agriculture-specific waters than for WFD waters because the number of monitoring locations is smaller for the agriculture-specific waters. This can also be seen in the broader interquartile range (the range between the 25th and 75th percentiles) for the agriculture-specific waters compared to WFD waters.

Figure 6.15a Calculated trend in nitrate concentration (winter average as NO₃ in mg/l) for agriculture-specific waters; running median (solid line) and the interquartile range trend (grey area). Period: 1990-2019. Note: winter 2019 means October 2018 – March 2019.

Figure 6.15b Calculated trend for nitrate concentration (winter average as NO₃ in mg/l) for regional WFD waters; see Figure 6.15a for an explanation.
Figure 6.15c Calculated trend for nitrate concentration (winter average as NO₃ in mg/l) for national WFD waters; see Figure 6.15a for an explanation.

Topographical picture of nitrate concentrations, eutrophication status and assessments of total N and total P

In the previous sections, a picture was given of the status and changes in nitrate concentrations and eutrophication parameters as diagrams and graphs. This section represents that information as a spatial distribution showing where the quality is already acceptable and where we are still seeing changes.

In addition to maps with winter average and winter maximum nitrate concentrations and the changes in them (see maps 6.1 to 6.4), a spatial picture is also given of the eutrophication status and its supporting parameters total N and total P for the WFD water bodies (see maps 6.5 to 6.7). For the latter parameters, Van Duijnhoven et al. (2019) and Buijs et al. (2020) give detailed descriptions of the topographical picture for the status and the trends for WFD water bodies and agriculture-specific waters respectively. A summary of that picture is given below.

Concentrations of N and P are still decreasing in much of the Netherlands. In recent years however, increasing concentrations have been seen again on a local level. When the three-year averages are compared, it is striking that the majority of sites with increases in total N are in the west of the Netherlands, the south-eastern part of the Sand Region and the Loess Region. Rises in total P occur primarily in the west of the Netherlands, with localised cases in the northern and eastern parts of the country. The soil type plays a role: phosphorus concentrations are naturally higher in sea clay areas and brackish waters.

Buijs et al. (2020) carried out analyses of the statuses and trends for agriculture-specific waters for the period from 1990 to 2018. The trend analysis shows that the water quality in agriculture-specific waters is improving. The status varies from one year to the next; meteorological conditions turn out to have a major effect on summer concentrations and then on the testing against the standards. During the period 2015 to 2018, less than half the monitoring locations on average (36 to 54%) met the water board requirements for total N. For total P, 48 to 55% of the locations met the water board standards. For total N, exceedances of the standards occurred throughout the country. For total P, exceedances largely occurred in the west of the country.
The trend analyses show significant falls in total N concentrations at 87% of MNLSO sites over the period 1990-2018 and for total P at 53% of the monitoring locations. Downward trends have also been observed for the summer and winter concentrations separately, for the Sand, Clay and Peat regions, for the WFD river basin subdistricts and for various monitoring periods. The only exception to this is the P concentrations in the Maas river basin district, which have shown an upward trend from 2004 onwards. Although the majority of MNLSO sites have shown downward trends in N and P concentrations, the number of waters that comply with the water board standards has not risen since the previous report, which contained data up to and including 2014. The median target gap (difference in concentration from the water board standard) for all sites where the standards are exceeded was 0.2 mg/l for total P and 2.0 mg/l for total N.

Van Duijnhoven et al. (2019) give a nationwide picture of the evolution of N and P concentrations at all Dutch WFD monitoring locations. Half of all Dutch WFD water bodies are in good condition in terms of both total N and total P. In 2009, 36% of the water bodies met the WFD nutrient targets. Over recent years, roughly half the water bodies met those targets. Between 2015 and 2019, the number of water bodies with a ‘good’ total P status increased further. The improvement has stagnated for total N and the number of water bodies with a ‘good’ status is in fact even decreasing slightly.

An upward trend can also be seen in the number of water bodies with a ‘good’ status for each river basin district, although there are large differences between the various river basin districts in terms of the percentage of water bodies that are ‘good’. A decrease in total P in terms of the numbers of water bodies with a ‘good’ status can only be seen in the Scheldt river basin district between 2015 and 2019.

