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

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Synopsis

Agricultural practices and water quality on farms registered for derogation in 2017

Dutch grassland farms that meet certain conditions may use more animal manure than the general limit of 170 kg nitrogen per hectare, as prescribed by the European Nitrates Directive. This partial exemption is referred to as 'derogation'. The National Institute for Public Health and the Environment (RIVM) and Wageningen Economic Research monitor the effects of this derogation on the water quality on 300 farms in the derogation monitoring network. This study shows the results for 2017 and the development from 2006 onwards.

Management
On average, derogation farms have used 245 kilograms of nitrogen from animal manure per hectare in 2017. The permissible amount of nitrogen from animal manure varies from 230 to 250 kilograms per hectare, depending on the soil and region.

In recent years, improvements in management resulted in more efficient use of nitrogen for crop production; the nitrogen surplus on the soil surface balance has dropped by 20 percent since 2006. And lower nitrogen surpluses lead to less nitrate leaching to groundwater.

Groundwater quality
From 2006, leaching of nitrate to the groundwater has decreased or stabilized on derogation farms. Since 2015, the average nitrate concentration in groundwater on derogation farms has been below the EU-standard of 50 milligram per litre, in all regions. Individual farms however, may still exceed the standard. Even so, during the last years more and more farms comply with the standard.

In 2017, highest nitrate concentrations have been found in the Loess Region (38 mg/l) and in Sand-230 (31 mg/l). In these regions there are soils in which nitrate is degraded in a lesser extent, and therefore a larger share can leach to groundwater.

Keywords: derogation, agricultural practice, manure, Nitrates Directive, water quality.

Publiekssamenvatting

Landbouwpraktijk en waterkwaliteit op landbouwbedrijven aangemeld voor derogatie in 2017

In Nederland mogen agrarische bedrijven die aan specifieke randvoorwaarden voldoen, meer dierlijke mest op hun land gebruiken dan in de algemene norm van de Nitraatrichtlijn is voorgeschreven. Deze verruiming wordt derogatie genoemd. Het RIVM en *Wageningen Economic Research* monitoren de gevolgen van deze derogatie voor de waterkwaliteit op driehonderd bedrijven. Dit rapport beschrijft de monitoringsresultaten voor derogatiebedrijven in het jaar 2017 en de trend vanaf 2006. Op basis van deze resultaten concluderen we dat de derogatie geen negatieve effecten heeft op de waterkwaliteit.

Bedrijfsvoering
In 2017 hebben derogatiebedrijven gemiddeld 245 kilogram stikstof uit dierlijke mest per hectare gebruikt. Een derogatiebedrijf mag 230 of 250 kilogram stikstof per hectare uit graasdiermest gebruiken, afhankelijk van de bodemsoort en regio.

Door verbeteringen in de bedrijfsvoering in de afgelopen jaren wordt meer stikstof uit mest gebruikt voor de aanwas, en dus productie, van gewassen: de indicator ‘stikstofbodemoverschot’ is daardoor sinds 2006 met 20 procent gedaald. Een dalend stikstofbodemoverschot houdt in dat stikstof efficiënter wordt gebruikt. Hierdoor kan er minder nitraat met regenwater wegzakken naar diepere lagen in de bodem en in het grondwater terechtkomen.

Grondwaterkwaliteit
Bij derogatiebedrijven is daardoor sinds 2006 minder of evenveel nitraat in het grondwater terechtgekomen. Sinds 2015 ligt de gemiddelde nitraatconcentratie van derogatiebedrijven in alle regio’s onder de EU-norm van 50 milligram per liter. Dit geldt voor gemiddelden per regio. Op bedrijfsniveau wordt de nitraatnorm soms nog wel overschreden, maar gemiddeld genomen voldoen steeds meer derogatiebedrijven de laatste jaren aan deze norm.

De hoogste nitraatconcentraties zijn in 2017 aangetroffen in de Lössregio (38 milligram per liter) en in het zuidelijk en oostelijk deel van de Zandregio (31 milligram per liter). In deze regio’s komen drogere gronden voor, waar nitraat in mindere mate in de bodem wordt afgebroken en daardoor meer kan wegzakken naar het grondwater.

De monitoring wordt uitgevoerd in opdracht van het Ministerie van Landbouw, Natuur en Voedselveiligheid (LNV).

Kernwoorden: derogatie, landbouwpraktijk, mest, Nitraatrichtlijn, waterkwaliteit

Foreword

This report provides an overview of agricultural practices and water quality in 2017 on the farms that registered for derogation in the derogation monitoring network. The agricultural practice data include data on fertiliser usage and actual nutrient surpluses. They also include the provisional data for the water quality in 2018.

This report was commissioned by the Dutch Ministry of Agriculture, Nature & Food Quality and was prepared by the National Institute for Public Health and the Environment (RIVM) in collaboration with *Wageningen Economic Research. Wageningen Economic Research* is responsible for the information about agricultural practices, while RIVM is responsible for the water quality data. RIVM also served as the official secretary for this project.

The derogation monitoring network was created in order to meet the conditions imposed by the European Commission when it granted a derogation to the Netherlands, permitting grassland farms to apply more nitrogen in the form of grazing livestock manure than the generally applicable standard of 170 kg of nitrogen per hectare. The purpose of the derogation monitoring network is to monitor the effects of this derogation on agricultural practices and water quality. The monitoring network covers 300 farms. The farms in the derogation monitoring network were either already participating in the Minerals Policy Monitoring Programme (Landelijk Meetnet effecten Mestbeleid: LMM), or were recruited and sampled during sampling campaigns.

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8 July 2019

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Summary

Introduction

The EU Nitrates Directive obligates Member States to limit the use of nitrogen in livestock manure to a maximum of 170 kg per hectare per year in nitrate-sensitive areas. The Netherlands has designated the entire country as being nitrate-sensitive but has received permission from the European Commission for certain farms to apply larger amounts of livestock manure, referred to as derogation. The derogation, as applicable over the period from 2014 up to and including 2017, has been granted to farms cultivating at least 80% of their total area as grassland. Farms registered for derogation in the provinces of Overijssel, Gelderland, Utrecht, North Brabant and Limburg are permitted to apply up to 230 kg of nitrogen per hectare in the form of grazing livestock manure on sandy and loessial soils. Farms registered for derogation on other soils and on sandy soils in other provinces may apply up to 250 kg of nitrogen per hectare in the form of grazing livestock manure. One of the other conditions attached to this derogation include an obligation for the Dutch government to set up a monitoring network comprising 300 farms that have registered for derogation (‘derogation farms’), and to submit annual reports on the results to the European Commission. This report describes the organisation of the monitoring network and the monitoring results for 2017.

Derogation monitoring network

The derogation monitoring network was set up by expanding the Minerals Policy Monitoring Programme (of RIVM and *Wageningen Economic Research*). A stratified random sampling method was used to select the 300 farms, distributed as evenly as possible according to soil type region (Sand Region, Loess Region, Clay Region and Peat Region), farm type (dairy farms and other grassland farms), and economic size. Of these 300 farms from the monitoring network, 293 actually made use of the derogation in 2017. Apart from data on agricultural practices and water quality in 2017, this report also presents data on water quality in 2018, as this information relates to agricultural practices in 2017.

Agricultural practices in 2017 on derogation farms

In 2017, the farms in the derogation monitoring network applied an average of 245 kg of nitrogen from livestock manure per hectare of cultivated land. Factoring in the statutory availability coefficients, the average quantity of plant-available nitrogen from livestock manure amounted to 120 kg of nitrogen per hectare. In addition, an average of 135 kg of nitrogen per hectare was applied in the form of inorganic fertilisers. The total amount of plant-available nitrogen applied was 255 kg per hectare.

The total amount of phosphate applied in the form of livestock manure and other organic fertilisers was 78 kg per hectare. The application of phosphate-containing fertilisers on derogation farms has not been permitted since 2014.

The average nitrogen surplus on the soil surface balance in 2017 was calculated at 155 kg/ha. The Peat Region had the highest nitrogen

surplus, primarily due to the nitrogen mineralisation in the soil, which is included in the surplus for peat soils. The Sand Region and the Loess Region had the lowest nitrogen surpluses. The average phosphate surplus on the soil surface balance was negative, namely -1 kg/ha.

Agricultural practices during the 2006-2017 period
In 2017, the developments in the dairy farming sector were primarily influenced by the need to reduce the total number of dairy cattle to ensure that the maximum phosphate level would not be exceeded and the derogation could remain in place.

The number of hectares of cultivated land per derogation farm increased over the 2006-2017 period. The quantity of milk produced per farm increased over the same period, namely by 5% per year, primarily due to an increase in the number of dairy cows. However, the increased milk production in 2017 was due to an increase in the amount of milk produced per dairy cow.

Over the same period, the phosphate production by intensive livestock (including veal calves and pigs) decreased due to a decrease in the number of intensive livestock farms. However, due to an increase in the number of milk cows in the dairy farming sector, the average phosphate production remained the same. These trends point to a steady increase in scale as well as intensification of milk production and specialisation in the dairy farming sector.

The average proportion of grassland on derogation farms increased from 83% in 2006 to 87% in 2017. During this period, the proportion of farms with grazing decreased from 89% to 81%.

Since 2006, the average quantity of nitrogen applied in the form of livestock manure has ranged from 231 kg to 245 kg of nitrogen per hectare. The statutory availability coefficient for nitrogen in livestock manure has gradually been increased, resulting in a rise in the calculated quantity of plant-available nitrogen from livestock manure.

Since 2014, the nitrogen application standard per hectare (on average per farm) has increased compared to previous years due to an increase in the proportion of grassland, which is subject to a higher application standard than arable land as well as a decrease in the proportion of farms with grazing. In the course of the derogation period (2006-2017), we have seen more advantage being taken from the margin available for nitrogen application.

The application standard for phosphate decreased by more than 20% between 2006 and 2017. This was paralleled by an almost equally large decrease in the use of phosphate.

Above-average crop yields of grass as well as silage maize were realised over the period from 2014 up to and including 2016. In 2017 the yield of grass returned to its long-term average. The yield of silage maize increased further in 2017. After a rather sharp decrease in the nitrogen soil surplus in 2014, it again increased somewhat in the following years. The nitrogen soil surplus decreased once again in 2017.

In 2016 and 2017, the phosphate soil surplus was -1 kg of phosphate per hectare, which is much lower than the average value over the 2006-2015 period.

Quality of water leaching from the root zone in 2017

In 2017, the nitrate concentrations in the water leaching from the root zone in all regions were, on average, lower than the nitrate standard of 50 mg/l. There is a marked difference between the nitrate concentration in the water leaching from the root zone in the Sand Region with an application standard of 230 kg N/ha (31 mg/l) and in the Sand Region with an application standard of 250 kg N/ha (16 mg/l). This can be explained by the higher proportion of drier soils in the southern provinces (Sand-230) as well as the higher proportion of wetland soils in the northern provinces (Sand-250). In drier soil, nitrate is broken down less via denitrification, which makes such soils more sensitive to nitrate leaching from the root zone. In wetlands, nitrate is actually broken down more quickly. The Loess Region is also characterised by drier soils. The average nitrate concentration there was 38 mg/l.

The lowest average nitrate concentrations in the water leaching from the root zone were measured in the Clay Region (15 mg/l) and the Peat Region (6 mg/l). This is due to the higher rate of nitrate decomposition as a result of denitrification in these regions due to the presence of soils that are wetter and richer in organic content.

Although the average nitrate concentration was below the EU standard of 50 mg/l, this standard was at times exceeded on individual farms. In Sand-230, 17% of the farms sampled had nitrate concentrations in the water leaching from the root zone that were higher than 50 mg/l; in the Loess Region this figure was 21%, and in Sand-250 and the Clay Region it was 5%. In the Peat Region, none of the farms had nitrate concentrations that exceeded the EU standard.

The highest phosphorus (P) concentrations in water leaching from the root zone were measured in the Peat Region (0.38 mg P/l), followed by the Clay Region (0.25 mg P/l) and Sand-250 (0.19 mg P/l). The average phosphorus concentration in Sand-230 was 0.12 mg P/l. These phosphorus concentrations are below the national target values for phosphorus in groundwater. The phosphorus data in the Loess Region for 2017 were rejected due to an error in the analytical equipment.

Water leaching from the root zone from 2007 up to and including 2018

The nitrate concentration in water leaching from the root zone in the Peat Region was stable and low throughout the entire measuring period. The nitrate concentrations in all the other regions decreased over the entire measuring period.
The nitrate concentrations in the water leaching from the root zone in the Peat Region, Clay Region, and Sand-250 were lower than 50 mg/l throughout the entire measuring period. The nitrate concentration in the Loess Region and in Sand-230 have remained below 50 mg/l since 2014.

During the measurement period, phosphorus concentrations in water leaching from the root zone decreased in the Clay Region and Peat Region, and remained stable in the other regions.

Relationship between agricultural practices and water quality
Between 2006 and 2017, the average nitrogen soil surpluses over all the regions showed a decreasing trend. The nitrate concentration decreased in all regions, with the exception of the Peat Region (where the average nitrate concentration is well below 50 mg/l). This meets the expectation that a decrease in soil surpluses results in lower nitrate concentrations. The increasing proportion of grassland and the decrease in grazing intensity could also contribute to the decrease in the nitrate concentration.

Due to the decreasing use of inorganic fertilisers, the phosphate surplus on the soil surface balance displayed a downward trend during the period from 2006 up to and including 2017. The phosphorus concentrations in water leaching from the root zone in the Clay Region and Peat Region also decreased during the measurement period.