The picture for the water managers is variable. That can also be seen if the target gap (the distance from the standard) is examined. In the results when the target gap is determined, the broad spread across the Netherlands is striking. For total N, the water bodies that exceed the standard by a factor of more than two are largely in the area managed by the Brabant water boards, the Limburg water board, Vechtstromen and Amstel, Gooi en Vecht. For total P, they are largely managed by the Noord-Holland and Zuid-Holland water boards and the Aa en Maas water board. The picture that arises from the monitoring data is backed up by the statistical trend analyses that have been carried out on that data. Three different statistical methods have been used for calculating the trends. All three show the same nationwide picture: the concentrations for both total N and total P are falling. For total N, over 80% of locations are showing a significant downward trend and the figure for total P is over 70%. However, the nutrient concentrations have been increasing at various locations over the past couple of years. A significant upward trend in total N and total P can be seen for 4% and 6% of the monitoring locations respectively.
Map 6.1 Winter average nitrate concentration (mg/l) in Dutch fresh surface waters for each WFD monitoring location over the period 2016-2019.

Map 6.2 Change in the winter average nitrate concentration (mg/l) in Dutch fresh surface waters for each WFD monitoring location between 2012-2015 and 2016-2019. The change is presented as the difference between the averages for 2012-2015 and 2016-2019.
Map 6.3 Winter maximum nitrate concentration (mg/l) in Dutch fresh surface waters for each WFD monitoring location over the period 2016-2019.

Map 6.4 Change in the winter maximum nitrate concentration (mg/l) in Dutch fresh surface water for each WFD monitoring location between 2012-2015 and 2016-2019. The change is shown as the difference between the maximums for 2012-2015 and 2016-2019.
Map 6.5 Eutrophication status, determined for each WFD water body for the period 2016-2018.
Source: Van Duijnighoven et al. (2019)
Map 6.6 Total N assessment for each WFD water body for the period 2016-2018.
Source: Van Duijnhoven et al. (2019)

Map 6.7 Total P assessment for each WFD water body for the period 2016-2018.
Source: Van Duijnhoven et al. (2019)
6.6 Source


Van Duijnhoven, N., Thiange, (2013) Belasting per KRW waterlichaam voor probleemstoffen in Nederland II. Deltares-rapport 1208190-000-ZWS-0004.


7 Marine and coastal water quality

7.1 Introduction
Saline waters have been categorised in accordance with the WFD into transitional and coastal waters. All other marine waters are more than 2 kilometres from the coast and are defined as the ‘open sea’. That category is not included in the waters covered by the WFD. As in the previous chapter about fresh surface waters, the first section here gives an overview of the nutrient load in saline surface waters. The data presented for nitrate is based on average or maximum concentrations during the winter (December to February), given that this is the period when biological activity is least. As a result, nitrate concentrations that are measured in the winter are a better indicator of changes in the water quality status than nitrate concentrations measured in the summer.

The graphs and tables give an overview of all measurements. At the end of the chapter, maps are used to give a spatial picture of the statuses and trends over the most recent period.

7.2 Nutrient load in marine and coastal waters
The bulk of the nutrient load in the North Sea and Wadden Sea from the Netherlands is carried there by the major rivers (the Rhine and the Maas) and via the IJsselmeer lake into the North Sea and Wadden Sea. The Scheldt and the Ems also contribute, but the loads from those two rivers are attributed to Belgium and Germany respectively. The quality of transitional and coastal waters is largely determined by the load arriving by this pathway. The further away from the coast you go, the higher the relative contribution from atmospheric deposition becomes. Looking at the entire Dutch part of the continental shelf, atmospheric deposition accounts for about 15% of the total nitrogen load for the area. Table 7.1 shows how the load via the various pathways and sources of nitrogen and phosphorus has developed over time.

Over the period 2016-2018, the nutrient load in the North Sea and Wadden Sea from the Netherlands was 232 million kg nitrogen and 6.5 million kg phosphorus annually (see Table 7.1). Direct discharges only comprise a limited contribution to the overall load from the water.

Compared against the first reporting period (1992-1995), the nitrogen load via the rivers has been reduced by almost 50%; for phosphorus, that reduction is in fact more than 75%. The load of phosphorus from the rivers is still decreasing; for nitrogen, however, the decrease seems to be stagnating when compared to the previous reporting period (2012-2015).
Table 7.1 Total nitrogen and phosphorus loads in the North Sea and Wadden Sea from and via the Netherlands and via atmospheric deposition (in millions of kg per year) for the period 1992-2018.1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge via rivers²</td>
<td>436</td>
<td>223</td>
<td>227</td>
<td>27.2</td>
<td>7.5</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Direct discharges³</td>
<td>13.7</td>
<td>5.1</td>
<td>5.1</td>
<td>3.89</td>
<td>0.67</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>Total emissions via water</td>
<td>450</td>
<td>228</td>
<td>232</td>
<td>31.1</td>
<td>8.2</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Atmospheric deposition⁴</td>
<td>53.3</td>
<td>35.9</td>
<td>35.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
| ...up to 1 mile | 24 | 19 | 17 |}

³ Calculated from the RWS-DONAR database – loads via the Rhine, Maas and IJsselmeer.
⁴ Data from the emissions registry (Emissieregistratie, 2020).
⁴ Atmospheric nitrogen deposition is given for the Dutch Continental Shelf (Gaus et al., 2019) and also separately for the coastal and transitional waters up to the one-mile zone. Phosphorus deposition is not relevant.

Increased discharges of nitrogen into the North Sea were calculated in 2018. In all probability, this can be attributed to the extremely dry summer (see also the inset text in Chapter 6). Given that agriculture is a key source of the nutrient load in surface waters, both domestically and abroad, this explanation is widely applicable. When viewed over several years, it can be seen that the downward trend in nitrate concentrations is flattening out. The consequence is that meteorological influences have a relatively large effect compared to the policy being implemented. The reductions in phosphorus are also proceeding more slowly, but are still greater than for nitrogen. This is resulting in further skewing of the N-P ratio of the load in marine waters. The possible effects of this shift (such as a change in the species composition of the algae) are still uncertain, although there are indications of changes in the species composition in coastal waters (a relatively large proportion of diatoms – Prins et al., 2012, Burson et al., 2016).

Table 7.2 gives the total loads of N and P for the OSPAR II region (North Sea, Kattegat and Skagerrak) stated by all adjacent member states. Combined with the data from Table 7.1, this data gives a picture of how the contributions from the river basin districts in the Netherlands that end up in the seas relate proportionally to the contributions from other North Sea countries. A decreasing contribution from the Netherlands has been seen in the past.

For phosphorus, it can be seen that the relative contribution to the overall load in the North Sea via rivers and point sources from the Netherlands has decreased, from 38% in the period 1992-1995 to 25% in 2016-2018. The contribution for nitrogen was 33% in 1992-1995. After a fall (27% in the previous reporting period), the relative contribution is now once again comparable to that in the first reporting period; it was estimated at 32% for 2016-2018.
Table 7.2 Total discharges for the nitrogen and phosphorus loads into the North Sea (in millions of kg per year) for the period 1992-2019.

<table>
<thead>
<tr>
<th>Nutrient Load</th>
<th>Nitrogen (N)</th>
<th>Phosphorus (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,373</td>
<td>849</td>
</tr>
<tr>
<td>Discharges via rivers and point sources</td>
<td>Atmospheric deposition</td>
<td>568</td>
</tr>
</tbody>
</table>

1 Average amounts discharged are given for each period (1992-1995, 2013-2015 and 2016-2018) for the OSPAR II region (North Sea, Skagerrak, Kattegat, English Channel zone). Source: Annual RID reports, Table 4b. Sum of Direct and Riverine Inputs to the Maritime area of the OSPAR Convention in 2015 by Sea Area.

2 Atmospheric deposition for the period 1992-1995 has been taken from the previous report; OSPAR doc. no. HASEC 16/07/01 add. 2.

3 For 2013-2015 and 2016-2017, the deposition figures come from a draft HASEC report: Preparation of the routine products for OSPAR by MSC-W of EMEP (HASEC 20/4/5). Data is not yet available for 2018.

4 Phosphorus deposition is not relevant.

7.3 Nitrate concentrations in marine and coastal waters

The quality of the transitional and coastal waters is determined to a large extent by the discharges from the major rivers. The highest nitrate concentrations are therefore found in the transitional waters; concentrations decrease further in coastal waters and are lowest in the open sea. The concentrations measured in all three types of salt waters have decreased since the 1990s.

The following sections describe the evolution of the winter average and winter maximum concentrations and the changes therein during the most recent period, with respect to the previous periods. The results for this reporting period are given for each monitoring location at the end of this chapter so that a spatial image can be produced of both the quality and the changes.