1 Introduction

1.1 Background

The EU Nitrates Directive obligates Member States to limit the use of nitrogen in livestock manure to a maximum of 170 kg per hectare per year (EU, 1991) in nitrate-sensitive areas. A Member State can request the European Commission for exemption from this obligation under certain conditions (hereinafter ‘derogation’). In December 2005, the European Commission issued the Netherlands with a derogation decision for the 2006-2009 period (EU, 2005). In February 2010, the derogation decision was extended until the end of December 2013 (EU, 2010). During this period, grassland farms cultivating at least 70% of their total area as grassland were allowed to apply on their total area up to 250 kg of nitrogen from livestock manure per hectare in the form of livestock manure originating from grazing livestock. In May 2014, a derogation decision was issued for the period until the end of December 2017 (EU, 2014). Stricter derogation conditions apply during this period. During this period, grassland farms cultivating at least 70% of their total area as grassland were allowed to apply on their total area up to 250 kg of nitrogen per hectare in the form of livestock manure originating from grazing livestock. Farms on sandy and loessial soils in the provinces of Overijssel, Gelderland, Utrecht, North Brabant and Limburg are permitted to apply up to 230 kg of nitrogen per hectare in the form of livestock manure originating from grazing livestock. As of 15 May 2014, farms participating in the derogation scheme are no longer permitted to import phosphate-containing fertilisers. On 31 May 2018, a new derogation decision with additional conditions was issued for the period until the end of December 2019 (EU, 2018). This report deals with the 2017 monitoring year and is therefore subject to the conditions of the 2014 derogation decision.

1.2 Research question, approach and scope

The present report compiled by RIVM and *Wageningen Economic Research*, together with the Netherlands Enterprise Agency report (2019)[1], fulfils the following obligations under the derogation decision (2014):

Article 8 Monitoring

8.1. Maps showing the percentage of grassland farms, percentage of livestock and percentage of agricultural land covered by individual derogation in each municipality shall be drawn up by the competent authority and shall be updated every year.

This obligation is fulfilled in the additional Netherlands Enterprise Agency report (2019).

[1] The Netherlands Enterprise Agency report also complies with additional conditions set out in the 2018 derogation decision.

8.2. A monitoring network for sampling of soil water, streams and shallow groundwater shall be established and maintained at derogation monitoring sites.

8.3. The monitoring network, corresponding to at least 300 farms benefiting from individual derogations, shall be representative of all soil types (clay, peat, sandy, and sandy loessial soils), fertilisation practices and crop rotations. The composition of the monitoring network shall not be modified during the period of applicability of this Decision.

This obligation is complied with as the derogation monitoring network has been incorporated into the Minerals Policy Monitoring Programme. The design of the derogation monitoring network is described in Chapter 2.

8.4. Surveys and continuous nutrient analyses shall provide data on local land use, crop rotations and agricultural practices on farms benefiting from individual derogations. Those data can be used for model-based calculations of the magnitude of nitrate leaching and phosphorus losses from fields where up to 230 kg or up to 250 kg of nitrogen in the form of manure from grazing livestock is applied per hectare per year.

This obligation is complied with via this monitoring report, in which section 3.1 (situation) and section 4.1 (trends) summarise the results of the 300 farms that participate in the derogation monitoring network. Appendix 5 presents the data of all derogation farms in the Netherlands, and discusses the differences arising from a number of factors, including a difference in approach.

8.5. The monitoring network, including shallow groundwater, soil water, drainage water and streams on farms belonging to the monitoring network, shall provide data on nitrate and phosphorus concentrations in water leaving the root zone and entering the groundwater and surface water system.

This obligation is complied with via this monitoring report, in which section 3.2 (situation) and section 4.2 (trends) provide data on the quality of ditch water and water leaching from the root zone on the 300 farms that participate in the derogation monitoring network.

8.6. More intensive water monitoring shall take place on agricultural catchments in sandy soils.

This obligation is complied with as the geographical distribution of the derogation monitoring network is such that 160 of the 300 targeted farms are located in the Sand Region (see section 2.4).

Article 9 Controls

9.1. The competent national authority shall carry out administrative controls in respect of all farms benefiting from an individual derogation for the assessment of compliance with the maximum amount of 230kg or 250 kg of nitrogen per hectare per year from *grazing livestock manure on farms with at least 80% grassland, compliance with total nitrogen and phosphate application standards, and compliance with conditions on land use. Where the control carried out by the national authorities demonstrate that the conditions stated in Articles 5 and 6 are not fulfilled, the applicant shall be informed thereof. In this instance, the application shall be considered to be refused.*

9.2. *A programme of inspections shall be established on a risk basis and with appropriate frequency, taking account of results of controls in previous years, results of general random controls of compliance with legislation implementing Directive91/676/EEC, and any information that might indicate non-compliance. Administrative inspections with regard to land use, livestock numbers and manure production shall address at least 5% of farms benefiting from an individual derogation under this Decision. On at least 7% of the farms,* field *inspections will be carried out in order to verify compliance with the conditions set out in Article 5 and 6 of this Decision.*

9.3. *The competent authorities shall be granted the necessary powers and means to verify compliance with a derogation granted under this Decision.*

The results of these controls are included in the Netherlands Enterprise Agency derogation report (2019).

Article 10 Reporting

10.1. The competent authorities shall submit to the Commission every year no later than March a report containing the following information:

a. data related to fertilisation on all farms which benefit from an individual derogation, including information on yields and on soil types;
b. trends in livestock numbers for each livestock category in the Netherlands and on derogation farms;
c. trends in national manure production as far as nitrogen and phosphate in manure are concerned;
d. a summary of the results of controls related to excretion coefficients for pig and poultry manure at the national level;
e. maps showing the percentage of farms, percentage of livestock and percentage of agricultural land covered by individual derogation in each municipality, as referred to in Article 8 (1);
f. the results of water quality monitoring, including information on water quality trends for ground and surface water, as well as the impact of derogation on water quality
g. information on nitrate and phosphorus concentrations in water leaving the root zone and entering the groundwater and surface water system as referred to in Article 8 (5) and the results of intensified water quality monitoring in agricultural catchments on sandy soils as referred to in Article 8 (6);
h. the results of surveys on local land use, crop rotations and agricultural practices, and the results of model-based calculations of the magnitude of nitrate and phosphorus losses

on farms benefiting from an individual derogation, as referred to in Article 8, (4);

i. *an evaluation of the implementation of the derogation conditions, on the basis of controls at farm level and information on non-compliant farms, on the basis of the results of the administrative controls and* field *inspections, as referred to in Article 9.*

The present report may be regarded as the report referred to in Article 10 as cited above. Details of controls and instances of non-compliance are presented in the Netherlands Enterprise Agency derogation report (2019). In consultation with the European Commission, these reports are submitted in June, as was the case for previous years.

Section 3.1 (situation) and section 4.1 (trends) summarise the agricultural practice results of the 300 farms that participate in the derogation monitoring network. Appendix 5 presents information on the average use of fertiliser on all derogation farms in the Netherlands, determined according to data from the LMM and Netherlands Enterprise Agency. Differences between both these sources can occur as a result of differences in their underlying goal and the specific population of farms involved. The obligation referred to in Article 10 (1) (d) is fulfilled in the Netherlands Enterprise Agency report (2019). Section 3.1.1 specifies the use of nitrogen in manure and fertilisers by crop and soil type.

10.2. The spatial data contained in the report shall, where applicable, fulfil the provisions of Directive 2007/2/EC. In collecting the necessary data, the Netherlands makes use, where appropriate, of the information generated under the Integrated Administration and Control System established pursuant to Chapter II of Title V of Regulation (EU) no. 1306/2013.

1.3 Previously published reports and contents of this report

This is the thirteenth annual report setting out the results of the derogation monitoring network. This report presents information on the use of fertiliser, crop yields, nutrient surpluses, and water quality.

The first report (Fraters *et al*., 2007b) was limited to a description of the derogation monitoring network, the progress made in 2006, and the design and content of the reports for the years from 2008 up to and including 2010. The derogation monitoring network results have been published in the subsequent reports (Fraters *et al*., 2008; Zwart *et al*., 2009, 2010 and 2011; Buis *et al*., 2012; Hooijboer *et al*., 2013 and 2014, Lukács *et al.*., 2015 and 2016 and Hooijboer *et al*., 2017, Lukács *et al*., 2018). Once results for multiple measurement years became available, the reports devoted more attention to the examination of trends in agricultural practices and water quality.

Chapter 2 describes the design and implementation of the derogation monitoring network. It also provides the agricultural characteristics of the participating farms (see section 2.7). Section 2.8describes the soil characteristics of the farms where water quality samples were taken.

Chapter 3 presents and discusses the measurement results of the monitoring of agricultural practices and water quality for 2017. This chapter also contains the provisional water quality monitoring results for 2018 (see section 3.2.4).

Chapter 4 describes developments related to agricultural practices and water quality. This includes a discussion of trend-based changes since the start of the derogation scheme as well as an analysis of the extent to which the last year differed from previous years. In addition, an assessment is provided of the effects of agricultural practices on water quality.

2 Design of the derogation monitoring network

2.1 General

The design of the derogation monitoring network must satisfy the requirements of the European Commission, as stipulated in the derogation decision of December 2005, the extension of the derogation granted in 2010, and the derogation decisions of May 2014 and 2018 (refer to section 1.2). Previous reports provided extensive information about the composition of the sample and the choices this entailed (Fraters en Boumans, 2005; Fraters *et al*., 2007b, De Goffau *et al.*, 2012).

During negotiations with the European Commission, it was agreed that the design of this monitoring network would tie in with the existing national network for monitoring the effectiveness of minerals policy, i.e. the Minerals Policy Monitoring Programme (LMM). Water quality and agricultural practices at farms selected for this purpose have been monitored under the LMM programme since 1992 (Fraters and Boumans, 2005, De Goffau *et al.*, 2012). Additionally, it was agreed that all LMM participants that satisfy the relevant conditions would be regarded as participants in the derogation monitoring network.

All agricultural practice data relevant to the derogation scheme were registered in the Farm Accountancy Data Network (FADN) (Poppe, 2004). Appendix 2 provides a description of the monitoring of the agricultural characteristics and the calculation methods for fertiliser usage and nutrient surpluses. Water samples on farms were taken in accordance with the standard LMM procedures (Fraters *et al*., 2004, De Goffau *et al.,* 2012). This sampling method is explained in Appendix 3.

The set-up of the derogation monitoring network and the reporting of results are based on the division of the Netherlands into regions as used in the action programmes of the Nitrate Directive (EU, 1991). Four regions are distinguished: the Sand Region, the Loess Region, the Clay Region, and the Peat Region. The acreage of agricultural land in the Sand Region accounts for about 47% of the approx. 1.85 million hectares of agricultural land in the Netherlands (Statistics Netherlands Agricultural Census, data processed by LEI, 2014). The acreage of agricultural land in the Loess Region accounts for approx. 1.5% of all agricultural land in the Netherlands, while the acreage in the Clay Region accounts for approx. 41% and the Peat Region for approx. 10.5%.

The data reported in the Sand Region makes a distinction according to the maximum derogation which may be applied for by farms. Starting in 2014, farms on sandy and loess soils in the provinces of Overijssel, Gelderland, Utrecht, North Brabant and Limburg were allowed to apply up to a maximum of 230 kg of nitrogen per hectare per year in the form of grazing livestock manure. Farms on other soils and on sandy soils in other provinces may apply up to 250 kg of nitrogen per hectare per year in the form of grazing livestock manure. In this report, the Sand Region is further divided into two sub-regions called ‘Sand-230’ and ‘Sand-250’.

The Sand-230 sub-region is defined as the part of the Sand Region located in the provinces mentioned above. The Sand-250 sub-region is defined as the other part of the Sand Region (also see Figure B1.1 in Appendix 1). Farms in the Sand-230 sub-region and the Loess Region are therefore permitted to apply up to a maximum of 230 kg of nitrogen per hectare per year on their sandy and loess soils in the form of grazing livestock manure. If a farm also has one or more fields on peat or clay soil, it can apply up to 250 kg N/ha in the form of grazing livestock manure on these fields.

In addition, farms participating in the derogation monitoring network that also participate in the ‘Koeien en Kansen’ (Cows and Opportunities) project are treated differently. ‘Koeien en Kansen’ (K&K) is a research project in which the effects of the future manure policy are investigated. A total of 15 K&K farms participate in the derogation monitoring network. K&K farms that are located in the Loess Region or in Sand-230 may also apply 250 kg/ha of grazing livestock manure on plots with sand and loess soils. A total of seven K&K farms are located in the 230 kg/ha area but have been given an additional increase in the grazing livestock manure standard to a maximum of 250 kg N/ha: six farms in Sand-230 and one farm in the Loess Region.

Five K&K farms participated in the BES (Farm-Specific Nitrogen Standard) project of *Wageningen University & Research*. In this research project the EU standard for the maximum release of nitrogen from livestock manure does not apply to the participating farms. However, they do have to meet the application standards for nitrogen and phosphate. Due to the different regulations that apply to these farms, their results in the area of minerals management and water quality are not included in this report. In the report, the other K&K farms were assigned to the region in which they are actually located.

The LMM calculations are aimed at calculating the fertilisation rates as accurately as possible, using as much farm-specific information as possible. The fertiliser usage on derogation farms calculated by the LMM and RVO.nl may differ from each other; also see appendix 5. It is explicitly not the goal of the LMM to monitor compliance with statutory fertilisation requirements. Differences may exist, for example, with regard to the area of cultivated land, (farm-specific) excretion, the influence of pilot farms (K&K) and other points of departure.