Winter average nitrate concentrations

December, January and February have been taken to comprise the winter period. The year number used for reporting is that of the January. A downward trend can be discerned in the average winter nitrate concentrations for both coastal waters and the open sea (see Figure 7.2). The highest nitrate concentrations are measure in the transitional waters. The reduction in concentrations that was still observed in the previous report seems to be stagnating and local increases in nitrate concentrations have been observed. Nitrate concentrations of above 10 mg/l have been measured at half the monitoring locations in transitional waters (see Figure 7.1a).

Figure 7.1b shows that changes (albeit small ones) do occur in the quality. About half the monitoring locations for transitional and coastal waters show slight improvements. There is a single location in the transitional waters where a small increase in nitrate concentration occurred.
Figure 7.1a Winter average nitrate concentration. Percentage of monitoring locations in marine waters (transitional waters, coastal waters and the open sea) for each nitrate concentration class (in mg/l NO₃) in the reporting periods 1992-1995, 2012-2015 and 2016-2019. The number of monitoring locations for each type of salt water is given above the columns.

Figure 7.1b Winter average nitrate concentration. Percentage of monitoring locations in marine waters with increasing or decreasing nitrate concentrations (in mg/l NO₃); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.
Figure 7.2 Average winter nitrate concentration (in mg/l NO₃) in the open sea and in Dutch transitional and coastal waters during the period 1992-2019

The data for the last two years shows considerable fluctuations that are probably (and certainly at least partially) attributable to weather effects. Some of the fluctuations can moreover be explained by the fact that the same monitoring locations were not used every time. Because the total number of monitoring locations is fairly low, the average is sensitive to this.

A substantial dip in the winter average for nitrate in the coastal and transitional waters in 2017 stands out. That is the period from December 2016 to February 2017. The underlying data shows that this is data from February for most of the measurements and also for January for some of them. January and February 2017 had relatively low nitrate concentrations; by March, the concentrations were back in line with the long-term average again. To find an explanation for this, information about excessive precipitation in the winter of 2016-2017 was examined and compared against other years. It turned out that January was fairly dry, but above all that November and December 2016 were much drier than in other years. As a result, there was less leaching that winter, resulting in a lower load of nitrogen flowing towards the sea. In 2018, the winter averages for nitrate were substantially higher again, probably because the surpluses that had accumulated over the preceding winter were then leached out after all. Inset 6.2 in Chapter 6 discusses the effect of the weather in greater detail.

**Winter maximum nitrate concentrations**

The maximum concentrations give a somewhat different picture to the average winter concentrations. Small improvements are visible in a few water bodies for all saltwater types. There are even as many as 4 locations in transitional waters where the maximum nitrate concentration has fallen slightly. On the other hand, there is a small number of water bodies (given the total number of monitoring locations for each type, this is generally just a single monitoring location) where
the winter nitrate maximum can be seen to be increasing (Figure 7.3b). As was the case for the previous period, the winter maximums at 70% of locations in transitional waters were above 10 mg/l (see Figure 7.3a); the concentration threshold of 25 mg/l has not been exceeded anywhere since 2012.

Figure 7.3a Winter maximum nitrate concentration. Percentage of monitoring locations in marine waters (transitional waters, coastal waters and the open sea) for each nitrate concentration class (in mg/l NO₃) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.
7.4 Eutrophication in marine and coastal waters

7.4.1 General status; the eutrophication characteristic

When determining eutrophication in saline waters, including coastal and transitional waters, the biological quality elements ‘algae’ (composition of *Phaeocystis* blooms and chlorophyll-$\alpha$) and nutrients were examined, in line with the WFD methods. Potentially eutrophic means that the biological condition is good, but that the nutrient concentrations do not comply with the WFD water quality target values. A more detailed explanation of the assessment method has been given in Chapter 2 (Subsection 2.6.3). The following sections show the trends for various parameters that help determine the eutrophication status, such as the concentration of dissolved organic nitrogen (DIN) and the chlorophyll-$\alpha$ concentration. DIN is the sum of nitrogen as nitrite (NO$_2$), nitrate (NO$_3$) and ammonium (NH$_4$); this measure is used for coastal and transitional waters.