2.2 Statistical method used to determine deviations and trends

Determination of deviations in the measurement year under consideration

The comparison aims to establish if there is a significant difference between the value measured in the measurement year and the average for the preceding years. The significance was determined using the *Restricted Maximum Likelihood* procedure (REML method). The REML method is suitable for unbalanced data sets and therefore takes account of farms which ‘drop out’ and are replaced. The water quality data and agricultural practice data were processed using the *Linear Mixed Effect Procedure* within R, version 3.5.0.

Calculations were made using unweighted annual farm averages. In other words, the data were not corrected for farm acreage, intensity, etc. All available annual farm averages were divided into two groups, with Group 1 comprising all the figures for the measurement year concerned, and Group 2 comprising all averages for the preceding years. The difference between Group 1 and Group 2 was subsequently estimated as a so-called '*fixed effect*', taking into account the fact that some data were not derived from the same farms, the '*random effect'*. A discussion of *fixed* and *random* effects may be found in standard statistical manuals on variance analysis, e.g. Kleinbaum *et al*. (1997) and Payne (2000). How estimates are made with such models is explained by Welham *et al*. (2004).

If the results for the most recent measurement year deviate significantly from the average of the preceding years (p < 0.05), the direction of the deviation compared to previous years is indicated by a plus sign (+) or a minus sign (-). If there is no significant difference (p > 0.05), this is indicated by the 'approximately equal' sign (≈). These symbols may be found in the 'Difference' column in the overview tables (e.g. see Appendix 4, Table B4.1B). The main text of this report only mentions differences if they are significant.

Determination of trends
The data were also analysed to identify any trends occurring during the measurement period. The REML method was used for this purpose as well, with the annual average concentrations per farm being grouped together. In the descriptive text, only significant trend changes (p <0.05) will be discussed.

2.3 Water quality and agricultural practices

The water quality in terms of nitrate concentration measured in any year partly reflects agricultural practices in the year preceding the water quality monitoring and in previous years. The extent to which agricultural practices in previous years affect the water quality measurements depends on various factors, including the size and fluctuation of the precipitation surplus during that year. The local hydrological circumstances also have an effect. In the High Netherlands, it is assumed that agricultural practices affect water quality at least one year later. In the Low Netherlands, the impact of agricultural practices on water quality is quicker to materialise. The 'Low Netherlands' comprises the Clay Region, the Peat Region and those parts of the Sand Region that are drained by means of ditches, possibly in combination with drainage pipes or surface drainage. The 'High Netherlands' comprises the other parts of the Sand Region, and the Loess Region. This difference in hydrological conditions (rate of leaching) also explains the different sampling methods and sampling periods employed in the Low Netherlands and High Netherlands (see Appendix 3).

In the Low Netherlands, water quality is determined in the winter season (November until April) following the year (the growing season) in which the agricultural practices were determined. In the Sand Region, groundwater is sampled in the summer following the year in which agricultural practices were determined. In the Loess Region, soil moisture samples are taken in the autumn following the year in which agricultural practices were determined (see Appendix 3).

This means that water quality samples for measurement year 2017 can be related to agricultural practices in 2016 (see Table 2.1). Water quality samples for measurement year 2017 were taken during the winter of 2016/2017 in the Low Netherlands, and during the summer and autumn of 2017 in the High Netherlands.

The present report also includes water quality sampling results for measurement year 2018, which can be related to agricultural practices in 2017 (see Table 2.1). These water samples were taken in the winter of 2017-2018 in the Low Netherlands, and in the summer of 2018 in the High Netherlands. The results for the Loess Region from sampling carried out in the autumn of 2018 are not yet available, and the other data are regarded as provisional because it is unknown at this time which farms will qualify for participation in the derogation scheme in 2018. The final figures will be reported in 2020, at which time the 2018 data for the Loess Region will also be available and finalised.

Table 2.1: Overview of data collection periods and presented results of monitoring of agricultural practices and water quality

Reporting	Agricultural practices	Water quality[2]		
		Clay and Peat	Sand	Loess
Lukács *et al*., 2018	2016	2015/2016 final, 2016/2017 provisional	2016 final, 2017 provisional	2016/2017 final, 2017/2018 not available
Lukács *et al*., 2019[1]	2017	2016/2017 final, 2017/2018 provisional	2017 final, 2018 provisional	2017/2018 final, 2018/2019 not available

[1] Present report.
[2] The provisional figures can be related to the agricultural practice data presented in the same report. The definitive figures can be related to the agricultural practice data presented in the previous report.

The nitrate concentrations are compared to the EU standard of 50 mg/l. This standard applies to groundwater and not to soil moisture, i.e. to water present in soil that is not saturated. 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 in farms. Strictly speaking the EU standard does not apply to soil moisture, but the Netherlands nevertheless reports the concentration in the soil moisture for the Loess Region.

2.4 Nitrate correction for weather conditions and sampling

Nitrate concentrations in water leaching from the root zone are not only affected by agricultural practices, but also by environmental factors.

Particularly precipitation and temperature have an effect on crop yields, and consequently also on nitrogen output, soil surpluses and nitrogen leaching. Even if a long-term balance is achieved between the annual input and decomposition of organic matter, mineralisation and immobilisation will not be perfectly balanced in each year. For instance, nitrate leaching may be significantly affected by the ploughing-up of grassland and grass-maize rotation (Velthof and Hummelink, 2012). As a result, there will be variations in soil surpluses and nitrogen leaching. The final nitrogen concentration is also affected by the precipitation surplus and changes in groundwater levels (Boumans *et al.*, 2005; Fraters *et al.*, 2005; Zwart *et al.*, 2009; Zwart *et al.*, 2010; Zwart *et al.*, 2011). Changes in the composition of the farm sample can also have an effect, since soil types and groundwater levels vary between farms (Boumans *et al.*, 1989).

A statistical method has been developed for the Sand Region in order to correct the measured nitrate concentrations for the effects of weather conditions, groundwater levels, and changes in the composition of the sample (Boumans and Fraters, 2011). This method uses relative evaporation as a yardstick for the impact of annual fluctuations in the precipitation surplus. Nitrate concentrations will rise as evaporation increases and groundwater levels decrease, provided other factors do not change. For a further explanation of the method, we refer the reader to Hooijboer *et al.* (2013; see Appendix 6). The method was further improved in 2016 by making use of detailed precipitation and evaporation data, by factoring in the sampling month, and by first indexing measured nitrate leaching instead of measured nitrate concentrations (Boumans and Fraters, 2017). For this purpose, the measured nitrate concentrations are divided by the precipitation surplus in which the nitrate has dissolved. The precipitation surplus is calculated using the SWAP model (Van Dam *et al.*, 2008). The indexed nitrate concentration is subsequently derived from the indexed nitrate leaching data. This method does not take all the processes into consideration that have an influence on the nitrate concentration, and is based only on correlations.

2.5 Number of farms in 2017

2.5.1 Number of farms where agricultural practices were determined

The derogation monitoring network is a fixed monitoring network. Nevertheless, a number of farms ‘drop out’ every year because they are no longer participating in the LMM programme or do not apply for or are no longer registered for inclusion in the derogation monitoring network. It is also possible that agricultural practices could not be reported due to incomplete data on nutrient flows. Incomplete nutrient flow data may be caused by the presence on the farm of animals owned by third parties, so that data on the input and output of feedstuffs, animals and manure is by definition incomplete. In addition, other improbable data may have been identified in the registration of inputs and/or outputs. In these cases, however, water quality samples have been taken.

Agricultural practices were successfully registered at 297 of the 300 planned farms (see Table 2.2). Of these 297 farms, 293 actually participated in the derogation scheme. Fifteen farms that participated in the derogation monitoring network in 2016 have since dropped out. These farms have therefore been replaced.

Table 2.2: Planned and actual number of analysed dairy and other grassland farms per region in 2017 (agricultural practices)

Farm type	Planned / Actual	Sand 250	Sand 230	Loess	Clay	Peat	Total
Dairy farms	Planned	140		18	54	54	266
	Actual:						
	- Of which were processed	45	93	18	54	53	263
	- Of which participated in the derogation scheme	45	91	18	54	52	260
	- Of which submitted complete nutrient flow data	45	89	18	51	51	254
Other grassland farms	Planned	20		2	6	6	34
	Actual:						
	- Of which were processed	2	18	2	6	6	34
	- Of which participated in the derogation scheme	2	17	2	6	6	33
	- Of which submitted complete nutrient flow data	2	9	2	4	4	21
Total	Planned	160		20	60	60	300
	Actual:						
	- Of which were processed	47	111	20	60	59	297
	- Of which participated in the derogation scheme	47	108	20	60	58	293
	- Of which submitted complete nutrient flow data	47	98	20	55	55	275

The various sections of this report describe agricultural practices based on the following numbers of farms:

- The description of general farm characteristics (see section 2.7) concerns all farms that could be fully processed in FADN in 2017 and that participated in the derogation scheme (293 farms).
- The description of agricultural practices in 2017 (see section 3.1) concerns all farms for which a full picture of nutrient flows could be obtained from FADN data and which did not participate in the BES pilot (275 farms).
- The comparison of agricultural practices in the 2006-2017 period (see section 4.1) concerns all farms that participated in the derogation monitoring network in the respective years. This number varies from year to year (see Appendix 4, Table B4.2A).

2.5.2 *Number of farms where water quality was sampled*

In 2017, the water quality was sampled on 299 farms (see Table 2.3). Of these 301 farms, 283 participated in the derogation monitoring network in 2017. The difference in 16 farms is caused by changes in the derogation monitoring network. As a result, samples were taken at a number of farms that later dropped out for measurement year 2017. The farms that dropped out were, however, used to determine trends in water quality. Four farms out of the 278 farms in the derogation monitoring network that were sampled did not make use of the derogation and five farms participated in the BES pilot. The water quality sampling results of the remaining 274 sampled farms are presented in this report.

Table 2.3: Planned and actual number of analysed dairy and other grassland farms per region in 2017 (water quality)

Farm type	Planned / Actual	Sand 250	Sand 230	Loess	Clay	Peat	Total
Dairy farms	Planned	140		17	52	52	261
	Actual:						
	- Sampled	44	96	17	54	54	265
	- Derogation monitoring network 2017[1]	42	92	17	52	52	255
	- participated in derogation scheme[2]	42	88	17	49	50	246
Other grassland farms	Planned	20		3	8	8	39
	Actual:						
	- sampled	1	19	2	6	6	34
	- Derogation monitoring network 2017[1]	1	14	2	6	5	28
	- participated in derogation scheme[2]	1	14	2	6	5	28
Total	Planned	160		20	60	60	300
	Actual:						
	- sampled	45	115	19	60	60	299
	- Derogation monitoring network 2017[1]	43	106	19	58	57	283
	- participated in derogation scheme[2]	43	102	19	55	55	274

[1] Samples are often taken at farms before the composition of the derogation monitoring network is known (and certain farms have dropped out). However, the farms that have dropped out are used to determine trends.
[2] Excluding farms that participated in the BES pilot

This report details the water quality on the following numbers of farms:

- The description of the water quality results for measurement year 2017 (see section 3.2) concerns all farms where water quality samples were taken in 2017 and that were granted derogation in 2017 with the exception of the farms that participated in the BES-pilot (274 farms).
- The description of the water quality results for measurement year 2018 (see section 3.2.4) concerns all farms participating in the derogation monitoring network in 2017 (except farms in the Loess Region) where water quality samples were taken in measurement year 2018 with the exception of the farms that participated in the BES-pilot in 2017 (273 farms).
- The analysis of water quality levels during the period from 2007 up to and including 2018 (see section 4.2) concerns all farms that participated in the derogation monitoring network in the agricultural practice year preceding the relevant measurement year, and that were granted derogation in that previous year. This number varies from year to year (see Table 2.4).

Table 2.4: Number of farms per year that was used for determining trends in water quality; these farms were granted derogation in the year preceding the relevant measurement year

Year	Number of farms leaching	Number of farms ditch water
2007	271	141
2008	272	140
2009	274	144
2010	273	144
2011	274	146
2012	277	144
2013	296	155
2014	288	145
2015	288	146
2016	295	147
2017	296	150
2018	267	147

Depending on the soil type region, samples were taken of water leaching from the root zone (groundwater, drain water or soil moisture) and/or ditch water (see Table 2.5).

Table 2.5: Number of farms that were sampled and reported on per region for 2017 and 2018, and the sampling frequency of the leaching water and ditch water rounds; the planned sampling frequency is shown between parentheses

Year		Sand		Loess	Clay	Peat	Total
		250	230				
2017	Number of farms	43	102	19	55	55	274
	Number of farms – Leaching water	43	102	19	55	55	274
	Number of rounds - Leaching water	1.0 (1)	1.0 (1)	1.0 (1)	3.3 (2-4)[1]	1.0 (1)	
	Number of farms – Ditch water	12	22	-	54	54	
	Number of rounds - Ditch water	4.0 (4)	4.1 (4)	-	4.1 (4)	4.1 (4)	
2018	Number of farms	47	111	-[2]	57	58	273
	Number of farms – Leaching water	47	111	-	57	56	271
	Number of rounds - Leaching water	1.0 (1)	1.0 (1)	-	3.3 (2-4)	1.0 (1)	
	Number of farms – Ditch water	12	22	-	56	58	
	Number of rounds - Ditch water	3.9 (4)	4.0 (4)	-	3.9 (4)	3.8 (4)	

[1] In the Clay Region, groundwater is sampled up to two times, and drain water is sampled up to four times, depending on the type of farm. Therefore, the average total number of samples will always be between two and four, depending on the proportion of farms with groundwater sampling versus farms with drain water sampling.
[2] The autumn 2018 data for the derogation farms in the Loess Region were not yet available when this report was being prepared.

2.6 Representativeness of the sample of farms

293 farms participating in the derogation monitoring network were known to have been registered for derogation in 2017. These farms have a combined total acreage of 17,786 hectares (accounting for 2.2% of all agricultural land on grassland farms in the Netherlands; see Table 2.6). The sample represents 89% of the farms and 97% of the acreage of all farms that registered for derogation in 2017 and that satisfied the LMM selection criteria (Appendix 1). Farms not included in the sample population which did register for derogation are mainly other grassland farms with a size of less than 25,000 Standard Output (SO) units.

Section 2.1 explains that the Sand Region has been subdivided into the ‘Sand-250’ and ‘Sand-230’ sub-regions starting in 2014. Although this distinction has not been taken into account in the selection of farms, Table 2.6 shows that the representativeness of the sample in both sand regions is not jeopardised. In 2017, in both regions, 2.8% and 1.9%, respectively, of the area of cultivated land covered by the derogation was included in the sample. That percentage amounts to 2.2% for the entire derogation monitoring network.

Furthermore, in all regions the proportion of sampled to total acreage is greater on dairy farms than on other grassland farms. This is because, during the selection and recruitment process, the required number of farms to be sampled for each farm type is derived from the share in the total acreage of cultivated land. On average, the other grassland farms selected are slightly smaller than the dairy farms in terms of their acreage of cultivated land.

The Loess Region is relatively small, and it contains relatively few farms compared to the larger regions. Because the study requires a minimum number of observations per region, a relatively large number of farms from the Loess Region (23%) has been included in the derogation monitoring network.

Table 2.6: Area of cultivated land (in hectares) included in the derogation monitoring network compared to the total area of cultivated land on derogation farms in 2017 in the sample population, according to the 2017 Agricultural Census

Region	Farm type	Sample population[1]	Derogation monitoring network	
		Acreage (hectares)	Acreage (hectares)	Percentage of acreage of total sample population
Sand 250	Dairy farms	114,225	3,462	3.0%
	Other grassland farms	8,334	85	1.0%
	Total	122,559	3,547	2.8%
Sand 230	Dairy farms	228,547	4,742	2.0%
	Other grassland farms	31,100	420	1.3%
	Total	259,648	5,163	1.9%
Loess	Dairy farms	4,052	986	25.3%
	Other grassland farms	375	32	5.5%
	Total	4,427	1,017	22.7%
Clay	Dairy farms	255,818	3,726	1.5%
	Other grassland farms	22,136	176	0.8%
	Total	277,955	3,901	1.4%
Peat	Dairy farms	129,070	3,952	2.8%
	Other grassland farms	12,220	207	1.5%
	Total	141,290	4,158	2.7%
All	Dairy farms	731,713	16,867	2.3%
	Other grassland farms	74,166	920	1.2%
	Total	805,878	17,786	2.2%

[1] Estimate based on the 2017 Agricultural Census performed by Statistics Netherlands, (data processed by Wageningen Economic Research). Refer to Appendix 1 for further information on how the sample population was defined.

2.7 Description of farms in the sample

The 293 farms which registered for derogation had an average of 61 hectares of cultivated land, of which 87% consisted of grassland. The average livestock density was 2.4 Phosphate Livestock Units (LSUs) per hectare (see Table 2.7). Farm data derived from the 2017 Agricultural Census have been included for purposes of comparison, in so far as these farms are in the sample population (see Appendix 1).

A comparison of the structural characteristics of the population of farms in the derogation monitoring network with the Agricultural Census data (see Table 2.8) shows that the farms in the derogation monitoring network use 25% more cultivated land on average than the overall population of farms. As the average livestock density in Livestock Units per hectare on the farms in the derogation monitoring network is also almost 5% higher, the number of cattle on these farms is on average approximately 30% higher than for the overall population of farms.

An analysis was carried out in 2019 to determine whether it would be possible by giving a weighting to the stratification variables to ensure that the derogation monitoring network is more in sync with the overall agricultural census data.

Table 2.7: Overview of a number of general farm characteristics in 2017 of farms participating in the derogation monitoring network (DMN), compared to average values for the Agricultural Census (AC) sample population

Farm characteristics[1]	**Population**	**Sand 250**	**Sand 230**	**Loess**	**Clay**	**Peat**	**Total**
Number of farms in DMN	DMN	47	108	20	60	58	293
Grassland area (hectares)	DMN	63	39	42	58	65	52
	AC	51	33	35	50	46	43
Area used to cultivate silage maize (hectares)	DMN	11.4	8.7	7.6	6.8	6.8	8.3
	AC	7.5	6.0	6.0	4.5	3.5	5.3
Other arable land (hectares)	DMN	1.4	0.6	1.2	0.7	0.3	0.7
	AC	0.4	0.4	1.2	0.8	0.2	0.5
Total area of cultivated land (hectares)	DMN	76	48	51	65	72	61
	AC	59	40	43	55	50	48
Percentage of grassland	DMN	84	83	85	89	93	87
	AC	88	85	84	92	94	89
Natural habitats (hectares)	DMN	2.4	0.3	0.6	3.2	2.3	1.7
	AC	2.4	1.1	2.6	2.2	2.5	1.8
Grazing livestock density (Phosphate LSUs/ per hectare) [2]	DMN	2.1	2.7	2.4	2.4	2.3	2.4
	AC	2.1	2.6	2.5	2.3	2.1	2.3
Percentage of intensive livestock farms	DMN	4	10	0	2	3	5
	AC	1	8	0	2	2	4
Grazing livestock density (Phosphate LSUs/ha)[2]							
Dairy cattle (including young livestock) (Phosphate LSUs/ per hectare)[2]	DMN	2.0	2.5	2.3	2.3	2.1	2.3
Other grazing livestock (Phosphate LSUs/ per hectare)[2]	DMN	0.1	0.2	0.1	0.1	0.2	0.2
Intensive livestock (total) (Phosphate LSUs per hectare)[2]	DMN	0.2	1.2	0.0	0.1	0.0	0.5
All animals (Phosphate LSUs/ per hectare)[2]	DMN	2.4	3.9	2.4	2.4	2.3	2.9

Source: Statistics Netherlands Agricultural Census 2017, data processed by Wageningen Economic Research and FADN.

[1] Surface areas are expressed in hectares of cultivated land; natural habitats have not been included.

[2] Phosphate Livestock Unit (LSU) is a standard used to compare numbers of animals based on their standard phosphate production (Ministry of Agriculture, Nature & Food Quality, 2000). The standard phosphate production of one dairy cow is equivalent to one Phosphate Livestock Unit.

The weighted average of the national sample for the Dutch part of the *Farm Accountancy Data Network* of the European Commission (FADN) has been used to determine the extent to which a number of the characteristics of dairy farms participating in the derogation monitoring network deviate from those of other dairy farms, as the Agricultural Census does not provide appropriate data for such a comparison. The comparison (see Table 2.8) shows that in all regions, the dairy farms participating in the derogation monitoring network produce more milk per farm than the national average. It is not clear whether this is actually the case, as the average values for the farms participating in the derogation monitoring network are not weighted in relation to the stratification variables, as opposed to the averages for the FADN. A similar comparison could not be carried out for the Loess Region due to an insufficient number of FADN-registered farms.

The monitoring results are generally calculated per unit of surface area. It is therefore likely that a farm's size has little or no influence on the results. The average milk production per hectare on dairy farms participating in the derogation monitoring network differs little from the national FADN average. The largest differences are found in the grazing characteristics. Particularly in the sand regions, the farms in the derogation monitoring network appear to make more use of grazing than in the national sample.

Table 2.8: Average milk production and grazing periods on dairy farms participating in the derogation monitoring network (DMN) in 2017, compared to the weighted average for dairy farms in the national FADN sample

Farm characteristic	Population	Sand 250	Sand 230	Loess	Clay	Peat	Total
Number of farms in DMN	DMN	45	91	18	54	51	259
kg FPCM[1]/farm (x1,000 kg)	DMN	1,234	1,090	987	1,237	1,297	1,179
	FADN	1,101	929		1,085	762	950
kg FPCM[1]per hectare of fodder crop	DMN	16,800	20,900	18,300	18,300	16,900	18,700
	FADN	16,300	20,800		16,800	17,400	18,000
FPCM production in kg[1] per dairy cow	DMN	9,300	9,400	9,000	9,100	8,900	9,200
	FADN	9,500	9,600		9,100	9,000	9,300
Percentage of farms with grazing in May-October period	DMN	87	76	89	83	80	81
	FADN	77	70		81	77	78
Percentage of farms with grazing in May-June period	DMN	87	76	83	81	80	80
	FADN	77	70		80	77	78
Percentage of farms with grazing in July-August period	DMN	87	76	89	83	80	81
	FADN	77	70		81	77	78
Percentage of farms with grazing in September-October period	DMN	84	73	89	70	76	76
	FADN	70	66		75	74	74

[1] FPCM = Fat and Protein Corrected Milk, a standard used to compare milk with different fat and protein contents (1 kg of FPCM is defined as 1 kg of milk with 4.00% fat content and 3.32% protein content).

2.8 Characteristics of farms where water quality samples were taken

The sampled farms are distributed across the four soil type regions (see Table 2.9). The soil type regions are further divided into districts (see Appendix B1.6). Table 2.9 makes a distinction between dairy farms and other grassland farms.

Table 2.9: Distribution of the 283 grassland farms where water quality samples were taken in 2017 and that were selected for the derogation monitoring network in that year, over the different soil type regions and the districts for policy-making purposes

Soil type regions and districts for policy-making purposes	Dairy farms	Other grassland farms	Total
Sand-250	**42**	**1**	**43**
• Sand Region – North	42	1	43
• Sand Region – West	-	-	-
Sand-230	**92**	**14**	**106**
• Sand Region – Central	65	10	75
• Sand Region – South	27	4	31
Clay Region	**52**	**6**	**58**
• Marine Clay – North	23	3	26
• Marine Clay – Central	8	-	8
• Marine Clay – South-West	4	-	4
• River Clay	17	3	30
Peat Region	**52**	**5**	**57**
• Peatland Pastures – West	26	3	29
• Peatland Pastures – North	26	2	28
Loess Region	**17**	**2**	**19**

Within a particular region, other soil types occur in addition to the main soil type for which the region is named (see Tables 2.10 and 2.11).

The Loess Region mainly consists of soils with good drainage, whereas the Peat Region mainly consists of soils with poor drainage. The Sand Region consists mostly of soils with good drainage, but the derogation farms are located on relatively less well-drained soils in the Sand Region. Traditionally, the best soils (with favourable drainage conditions and nutrient status) were used for arable farming, while poorer (e.g. wetter) soils were used for dairy farming. In addition, the driest soils in the Sand Region are generally not used for agriculture. Wetter sandy soils are therefore over-represented in the derogation monitoring network.

On average, the farms in Sand-230 have a higher percentage of sandy soil (89%) than the farms in Sand-250 (79%). The farms in Sand-230 are on average also located more on clay soil. The farms in Sand-250 are located somewhat more on peat soil and wetland soil. The farms in Sand-230 have a higher percentage of well-drained soils as well as poorly drained soils in comparison to farms in Sand-250. Compared to the farms in Sand-230, the farms in Sand-250 are found more frequently on moderately drained soils.

The differences with respect to soil type and drainage class between 2017 and the provisional figures for 2018 are minimal (see Table 2.10 and Table 2.11). The figures for 2018 are provisional, as it was not yet known which farms actually made use of the derogation when this report was released.

Table 2.10: Soil type and drainage class (%) per region on the derogation farms sampled in 2017

Region	Soil type				Drainage class[1]		
	Sand	**Loess**	**Clay**	**Peat**	**Poor**	**Moderate**	**Good**
Sand-250	79	0	1	20	36	61	3
Sand-230	89	0	7	4	42	45	13
Loess Region	2	75	23	0	1	3	96
Clay Region	5	0	91	4	51	46	3
Peat Region	17	0	19	64	95	5	0

[1] The drainage class is linked to the water table class (‘Grondwatertrap’, Gt). The ‘Poor natural drainage’ class comprises water table classes Gt I through Gt IV; the ‘Moderate drainage’ class comprises water table classes Gt V, V* and VI, and the ‘Good drainage’ class comprises water table classes Gt VII and Gt VIII.

Table 2.11: Soil type and drainage class (%) per region on farms from the derogation monitoring network sampled in 2018

Region	Soil type				Drainage class[1]		
	Sand	**Loess**	**Clay**	**Peat**	**Poor**	**Moderate**	**Good**
Sand-250	80	0	1	19	36	61	3
Sand-230	89	0	8	3	42	45	13
Loess Region	*	*	*	*	*	*	*
Clay Region	5	0	92	3	53	44	3
Peat Region	15	0	20	65	95	5	0

[1] The drainage class is linked to the water table class (‘Grondwatertrap’, Gt). The ‘Poor natural drainage’ class comprises water table classes Gt I through Gt IV; the ‘Moderate drainage’ class comprises water table classes Gt V, V* and VI, and the ‘Good drainage’ class comprises water table classes Gt VII and Gt VIII.
* Results from the Loess Region were not yet available at the time the present report was being prepared.