In this reporting period, 7% of the transitional and coastal waters (WFD water bodies) were assessed as 'non-eutrophic', 50% as 'potentially eutrophic' and 43% as 'eutrophic' (see Table 7.3).
Table 7.3 Eutrophication characteristic for transitional and coastal waters (%) for the various periods; the number of water bodies concerned is given in parentheses.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>non-eutrophic</td>
<td>6% (1)</td>
<td>0% (0)</td>
<td>7% (1)</td>
</tr>
<tr>
<td>potentially eutrophic</td>
<td>81% (13)</td>
<td>71% (10)</td>
<td>50% (7)</td>
</tr>
<tr>
<td>eutrophic</td>
<td>13% (2)</td>
<td>29% (4)</td>
<td>43% (6)</td>
</tr>
<tr>
<td>number</td>
<td>16</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

In the period 2016-2018, four marine water bodies moved from ‘potentially eutrophic’ to ‘eutrophic’ compared against the period 2012-2014. This is particularly the result of an increase in the chlorophyll-α concentration, for which values that at some locations were previously just below the class threshold are now just above it. The quality at three other locations improved: two water bodies have gone from ‘eutrophic’ to ‘potentially eutrophic’ (i.e. the biology has improved) and one has moved from ‘potentially eutrophic’ to ‘non-eutrophic’. Of the five water bodies that are categorised as transitional waters, the status of two has improved since the previous period from ‘eutrophic’ to ‘potentially eutrophic’; all five are in the status ‘potentially eutrophic’ for the current period. Of the coastal waters, the class of four water bodies has deteriorated, from ‘potentially eutrophic’ to ‘eutrophic’.

However, the time series for chlorophyll-α (see Figure 7.6) do not show any clear trends that indicate improvement or deterioration.

For monitoring locations that are close to the coast, it should be noted that changes in salinity (i.e. fluctuations in the proportion of freshwater reaching such stations) can have a substantial effect on nutrient concentrations (more freshwater means a greater supply and thereby higher nutrient concentrations) and in turn on the chlorophyll-α concentration. Given the downward trend in nutrient amounts and concentrations, those peaks in chlorophyll-α cannot be immediately explained by the nutrient load and they may also be the consequence of randomly favourable growing conditions, e.g. due to sunny weather in the spring.

Additionally, the sampling frequency can have an effect in that a sampling frequency of once a month may make a big difference by neatly including or precisely missing a spring peak, as blooms sometimes only last a few days. This is exacerbated by the fact that the chlorophyll-α concentration at several locations is close to the upper limit of the ‘good’ class, meaning that small changes can easily cause a shift to another status. The results can vary widely from year to year as a result. The analysis of these factors is still ongoing.

7.4.2 Inorganic nitrogen (DIN)

The concentrations of dissolved inorganic nitrogen (DIN) in the winter (see Figure 7.5) show the same trend as the average winter nitrate concentration (see Figure 7.2).
Normalised to a salinity of 30 psu, the DIN concentrations have fluctuated since 2010 around the standard value of 0.46 mg N/l. The fluctuations in the first decade of the time series for the transitional waters may possibly be explained by meteorological variations (Fraters et al., 2016).

**Chlorophyll-α**

Summer averages (April to September) are presented for chlorophyll-α concentrations. There are just a few locations in coastal waters and the open sea where these concentrations have increased (see Figure 7.5b). Taken as a whole, a slight increase in chlorophyll concentrations can be seen since the previous reporting period for all types of salt waters, although Figure 7.6 shows that the chlorophyll concentrations have been decreasing again in recent years. For the most recent reporting period (2016-2019), the concentrations at almost all monitoring locations were below 23 μg/l. For the transitional waters, as for the monitoring locations in the open sea, more than 90% have concentrations of below 10.8 μg/l (see Figure 7.5a). This is also the case for 75% of the monitoring locations in coastal waters. The standard for chlorophyll-α in coastal waters is 14 μg/l. This applies for the 90th percentile value in the growing season (March-September).
Figure 7.5a Chlorophyll-α-concentration, summer average. Percentage of monitoring locations per concentration class (in µg/l) in marine waters (transitional waters, coastal waters and the open sea) in the reporting periods 1992-1995, 2012-2015 and 2016-2019.

Figure 7.5b Chlorophyll-α-concentration, summer average. Percentage of monitoring locations in marine waters with increasing or decreasing chlorophyll-α concentrations (in µg/l); changes over the reporting periods 1992-1995 to 2012-2015 and 2012-2015 to 2016-2019.
Discussion of the trends in agricultural practices and quality of saltwater bodies

Similarly to the decrease measured in fresh surface waters (see Chapter 6), there have also been decreases in the nitrate concentrations in salt waters. There were decreases in the nitrate concentrations at 80% of the monitoring locations in transitional and coastal waters between the periods 1992-1995 and 2012-2015; no instances of increases were observed. Between 2012-2015 and 2016-2018, at 50% of the monitoring locations in transitional water the concentration decreased, and there were no changes in the coastal waters or the open sea.

For nitrate, in terms of both the winter average and winter maximum and for inorganic nitrogen (DIN), a steady reduction in concentrations can be seen. The drop is strongest in the transitional waters and occurs to a lesser extent in coastal waters and in the open sea. This downward trend is also evident when aggregated trend lines are calculated (using the LOWESS method – see Subsection 2.6.3) for the average winter nitrate concentrations for the three distinct types of salt waters (transitional waters, coastal waters and open sea). This is shown in figures 7.8a to 7.8c. The trend lines show whether a trend is accelerating or flattening out. The bandwidth between the 25th and 75th percentiles in LOWESS – the interquartile range – shows the concentration levels within which half the measurements can be found. The reduction in the nitrate concentration (winter measurements) is greatest in the transitional waters. When the trend lines for nitrate concentrations in the winter for transitional waters (see Figure 7.7a) are compared against the evolution of average winter nitrate concentrations (see Figure 7.2), the picture does match but the concentrations are...
different and are lower in the trendline (which uses medians) than in the average (mean) values in the evolution. The analysis, as described in Subsection 2.6.3, shows a downward trend for nitrate (winter average) for both the transitional waters (see Figure 7.7a) and the open sea (see Figure 7.7c). This trend has been sharper for the locations in coastal waters since 2000.

**Spatial picture for nitrate, DIN and the eutrophication characteristic**

For saline water bodies as well, it can be seen that the dissolved nitrogen concentrations (nitrate and ammonium) are too high almost everywhere despite the improvements in nitrate concentrations. Eutrophication effects can be seen in the biology in 13% of water bodies; in 81% of water bodies, the biology is still in order despite excessively high dissolved nitrogen concentrations. This may be caused by the bandwidth around the quantitative relationship between DIN and the biology. The fact that the biology is in order despite the high DIN levels may partly be due to other factors restricting the biology, such as limitations on the amount of light, grazing by shellfish or plankton, or shortages of nutrients other than nitrogen. The following maps give a spatial picture of the status and of the changes in that status for nitrate, and of the assessments regarding DIN and the eutrophication status. Nitrate concentrations decrease from transitional waters via coastal waters to the open sea. Changes between this period and the previous one can be seen above all in the transitional waters, with improvements in the average winter concentration above all visible in the Scheldt estuary. As can be seen in Map 7.6, there are still a lot of monitoring locations in the Southern Delta and the Wadden Sea that are classed as eutrophic.
Figure 7.7a Calculated trend in nitrate concentration (winter average as NO₃ in mg/l) for WFD transitional waters; running median (solid line) and the interquartile range trend (grey area).

Figure 7.7b Calculated trend for nitrate concentration (winter average as NO₃ in mg/l) for the coastal water locations; see Figure 7.7a for an explanation.

Figure 7.7c Calculated trend for nitrate concentration (winter average as NO₃ in mg/l) for the open sea locations; see Figure 7.7a for an explanation.
Map 7.1 Winter average nitrate concentration (mg/l) in Dutch coastal and transitional waters and the open sea for each monitoring location over the period 2016-2018.

Map 7.2 Change in the winter average nitrate concentration (mg/l) in Dutch coastal and transitional waters and the open sea for each monitoring location between 2012-2015 and 2016-2018. The change is shown as the difference between the averages for 2012-2015 and 2016-2018.
Map 7.3 Winter maximum nitrate concentration (mg/l) in Dutch coastal and transitional waters and the open sea for each monitoring location over the period 2015-2018.

Map 7.4 Change in the winter maximum nitrate concentration (mg/l) in Dutch coastal and transitional waters and the open sea for each monitoring location between 2012-2015 and 2016-2018. The change is shown as the difference between the averages for 2012-2015 and 2016-2018.
Map 7.5 Assessment of dissolved inorganic nitrogen (DIN as N in mg/l) for the period 2016-2018 for each monitoring location in the coastal and transitional waters.