3 Results

3.1 Agricultural characteristics

3.1.1 Nitrogen use in livestock manure

In 2017, the average use of nitrogen in livestock manure on derogation farms amounted to 246 kg/ha (including nitrogen in the manure excreted during grazing: see Table 3.1). The differences between the regions are relatively small. The Loess Region had the lowest average amount of nitrogen from livestock manure being used: 239 kg N/ha. In 2017, the average amount of nitrogen used was highest in the Clay Region: 253 kg N/ha. In all regions, less nitrogen from livestock manure was applied on arable land (mainly land used for cultivation of silage maize) than on grassland. The farms in the derogation monitoring network both put in and put out livestock manure. As average manure production exceeded the permitted use in terms of nitrogen or phosphate, the average manure output exceeded the input (including stock changes). This was true of all regions (see Table 3.1).

Table 3.1: Average nitrogen use in livestock manure in the different regions (in kg of nitrogen per hectare) in 2017 on farms participating in the derogation monitoring network

Description	**Sand**		**Loess**	**Clay**	**Peat**	**Total**
	250	**230**				
Number of farms	47	98	20	55	55	275
Produced on farm[1]	271	352	290	288	282	309
+ Inputs	10	7	2	6	7	7
+ stock changes[2]	-1	-10	-5	-3	-1	-5
– Outputs	39	106	48	41	38	64
Total amount used on farm	242	242	239	250	250	245
Use on arable land[3.4]	177	179	176	171	197	180
Use on grassland[3.5]	256	253	251	261	258	256

[1] Calculated on the basis of standard quantities (N=110) with the exception of dairy farms that stated they were using the guidance document on farm-specific excretion by dairy cattle (N=165) (see Appendix 2).
[2] A negative change in stocks is a stock increase.
[3] The average use data for grassland and arable land is based on 265 farms and 202 farms, respectively, instead of on 275 farms. This is because on 10 farms the allocation of fertilisers to arable land did not fall within the confidence intervals, and because 63 farms had no arable land.
[4] The figures concerning use on arable land are reported by the farmer himself.
[5] Grassland usage levels are calculated by deducting the quantity applied on arable land from the total quantity applied.

The use of livestock manure was slightly higher in 2017 than in previous years (see Appendix 4, Table B4.2) and, in Sand-230 and in the Loess Region, it was on average slightly higher than permitted by the application standard for livestock manure. This seems to be due to the participation of the K&K farms in the derogation monitoring network. In addition, farms in Sand-230 and the Loess Region are permitted to use 250 kg N/ha on their peat and clay soils, which causes the average use to exceed 230 kg N/ha. It should be noted that the LMM is definitely not suitable for monitoring compliance with the statutory fertilisation requirements; also see section 2.1.

The average quantity of nitrogen in livestock manure produced in the Sand-230 sub-region exceeded the average quantity in the Sand-250 sub-region by 81 kg of nitrogen per hectare. As a result, the output of nitrogen also increased. The amount of nitrogen used on arable land and grassland was about the same in both regions. Roughly 1 out of every 6 derogation farms did not put in or put out any livestock manure (see Table 3.2). 13% of the farms put in livestock manure but did not put out any. These farmers probably put in livestock manure because this offered economic benefits compared to using inorganic fertilisers. This may also apply to the farmers who both put in and put out livestock manure (11%). The percentage of farms in the derogation monitoring network that only put out manure was 62%.

Table 3.2: Average percentage of farms participating in the derogation monitoring network with livestock manure inputs and/or outputs in 2017

Description	**Sand**		**Loess**	**Clay**	**Peat**	**Total**
	250	**230**				
No inputs or outputs	17	6	20	20	18	14
Only outputs	38	77	75	60	53	62
Only inputs	26	8	5	13	13	13
Inputs and outputs	19	9	0	7	16	11

3.1.2 *Nitrogen and phosphate use compared to nitrogen and phosphate application standards*

On average, the calculated total use of plant-available nitrogen on farms participating in the derogation monitoring network was lower than the nitrogen application standard in all regions in 2017. In Sand-250, Sand-230, and the Loess Region, the average use of nitrogen-containing fertilisers was closer to the nitrogen application standard than in the Clay Region and the Peat Region (see Table 3.3).

Table 3.3: Average use of nitrogen in fertilisers (in kg of plant-available N/ha)[1] on farms participating in the derogation monitoring network in 2017

Description	**Item**	**Sand 250**	**Sand 230**	**Loess**	**Clay**	**Peat**	**Total**
Number of farms		47	98	20	55	55	275
Average statutory availability coefficient for livestock manure (%)[1]		48	50	47	49	49	49
fertiliser usage	Livestock manure	117	121	112	122	123	120
	Other organic fertilisers	1	0	0	1	0	0
	Inorganic fertilisers	121	129	135	168	125	135
	Average total	238	250	247	291	248	255
Nitrogen application standard		248	250	248	325	283	271
Use of plant-available nitrogen on arable land[2,3]		123	124	120	131	139	127
Application standard for arable land[2]		142	135	114	157	154	141
Use of plant-available nitrogen on arable land[2,4]		260	277	272	315	259	278
Application standard for arable land[2]		268	274	271	345	294	291

[1] Calculated on the basis of the applicable statutory availability coefficients (see Appendix 2). [2] The average use data for grassland and arable land is based on 265 farms and 202 farms, respectively, instead of on 275 farms. This is because on 10 farms the allocation of fertilisers to arable land did not fall within the confidence intervals, and because 63 farms had no arable land. [3] The figures concerning use on arable land are reported by the farmer himself. [4] Grassland usage levels are calculated by deducting the quantity applied on arable land from the total quantity applied.

In 2017, the average total use of phosphate on farms participating in the derogation monitoring network was lower than the average phosphate application standard of 84 kg per hectare (see Table 3.4). On average, 78 kg of phosphate was applied per hectare, of which 77 kg via livestock manure. As of 15 May 2014, inorganic phosphate-containing fertilisers were no longer allowed to be used on derogation farms.

Table 3.4: Average use of nitrogen in fertilisers (in kg of P_2O_5//ha) on farms participating in the derogation monitoring network in 2017

Description	**Item**	**Sand 250**	**Sand 230**	**Loess**	**Clay**	**Peat**	**Total**
Number of farms		47	98	20	55	55	275
fertiliser usage	Livestock manure	78	74	73	82	81	77
	Other organic fertilisers	0	1	1	0	0	1
	Inorganic fertilisers	0	0	1*	0	0	0
	Average total	78	75	76	82	81	78
Phosphate application standard		85	81	87	85	88	84
Use of phosphate on arable land[1,2]		61	63	62	58	68	62
Application standard for arable land[1]		59	57	65	60	66	60
Use of phosphate on arable land[1,3]		82	77	78	85	83	81
Application standard for arable land[1]		90	86	90	87	90	88

[1] The average use data for grassland and arable land is based on 265 farms and 202 farms, respectively, instead of on 275 farms. This is because on 10 farms the allocation of fertilisers to arable land did not fall within the confidence intervals, and because 63 farms had no arable land. [2] The figures concerning use on arable land are reported by the farmer himself. [3] Grassland usage levels are calculated by deducting the quantity applied on arable land from the total quantity applied. * Originating from mineral concentrate that is categorised as inorganic fertiliser for the calculations.

3.1.3 *Crop yields*

In 2017, the farms participating in the derogation monitoring network had an estimated average dry-matter yield of silage maize of 18,800 kg per hectare. This resulted in an estimated average yield of 203 kg of nitrogen and 32 kg of phosphorus (74 kg P_2O_5). The average yield was highest in Sand-230 and lowest in the Peat Region (see Table 3.5).

The calculated grassland yield of dry matter per hectare was an average of 10,000 kg. Both the nitrogen and phosphorus yields per hectare were higher for grassland than for silage maize, due to higher nitrogen and phosphorus levels in grass. In 2017, the calculated grassland dry-matter yields were lowest in Sand-250 (see Table 3.5).

Table 3.5: Average crop yields (in kg of dry matter, nitrogen, phosphorus and P_2O_5 per hectare) for silage maize (estimated) and grassland (calculated) in 2017 on farms participating in the derogation monitoring network that meet the criteria for application of the calculation method (Aarts et al., *2008)*

Description	**Sand**		**Loess**	**Clay**	**Peat**	**Total**
	250	**230**				
Silage maize yields						
Number of farms	38	82	13	29	25	187
kg of dry matter per hectare	18,600	19,200	19,000	18,300	18,000	18,800
kg N/ha	194	207	217	201	194	203
kg P/ha	33	32	35	33	31	32
kg P_2O_5/ha	75	73	81	75	72	74
Grassland yields						
Number of farms	42	88	15	46	51	242
kg of dry matter per hectare	8,400	10,300	10,000	10,600	10,300	10,000
kg N/ha	250	301	298	398	304	293
kg P/ha	31	38	36	41	36	37
kg P_2O_5/ha	71	87	83	93	83	85

3.1.4 *Nutrient surpluses*

The calculated average nitrogen surplus on the soil surface balance of farms participating in the derogation monitoring network amounted to 155 kg per hectare in 2017 (see Table 3.6). In 2017, the calculated inputs (nitrogen via feed products and manure) as well as calculated outputs (nitrogen via animals, milk and manure) were higher than in 2016 (see Table B4.6 in Appendix 4). The nitrogen surpluses on the soil surface showed considerable variation. The 25% of farms with the lowest surpluses realised a surplus of less than 113 kg N/ha, whereas the surplus exceeded 299kg N/ha on the 25% of farms with the highest surpluses (see Table 3.6).

Table 3.6: Nitrogen surpluses on the soil surface balance (in kg N/ha) on farms participating in the derogation monitoring network in 2017; average values and 25th and 75th percentile values per region

Description	Item	Sand 250	Sand 230	Loess	Clay	Peat	Total
Number of farms		47	98	20	55	55	275
Farm inputs	Inorganic fertilisers	121	129	135	168	125	135
	Organic fertilisers	11	7	2	11	6	8
	Feedstuffs	205	320	204	180	168	234
	Animals	2	6	1	3	2	4
	Other	1	2	4	2	2	2
	Total	339	465	346	365	304	382
Farm outputs	Milk and other animal products	89	108	83	85	86	94
	Animals	22	47	13	18	13	28
	Organic fertilisers	40	114	53	48	38	69
	Other	23	31	30	36	26	30
	Total	173	300	180	187	163	220
Average nitrogen surplus per farm		166	165	166	181	141	163
+ Deposition, mineralisation and organic nitrogen fixation		48	35	38	36	119[1]	55
- Gaseous emissions[2]		60	67	52	61	61	62
Nitrogen surplus on soil surface balance average[3]		154	131	152	153	199	155
25th percentile		136	85	128	121	150	113
75th percentile		191	182	191	196	256	199

[1] Based on the assumption of higher nitrogen mineralisation from organic matter on peat soil (see Appendix 2)
[2] Gaseous emissions resulting from stabling, storage, application and grazing
[3] Calculated in accordance with the method described in Appendix 2

The phosphate output calculated for 2017 was on average slightly higher than the input. This means that the average phosphate surplus on the soil surface balance was negative, namely -1 kg per hectare (see Table 3.7). The phosphate surplus per hectare was therefore the same as in 2016. A striking aspect was the higher output of phosphate via the animals. This was due to the reduction in the number of dairy cattle in 2017. In contrast, the average output of phosphate via fertilisers was slightly lower than in 2016 (see Table B4.8 in Appendix 4). The 25% of farms with the lowest phosphate surpluses realised a negative surplus of at least 15 kg per hectare, whereas the 25% of farms with the highest surpluses realised a minimum positive surplus of 15 kg per hectare.

Table 3.7: Phosphate surpluses on the soil surface balance (in kg P_2O_5 per hectare) on farms participating in the derogation monitoring network in 2017; average values and 25th and 75th percentile values per region

Description	Item	Sand 250	Sand 230	Loess	Clay	Peat	Total
Number of farms		47	98	20	55	55	275
Farm inputs	Inorganic fertilisers	0	0	1	0	0	0
	Organic fertilisers	4	3	2	4	3	3
	Feedstuffs	68	114	69	59	57	80
	Animals	1	3	1	2	2	2
	Other	0	1	1	1	0	1
	Total	73	121	74	66	61	86
Farm outputs	Milk and other animal products	35	42	33	34	34	37
	Animals	11	26	9	12	9	16
	Organic fertilisers	17	47	19	18	14	27
	Other	6	8	7	9	5	7
	Total	70	122	68	72	62	87
Phosphate surplus on soil surface balance:							
average[1]		4	-1	6	-6	-1	-1
25th percentile		-2	-20	-9	-21	-14	-15
75th percentile		14	16	15	15	14	15

[1] Calculated in accordance with the method described in Appendix 2

3.2 Water quality

3.2.1 *Water leaching from the root zone, measured in 2017 (NO_3, N and P)*

In 2017, the nitrate concentration in all regions was, on average, lower than the nitrate standard of 50 mg/l (see Table 3.8).

There is a marked difference between the nitrate concentration in the water leaching from the root zone in Sand-230 (31 mg/l) and in Sand-250 (16 mg/l). This can be explained by the higher proportion of drier soils in the southern provinces. In addition, the northern provinces (Sand-250) contain more peat soils and wetland soils, which are associated with higher rates of denitrification.

The average nitrate concentration in the Peat Region was lower than in the Clay Region. The total nitrogen concentration, which also includes nitrate, was actually higher in the Peat Region than in the Clay Region. This is caused by higher ammonium concentrations in groundwater in the Peat Region. The higher ammonium concentrations are probably due to the decomposition of organic matter in peat, whereby nitrogen is released in the form of ammonium (Butterbach-Bahl and Gundersen, 2011, Van Beek *et al*., 2004).

Groundwater that is or has been in contact with nutrient-rich peat layers often also has high phosphorus concentrations (Van Beek *et al*., 2004). These nutrient-rich peat layers may also contribute to the higher average phosphorus concentrations measured in the Peat Region and

Clay Region compared to the concentrations measured in Sand-230 and Sand-250. In addition, phosphate ions are easily adsorbed by iron and aluminium oxides, and iron and aluminium hydroxides and clay minerals, particularly under aerobic (oxygen-rich) conditions such as those occurring in the Sand Region, as a result of which these ions do not end up in the groundwater. Phosphate also readily precipitates under aerobic conditions in the form of poorly soluble aluminium, iron and calcium phosphates.

Table 3.8: Nutrient concentrations in 2017 (in mg/l) in water leaching from the root zone on farms participating in the derogation monitoring network: average concentrations per region and percentage of observations below the phosphorus detection threshold

Reference	Sand-250	Sand-230	Loess	Clay	Peat
Number of farms	43	102	19	55	55
Nitrate (NO_3)	16	31	38	15	6.4
Nitrogen[1] (N)	7.2	9.7	9.0	5.2	8.5
Phosphorus[2,3] (P)	0.19 (49)	0.12 (56)	*	0.25 (13)	0.38 (7.3)

[1] Nitrogen was measured as total dissolved nitrogen. [2] The percentage of farms with average concentrations below the Detection Threshold (DT) is stated in parentheses. [3] Phosphorus was measured as the total amount of dissolved phosphorus. * Phosphorus concentrations measured in the Loess Region his year were rejected.

In the Peat Region, the nitrate concentration in the water leaching from the root zone on all the farms was lower than the nitrate standard of 50 mg/l (see Table 3.9). In the Clay Region, over 94% of the farms had concentrations lower than the standard, and in the Sand 250 sub-region over 95% of the farms were below the standard.

In general, higher average nitrate concentrations were measured in the Sand-230 sub-region and Loess Region due to a higher percentage of soils prone to leaching in these regions. These are soils where less denitrification occurs, partly due to lower groundwater levels and/or limited availability of organic material and pyrite (Biesheuvel, 2002; Fraters *et al*., 2007a, Boumans and Fraters, 2011). There were also more farms in these regions that had higher concentrations, on average, than in the other regions (see Table 3.9). In Sand-230, 18% of the farms had concentrations higher than 50 mg/l; in the Loess Region, that percentage was 21%.

Table 3.9: Frequency distribution (%) in 2017 of farm-specific average nitrate concentrations (in mg/l) in water leaching from the root zone on farms participating in the derogation monitoring network per region, expressed as percentages per class

Nitrate concentration class (mg/l)	Sand-250	Sand-230	Loess	Clay	Peat
Number of farms	43	102	19	55	55
<15	51	30	11	67	82
15-25	35	12	21	16	12
25-40	7.0	22	26	9.1	3.6
40-50	2.3	18	21	1.8	1.8
>50	4.7	18	21	5.5	0

In 2017, the farms in Sand-230 also had the highest median nitrogen concentration of all the regions; 50% of the farms in this region had a nitrogen concentration of 9.0 mg N/l or higher (see Table 3.10).

Table 3.10: Nitrogen concentrations[1] (in mg N/l) in water leaching from the root zone in 2017 on farms participating in the derogation monitoring network; 25th percentile, median and 75th percentile values per region

Reference	Sand-250	Sand-230	Loess	Clay	Peat
Number of farms	43	102	19	55	55
First quartile (25th percentile)	5.4	5.9	5.5	3.3	7.2
Median (50th percentile)	7.0	9.0	8.5	4.1	8.1
Third quartile (75th percentile)	8.6	12	12	6.5	10

[2] Nitrogen was measured as total dissolved nitrogen.

The highest median phosphorus concentration in the water leaching from the root zone was measured in the Peat Region; 50% of the farms in the Peat Region had a phosphorus concentration higher than 0.30 mg P/l (see Table 3.11).

Table 3.11: Phosphorus concentrations[1,2] (in mg P/l) in water leaching from the root zone on farms participating in the derogation monitoring network in 2017; 25th percentile, median and 75th percentile values per region

Reference	Sand-250	Sand-230	Loess	Clay	Peat
Number of farms	43	102	19	55	55
First quartile (25th percentile)	<DT	<DT	*	0.094	0.11
Median (50th percentile)	<DT	<DT	*	0.20	0.30
Third quartile (75th percentile)	0.11	0.10	*	0.38	0.53

[1] Average values below the detection threshold of 0.062 mg/l are indicated by the abbreviation <DT. [3] Phosphorus was measured as the total amount of dissolved phosphorus. * Phosphorus concentrations measured in the Loess Region this year were rejected.

3.2.2 *Ditch water quality measurements in 2016-2017*

Average nitrate concentrations in ditch water in the winter were highest in Sand-230 at 28 mg/l, and lowest in the Peat Region at 3.0 mg/l (see Table 3.12). Total nitrogen concentrations, too, were highest in Sand-230 (8.5 mg N/l). The total nitrogen concentration in the Peat Region (4.1 mg N/l) was slightly higher than in the Clay Region (3.8 mg N/l). Phosphorus concentrations in ditch water were highest in the Clay Region, and lowest in Sand-230

Table 3.12: Average nutrient concentrations (in mg/l) in ditch water in the winter of 2016-2017 per region on farms participating in the derogation monitoring network and percentage of observations below the phosphorus detection threshold

Reference	**Sand-250**	**Sand-230**	**Loess[1]**	**Clay**	**Peat**
Number of farms	12	22	-	54	54
Nitrate (NO_3)	18	28	-	7.9	3.0
Nitrogen (N)	6.7	8.5	-	3.8	4.1
Phosphorus[3] (P)	0.17 (8.3)	0.098 (64)	-	0.24 (28)	0.17 (24)

[1] There are no LMM farms with ditches in the Loess Region. [2] Nitrogen was measured as total dissolved nitrogen. [3] Phosphorus was measured as total dissolved phosphorus. The percentage of farms with average concentrations below the Detection Threshold (DT) is stated in parentheses.

In Sand-250, 14% of the farms had ditch water nitrate concentrations higher than 50 mg/l (see Table 3.13). In Sand-230, the corresponding figure was 8.3% and in the Clay region it was 1.9% of the farms. None of the farms in the Peat Region had a ditch water nitrate concentration higher than 50 mg/l.

Table 3.13: Frequency distribution (%) of farm-specific average nitrate concentrations (in mg/l) in ditch water on farms participating in the derogation monitoring network per region in the winter of 2016-2017, expressed as percentages per class

Nitrate concentration class (mg/l)	**Sand-250**	**Sand-230**	**Loess[1]**	**Clay**	**Peat**
Number of farms	22	12	-	54	54
<15	32	42	-	87	98
15-25	27	25	-	7.4	0
25-40	18	25	-	3.7	1.9
40-50	9.1	0	-	0	0
>50	14	8.3	-	1.9	0

[1] There are no LMM farms with ditches in the Loess Region.

The highest median concentration of nitrogen was found in Sand-230. Fifty percent of the farms in Sand-230 had ditch water nitrogen concentrations higher than 7.6 mg N/l (see Table 3.14).

Table 3.14: Ditch water nitrogen concentrations[1] (in mg N/l) measured in the winter of 2016-2017 on farms participating in the derogation monitoring network; 25th percentile, median and 75th percentile values per region

Reference	**Sand-250**	**Sand-230**	**Loess[2]**	**Clay**	**Peat**
Number of farms	12	22	-	54	54
First quartile (25th percentile)	4.0	5.7	-	1.9	3.1
Median (50th percentile)	6.4	7.6	-	3.2	4.0
Third quartile (75th percentile)	7.9	11	-	4.3	5.6

[1] Nitrogen was measured as total dissolved nitrogen. [2] There are no farms with ditches in the Loess Region.

The highest median concentration of phosphorus was measured in Sand-250. In this region, the phosphorus concentration measured on 50% of the farms was higher than 0.13 mg P/l (see Table 3.15).

Table 3.15: Phosphorus concentrations[1,2] (in mg P/l) in ditch water in the winter of 2016-2017 on farms participating in the derogation monitoring network; 25th percentile, median and 75th percentile values per region

Reference	Sand-250	Sand-230	Loess[3]	Clay	Peat
Number of farms	12	22	-	54	54
First quartile (25th percentile)	0.092	<DT	-	<DT	<DT
Median (50th percentile)	0.13	<DT	-	0.12	0.083
Third quartile (75th percentile)	0.23	0.078	-	0.31	0.17

[1] Average values below the detection threshold of 0.062 mg/l are indicated by the abbreviation <DT. [2] Phosphorus was measured as total dissolved phosphorus. [3] There are no LMM farms with ditches in the Loess Region.

3.2.3 *Comparison of the final figures with the provisional figures for 2017*

The figures presented in this section hardly deviate from the provisional figures reported by Lukács *et al.* (2018). The minor differences are mainly caused by a number of farms having 'dropped out' because they did not make use of the derogation or were not granted derogation, or because the farms were replaced in the derogation monitoring network.

3.2.4 *Provisional figures for measurement year 2018*

At the time of writing, provisional results were available for 2018, with the exception of the Loess Region for which no results were yet available. The results are 'provisional' because it is unknown at this time which farms will be actually granted derogation for measurement year 2018. This could mean that some concentration data might be changed in the final report for 2016, which will be published in 2020.

In 2018, the average nitrate concentration in the water leaching from the root zone in Sand-250 was 17 mg/l, and in Sand-230, it was 42 mg/l (see Table 3.16). In Sand-230, 71% had concentrations lower than 50 mg/l; in Sand-250, that percentage was over 95% (see Table 3.16).

In 2018, the average nitrate concentration in water leaching from the root zone in the Clay Region was 14 mg/l. Of the farms in the Clay Region, over 91% had nitrate concentrations below 50 mg/l (see Table 3.16). The average nitrate concentration on the farms in the Peat Region was 6.7 mg/l, and the nitrate concentrations on over 98% of the farms in this region was below 50 mg/l.

Table 3.16: Frequency distribution (%) of farm-specific average nitrate concentrations (in mg/l) in water leaching from the root zone on farms participating in the derogation monitoring network per region in 2018, expressed as percentages per class and average nitrate concentration per region

Nitrate concentration class (mg/l)	**Sand-250**	**Sand-230**	**Loess[1]**	**Clay**	**Peat**
Number of farms	47	111	-	57	56
Average concentration	17	42	-	14	6.7
<15	49	15	-	67	86
15-25	23	11	-	14	5.4
25-40	17	29	-	8.8	1.8
40-50	6.4	16	-	1.8	5.4
>50	4.3	29	-	8.8	1.8

[1] Results from the Loess Region were not yet available at the time the present report was being prepared.

In 2018, the average ditch water nitrate concentration in the Clay Region and the Peat Region amounted to 7.3 mg/l and 4.0 mg/l, respectively (see Table 3.17). The average nitrate concentration was 33 mg/l in the Sand-230 sub-region and 12 mg/l in the Sand-250 sub-region.

Table 3.17: Frequency distribution (%) of average ditch water nitrate concentrations (in mg/l) per farm, on farms participating in the derogation monitoring network per region in the winter of 2017-2018, expressed as percentages per class and average nitrate concentrations per region

Nitrate concentration class (mg/l)	**Sand-250**	**Sand-230**	**Loess***	**Clay**	**Peat**
Number of farms	12	22	-	56	58
Average concentration	12	33	-	7.3	4.0
<15	67	23	-	88	95
15-25	25	32	-	5.4	1.7
25-40	0	18	-	5.4	1.7
40-50	8.3	9.1	-	0	1.7
>50	0	18	-	1.8	0

*There are no LMM farms with ditches in the Loess Region.

The nitrogen concentration in the water leaching from the root zone was also the highest in Sand-230 (see Table 3.18). The nitrogen concentrations in the Peat Region were also higher than in the Clay Region due to the higher concentrations of ammonium in the Peat Region.

Table 3.18: Nitrogen concentrations[1] (in mg N/l) in water leaching from the root zone, measured in 2018 on farms participating in the derogation monitoring network; average, 25th percentile, median and 75th percentile values per region

Reference	**Sand-250**	**Sand-230**	**Loess[2]**	**Clay**	**Peat**
Number of farms	47	111	-	57	56
Average	7.2	12	-	5.1	8.3
First quartile (25th percentile)	4.9	8.2	-	2.67	6.3
Median (50th percentile)	6.8	11	-	3.9	7.7
Third quartile (75th percentile)	8.7	15	-	6.6	9.4

[1]Nitrogen was measured as total dissolved nitrogen. [2] Results from the Loess Region were not yet available at the time the present report was being prepared.

The nitrogen concentration in ditch water was also the highest in Sand-230 (see Table 3.19).

Table 3.19: Ditch water nitrogen concentrations[1] (in mg N/l) measured in the winter of 2017-2018 on farms participating in the derogation monitoring network; 25th percentile, median and 75th percentile values per region

Reference	**Sand-250**	**Sand-230**	**Loess[2]**	**Clay**	**Peat**
Number of farms	12	22	-	56	58
Average	5.3	10	-	3.6	4.5
First quartile (25th percentile)	3.7	5.6	-	2.1	3.3
Median (50th percentile)	4.3	8.7	-	3.0	4.1
Third quartile (75th percentile)	6.7	12	-	4.0	6.9

[1] Nitrogen was measured as total dissolved nitrogen. [2] There are no LMM farms with ditches in the Loess Region.

Unlike the nitrogen concentrations, the phosphorus concentrations in water leaching from the root zone were higher in the Peat Region and the Clay Region than in the Sand Region (see Table 3.20). In 2018, the ditch water phosphorus concentrations were highest in the Clay Region (see Table 3.21).