Map 7.6 Eutrophication status, determined for the period 2016-2018 for each monitoring location in the transitional and coastal waters.
7.6 **Source**


Norwegian Meteorological Institute


The future developments in water quality

8.1 Assessment of forecasting options

In the previous chapters, we have seen that the increases in nitrogen and phosphate surpluses in agriculture over the period 1950-1987 have been turned around into decreases since 1987. Nitrate concentrations in the water on farms have fallen as a result, just as they have in the groundwater and surface water. Eutrophication of surface water bodies has decreased as well. This is a consequence of measures that Dutch agriculture has taken as a result of the Dutch fertiliser legislation and the European Nitrates Directive, such as reduced application of animal manure and artificial fertiliser and implementing closed application periods in the autumn and winter when the risk of leaching is greatest. However, the desired water quality level has certainly not been achieved everywhere yet.

Current water quality reflects the effects of earlier Nitrate Action Programmes in particular, above all the fourth and fifth (2010-2013 and 2014-2017 respectively). For that reason, a prognosis is also important for the water quality level that will be achieved by the current Nitrate Action Programme (2018-2021), the sixth.

It is however exceptionally difficult to determine exactly how long it will take for changes in agricultural practices to yield changes in water quality. The transit times of groundwater increase for water that is at greater depths as well as vary hugely for any given depth. Moreover, biological and natural processes (such as denitrification and ammonification or dispersion, diffusion and dilution respectively) lead to differences in water quality over time and space because of the wide variety of physical and chemical properties of the saturated zones, aquifers and impermeable layers. Regional surface waters are fed by groundwater of various origins (agriculture, nature and urban areas) and ages. They are additionally supplied by rainwater and sometimes by wastewater from e.g. farms, sewage treatment plants or even industrial plants.

The transit time of water that leaches from the root zone, as examined for the Minerals Policy Monitoring Programme, is estimated to be less than five years (Meinardi & Schotten, 1999; Meinardi et al., 1998a, 1998b). It has therefore been assumed that the results yielded by the fifth Action Programme (2014-2017) for the quality of the upper groundwater at farms will become manifest between 2018 and 2023, and those of the sixth Action Programme (2018-2021) will only be seen between 2022 and 2027. The transit time of groundwater in the Sand Region at depths of 5-15 metres is 12 years on average but varies from less than 5 years to more than 30 (Meinardi, 1994). The transit time of groundwater at depths of 15-30 metres is 36 years on average but varies from less than 25 years to more than 80 (Meinardi, 1994). In the Clay Region and Peat Region, the transit times are generally a lot longer because the permeability of the clay and peat layers is much lower.
It will therefore take at least a further ten years before the effects of measures to tackle nitrate concentrations are noticeable in the groundwater at depths of 5-15 metres. Because of the major differences in transit times at a given depth, the nitrate concentrations will fall slowly. In areas with Artesian aquifers and/or aquifers with a high capacity for denitrification, the nitrate concentrations are already low and there will be no change.

It will still take at least several decades before the effects of measures to tackle nitrate leaching are detectable at depths of over 15 metres (and certainly at depths of over 30 metres). The nitrate concentrations will only change gradually because of the large differences in transit times for the greater depths. The concentrations could increase further over the coming years before starting to fall.

The effects of measures to tackle nitrate concentrations in fresh surface waters that are specific to agriculture will become manifest reasonably quickly compared to the nitrate concentrations in groundwater at depths of greater than 5 metres. The changes in the quality will probably be seen just as quickly as in the water on farms. The effects of changes in agricultural practices on surface water quality in the Clay Region and Peat Region will occur as just quickly as the effects on the quality of the water leaching from the root zones of farms. The contribution from young groundwater (aged less than 5 years) to surface waters in the Sand Region ranges from under 10% to more than 70%. Because of the greater proportion of older water, it is assumed that the effects of measures in the sixth Action Programme to tackle nitrate concentrations in fresh surface waters in the Sand Region will become apparent later than in the Clay and Peat regions. Moreover, as a result of mixing, it will probably be more awkward to distinguish the effects of measures tackling nitrate concentrations from the effects that natural conditions have on nitrate concentrations. These could be caused for instance by factors such as differences in precipitation.

It is even more difficult to make predictions of the future progress of eutrophication than it is for nitrate concentrations. The main reasons for this are:
- the differences between surface water bodies in terms of how susceptible they are to eutrophication;
- phosphorus concentrations and other factors such as the hydromorphology that also play significant roles in the eutrophication process;
- contributions from other sources of incoming nutrients such as urban wastewater and cross-border rivers;
- the difficulty of predicting the response times of aquatic ecosystems to a substantial reduction of nutrient supplies and concentrations.