Table 3.20: Phosphorus concentrations[1,2] (in mg P/l) in water leaching from the root zone, measured in 2018 on farms participating in the derogation monitoring network; average, 25th percentile, median and 75th percentile values per region

Reference	Sand-250	Sand-230	Loess[3]	Clay	Peat
Number of farms	47	111	-	57	56
Average	0.17	0.14	-	0.25	0.33
First quartile (25th percentile)	<DT	<DT	-	0.097	0.14
Median (50th percentile)	<DT	<DT	-	0.17	0.30
Third quartile (75th percentile)	0.14	0.15	-	0.39	0.46

[1] Average values below the detection threshold of 0.062 mg/l are indicated by the abbreviation <DT.
[2] Phosphorus was measured as total dissolved phosphorus. [3] Results from the Loess Region were not yet available at the time the present report was being prepared.

Table 3.21: phosphorus concentrations[1,2] (in mg P/l) in ditch water measured in the winter of 2017-2018 on farms participating in the derogation monitoring network; average, 25th percentile, median and 75th percentile values per region

Reference	Sand-250	Sand-230	Loess[3]	Clay	Peat
Number of farms	12	22	-	56	58
Average	0.20	0.18	-	0.26	0.19
First quartile (25th percentile)	0.093	<DT	-	0.062	0.068
Median (50th percentile)	0.17	<DT	-	0.13	0.12
Third quartile (75th percentile)	0.29	0.14	-	0.44	0.23

[1] Average values below the detection threshold of 0.062 mg/l are indicated by the abbreviation <DT.
[2] Phosphorus was measured as total dissolved phosphorus. [3] There are no LMM farms with ditches in the Loess Region.

4 Developments in monitoring results

4.1 Developments in agricultural practices

4.1.1 Developments in farm characteristics[2]

In 2017, the developments in the dairy farming sector were primarily influenced by the need to reduce the total number of dairy cattle to ensure that the maximum phosphate level would not be exceeded and the derogation could remain in place.

The effects of these measures are also clearly reflected in the derogation monitoring network. The quantity of *Fat and Protein Corrected Milk* (FPCM) produced per farm increased continually during the 2006-2017 period by an average of almost 5% per year (see Figure 4.1). This rise up to and including 2016 was caused by the growing number of dairy cows. The area of cultivated land per farm also increased, but to a relatively lesser extent than the number of dairy cows. This resulted in an increase in milk production per hectare. The milk production (FPCM) per dairy cow remained fairly constant until 2016, but increased by almost 5% in 2017. The proportion of intensive livestock farms (such as pigs and poultry) gradually decreased from 12% in 2006 to somewhat over 5% in 2017.

The Phosphate Livestock Unit (LSU) is a standard used to compare numbers of animals based on their standard phosphate production (Ministry of Agriculture, Nature & Food Quality, 2000) (1 LSU = standard phosphate production from 1 dairy cow). The use of LSUs enables the aggregation of all animals present on a farm (dairy cows, young livestock, pigs, chickens, sheep, etc.). Livestock density in Phosphate Livestock Units per hectare decreased until 2013, but in 2015 it returned to the level of 2006. In 2017, average livestock density was 2.9 Livestock Units per hectare (see Figure 4.2).

Phosphate production by intensive livestock declined over time due to the decreasing number of farms with intensive livestock. However, this effect was largely compensated by the increase in the number of dairy cows in the dairy farming sector. This trend points to a steady increase in scale and specialisation in the dairy farming sector, as well as intensification resulting in higher milk production per hectare of fodder crop (see Appendix 4, Table B4.1).

[2] This section only concerns dairy farms participating in the derogation monitoring network; other grassland farms have not been taken into consideration

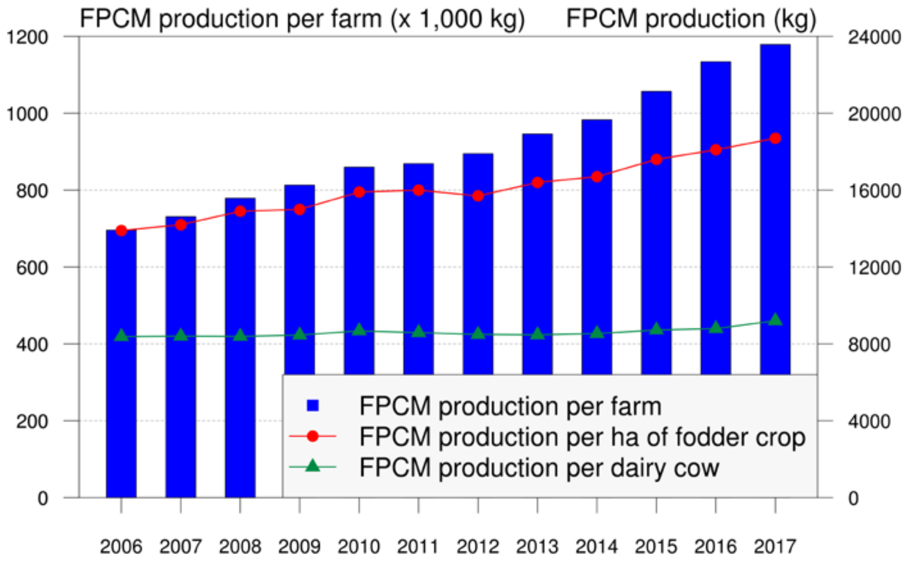

Figure 4.1: Average production of Fat and Protein Corrected Milk (FPCM) per farm (left y-axis), and per cow and per hectare of fodder crop (right y-axis) in the 2006-2017 period

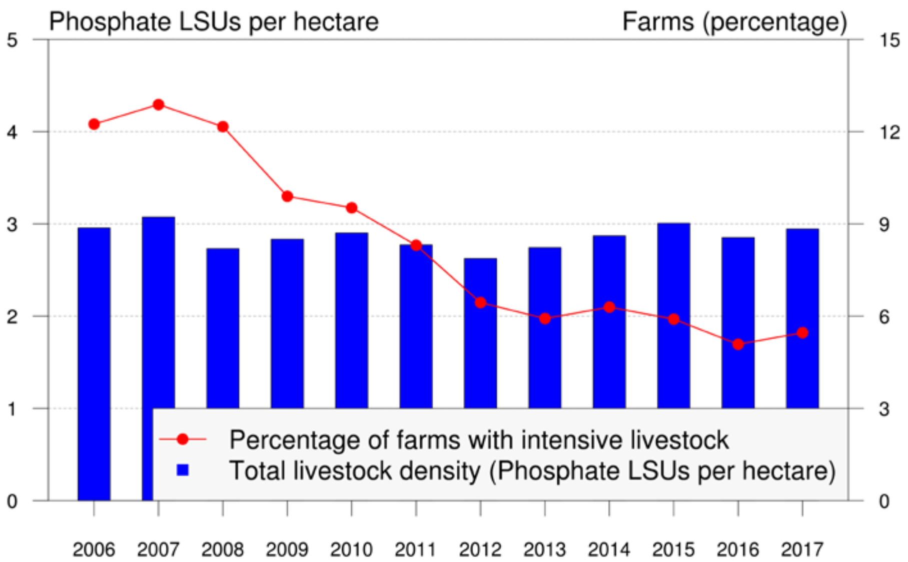

Figure 4.2: Average livestock density expressed in Phosphate Livestock Units per hectare, and percentage of dairy farms with intensive livestock (e.g. pigs and chickens) in the 2006-2017 period

The proportion of farms with grazing in the derogation monitoring network increased somewhat once again in 2017 (see Figure 4.3; Appendix 4, Table B4.1). Over the period from 2006 up to and including 2015, the percentage of dairy farms with grazing decreased from 89% to 76%. After that, the number of derogation farms with grazing again increased somewhat. In 2017, this proportion increased to 81%.

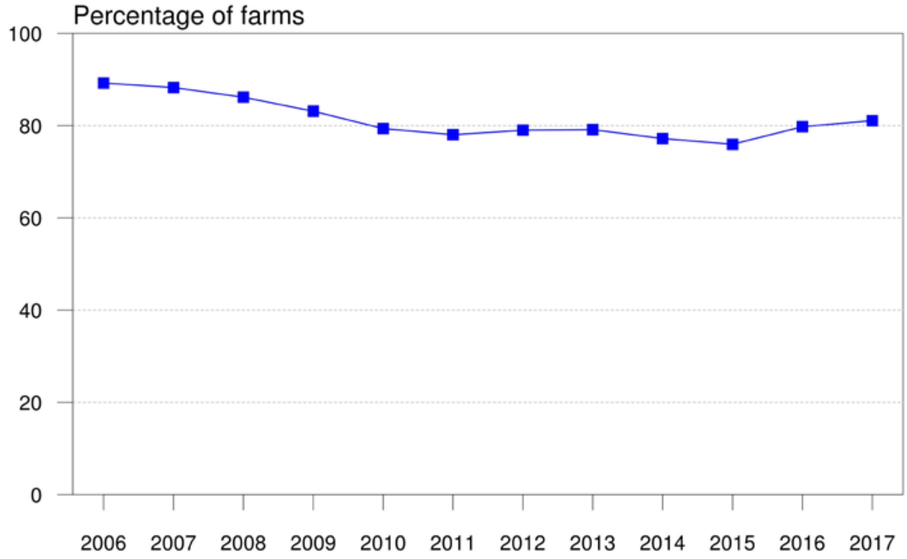

Figure 4.3: Proportion of dairy farms (%) where cows are grazed in the 2006-2017 period

4.1.2 *Use of livestock manure*

Between 2006 and 2016, the average use of nitrogen in the form of livestock manure ranged from 230 kg to 240 kg of nitrogen per hectare. In 2017, 245 kg of nitrogen in the form of livestock manure was used per hectare (see Figure 4.4; Appendix 4, Table B4.2). In 2017, the average use of phosphate in the form of livestock manure was 77 kg per hectare. This is the same quantity as in 2016 (see Appendix 4, Table B4.4).

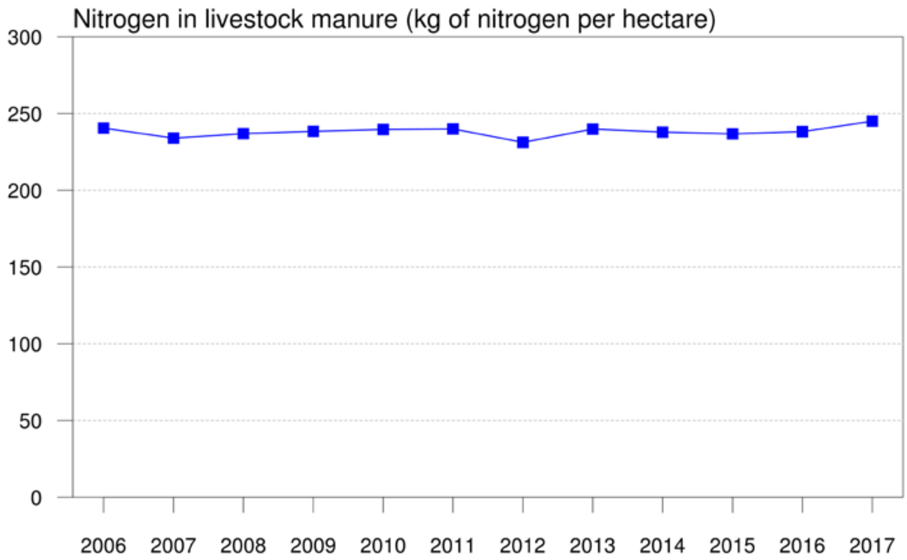

Figure 4.4: Use of nitrogen in livestock manure (in kg N/ha) in the 2006-2017 period

4.1.3 *Use of fertilisers compared to application standards*

In 2017, as was the case in previous years, the total use of plant-available nitrogen per hectare was below the nitrogen application standard. The difference between the actual nitrogen usage and the nitrogen application standard decreased significantly in the past few years, particularly in the 2006-2009 period (see Appendix 4, Table B4.3). Whereas the difference between actual usage and the application standard for plant-available nitrogen amounted to approx. 60 kg per hectare in 2006, this difference had decreased to 16 kg per hectare in 2017.

It is worth noting that, since 2014, the average nitrogen application standard on derogation farms has been higher than in the previous five years. The most important factor in this regard was the higher proportion of grassland, which is subject to a higher application standard than silage maize. The proportion of grassland was roughly 83% between 2006 and 2013 and, as a result of the stricter derogation conditions, this increased to 87% between 2014 and 2017.

The use of inorganic nitrogen-containing fertilisers remained fairly stable during the 2006-2017 period (see Appendix 4, Table B4.3). The total quantity of plant-available nitrogen in 2017 was 3.5% higher than in the previous year.