8.2 The future development of water quality
A ‘National water quality analysis’ has recently been carried out (Van Gaalen et al., 2020). The national analysis provides the background knowledge for drawing up the package of measures for the next round of what are known as the ‘River basin management plans’ (2022-2027).
for the Water Framework Directive (WFD). A brief summary of that analysis is given below; for details, please refer to the report by Van Gaalen et al. (2020).

The analysis concludes that the model calculations, assuming the existing and proposed measures, suggest a gradual improvement in terms of the target ranges for the biological WFD standards. Together with technical adaptations of the standards, this improvement with respect to the situation in 2018 will lead to an increase in the number of water bodies that comply with the biological standards. According to the model calculations, however, the measures envisaged will not achieve all the objectives everywhere: the proportion of regional surface water bodies that are compliant by 2027 will be between 30% and 60%, depending on the biological standard; for national freshwater bodies, the target range is calculated to be almost 100%. The analysis also shows that the WFD standards for nutrients will not be met everywhere. That will also not be achieved by implementing the package of measures in which the water managers maximise their efforts to meet the standards and in which it is assumed that all farms will comply with the measures in the DAW (Delta Plan for Agricultural Water Management). If the objectives are to be achieved, more radical structural measures will be needed for some of the surface waters, including parts of the Maas river basin district. For these areas, policy mechanisms such as the development of closed-cycle agriculture and the outcomes of rethinking fertiliser policy could offer the requisite structural solutions.

The effects of current policy have been calculated as part of the National Analysis. Current policy is taken to include the WFD measures determined for the river basin management plans for 2016-2021, the sixth Nitrate Action Programme and current measures that are part of the DAW.

The results suggest that the measures for the sixth Nitrate Action Programme, when calculated through, will have a limited effect on the nationwide emission from agricultural land. The mandatory measures will be deployed in a targeted way, focusing on specific sectors and areas rather than nationwide coverage; this means that the effect may be greater regionally or locally. This picture is in line with the results of the environmental impact assessment on the measures of the sixth Action Programme (Groenendijk et al., 2017).

One example of the approach of targeting specific areas is the management agreement for the additional efforts against nitrate leaching from agricultural activities in specific groundwater protection areas (see Subsection 3.6.3). The ex-ante analysis of this approach shows that the measures envisaged will not necessarily be able to bring the nitrate concentrations beneath agricultural land below the target of 50 mg/l in 23 of the 34 groundwater protection areas that are considered to be vulnerable. For 12 areas, the parties involved have said that the target range is within sight but that additional voluntary efforts are needed, such as a greater acreage taking part. For the remaining 11 areas, it is expected that the target range is not going to be realistic within the given context and scope of the administrative agreement (LNV, 2020). The action plans are being updated for all areas in the time
frame up to September 2020 so that the target ranges can be achieved sustainably as quickly as possible and by no later than the period covered by the seventh Action Programme (2022-2025).

8.3 Source


With thanks to

**Project management**
Wilbert van Zeventer (Ministry of Infrastructure and Water Management)
Marijke Koning (Ministry of Agriculture, Nature and Food Quality)

**Contribution to the report and/or making comments on the drafts:**
*Statistics Netherlands*
Arthur Denneman and Cor van Bruggen

*Deltas*
Kevin Ouwerkerk and Theo Prins

*RWS/Water, Traffic and the Environment*
Marcel van den Berg, Marcel Kotte, Bert Bellert and Rob Berbee

**RIVM**
Harald Dik, Saskia Lukács and Julika Vermolen

**Wageningen Economic Research**
Ton van Leeuwen

**Reviewing and consistency checks with other reports**
Gerard Velthof (CDM/ Scientific Committee on Nutrient Management Policy)
Oene Oenema (CDM/ Scientific Committee on Nutrient Management Policy)
Hein ten Berge (Wageningen University & Research)
Mart Ros (Wageningen University & Research)

**Water boards and IHW/Water Information House**
To obtain the data for 2019 in good time, the various water managers and other monitoring network managers were asked to provide the data earlier than usual. For the surface water bodies, this meant that the data had to be provided about five months earlier than usual; thanks to major efforts by the water boards and the Water Information House (Paul Latour), this was done successfully.

**Translation**
AVB Vertalingen, Amstelveen

The 2020 Nitrate Report with the results of the monitoring of the effects of the EU Nitrates Directive Action Programmes