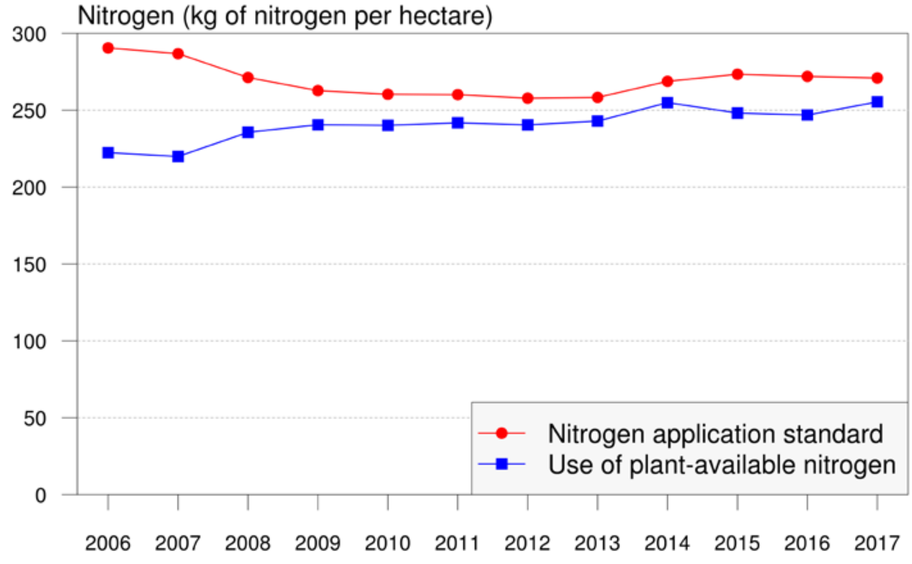

Figure 4.5: Use of plant-available nitrogen in livestock manure and inorganic fertilisers (kg N/ha) and total nitrogen application standard (kg N/ha) during the 2006-2017 period

During the 2006-2017 period, the use of phosphate-containing fertilisers on farms participating in the derogation monitoring network decreased by approx. 20%, while the phosphate application standard decreased by approx. 22% (see Figure 4.6). As a result, the difference between actual phosphate use and the phosphate application standard decreased from approx. 10 kg/ha in 2006 to 6 kg/ha in 2017. Between 2006 and 2017, the phosphate application standards were reduced from an average of

108 kg/ha to an average of 84 kg/ha. As a result, the initial margin between actual usage and the application standard disappeared. At first this resulted in a reduction in the use of inorganic phosphate-containing fertilisers. Between 2012 and 2014, the use of inorganic phosphate-containing fertilisers on derogation farms remained fairly constant, but after 2015 it again decreased to almost zero (see Appendix 4, Table B4.4). The reason for this is that, since 15 May 2014, inorganic phosphate-containing fertilisers may no longer be used on derogation farms.

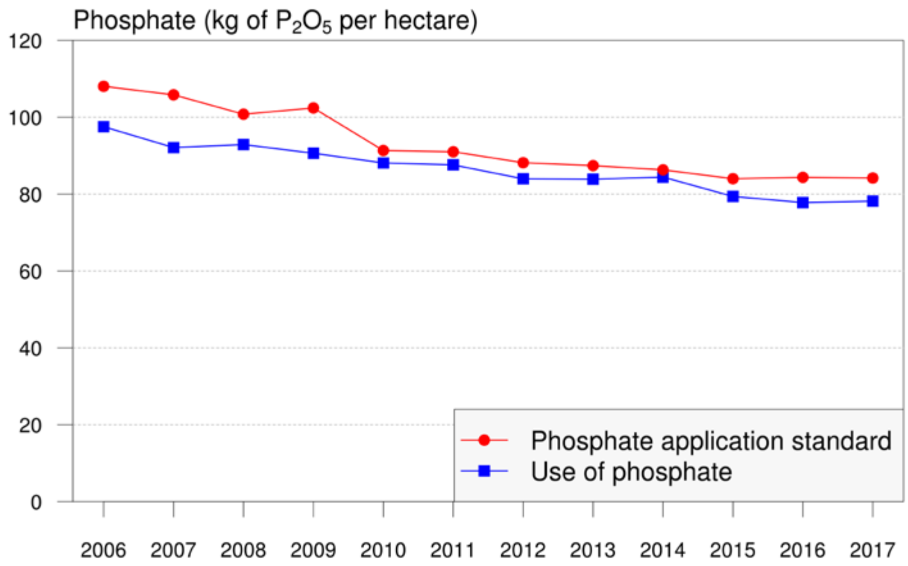

Figure 4.6: The use of phosphate via livestock manure and inorganic fertilisers (kg P_2O_5/ha) and the total phosphate application standard (kg P_2O_5/ha) in the 2006-2017 period

4.1.4 *Crop yields*

The average dry-matter yield for grassland in 2017 was lower; 10,000 kg/ha (see Figure 4.; Appendix4, Table B4.5A+B). In contrast, the average dry-matter yield for silage maze reached a record level. The average nitrogen yields for both crops were higher than in 2016. The phosphorus yields for both years were quite similar (see Figure 4.8 and Figure 4.9; Appendix 4, Table B 4.5).

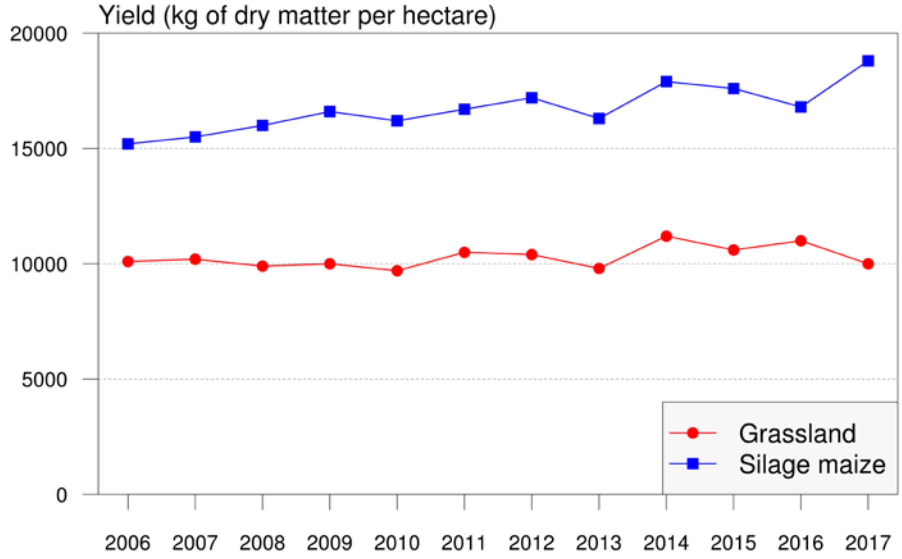

Figure 4.7: Average dry-matter yields for grassland and silage maize on derogation farms in the 2006-2017 period

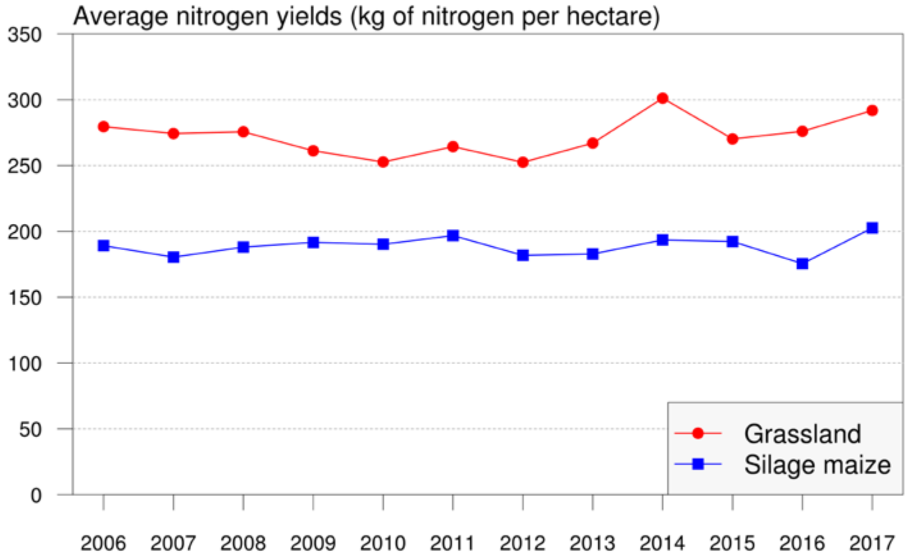

Figure 4.8: Average nitrogen yields (kg N/ha) for grassland and silage maize on derogation farms in the 2006-2017 period

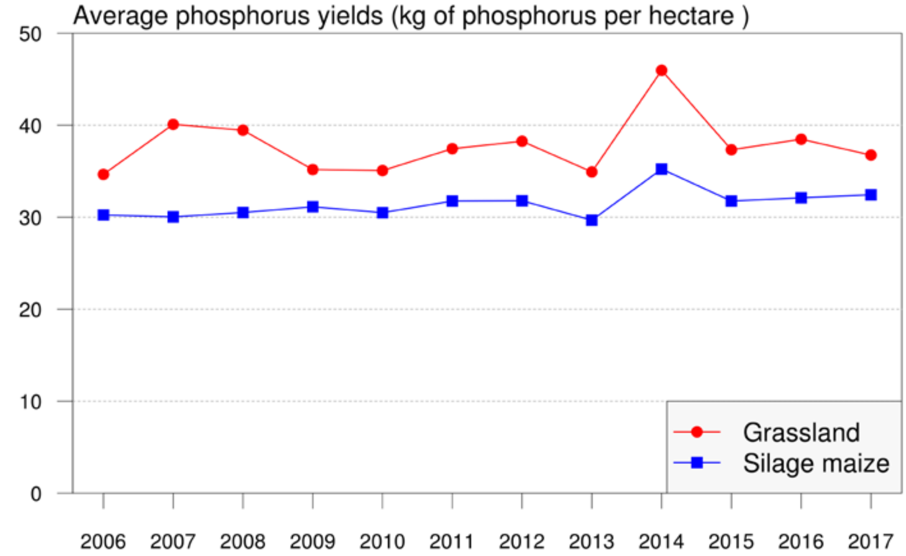

Figure 4.9: Average phosphorus yields (kg P/ha; 1 kg of phosphorus = 2.29 kg of P_2O_5) for grassland and silage maize on derogation farms in the 2006-2017 period

4.1.5 *Nutrient surpluses on the soil surface balance*

The average nitrogen surplus on the soil surface balance in 2017 was 155 kg N/ha, which was 20 kg/ha lower than the average for the 2006-2016 period. The low nitrogen surplus on the soil surface balance in 2017 was caused primarily by the high nitrogen yields for grassland as well as silage maze. In addition, the reduction in the number of dairy cows led to higher nitrogen outputs from the farms. A significant downward trend in the average nitrogen soil surplus was observed during the period from 2006 up to and including 2017 (see Figure 4.10; Appendix 4, Table B4.6).

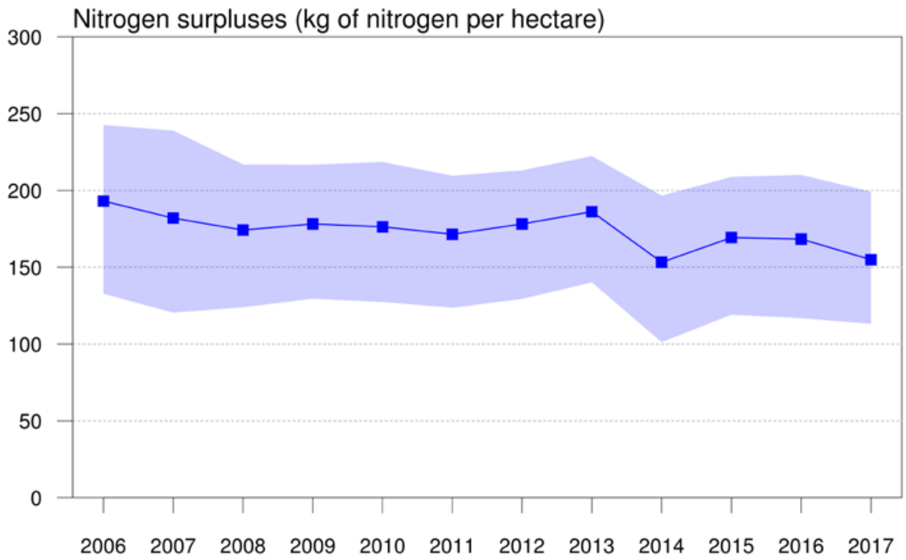

Figure 4.10: Average nitrogen surpluses (kg N/ha), and the nitrogen surpluses on the 25% of farms with the lowest surpluses (first quartile or 25th percentile), and nitrogen surpluses on the 25% of derogation farms with the highest surpluses (third quartile or 75th percentile) during the 2006-2017 period

The nitrogen surplus on the soil surface balance is consistently higher in the Peat Region than in the other regions (see Figure 4.11). This is mainly due to additional mineralisation on peat soils, which has been estimated and included on the input side of the balance sheet (see Appendix 2, Table B2.3). Until 2013, no clear trends were observable with respect to the different soil type regions. However, if the results for the past 3 years are included in the analysis, then a significant downward trend can be observed in most regions. This is due to the relatively low nitrogen soil surpluses in 2014, 2015 and 2017 (see Figure 4.11; see Appendix 4, Table B4.7).

No significant downward trend in the nitrogen soil surpluses was observed for the Loess Region (Figure 4.11; Appendix 4, Table B4.7).

In 2016 (Lukács et al., 2016), the first derogation report was published that drew a distinction between the Sand-250 and Sand-230 sub-regions. Figure 4.11 shows that the nitrogen surplus in both sub-regions is virtually the same in most years, despite differences in farm characteristics. In 2017, the nitrogen soil surplus in Sand-230 was 21 kg per hectare lower than in Sand-250. In 2017, the average input of nitrogen on farms in Sand-230 exceeded the average input on farms in Sand-250 by 125 kg of nitrogen per hectare, due to the fact that the farms in Sand-230 are generally characterised by more intensive farming practices. This was more than compensated in that year by the increased output of nitrogen via products and manure (increase of 127 kg of nitrogen per hectare) and by differences in deposition, organic nitrogen fixation and gaseous emissions. Other differences in nitrogen soil surpluses may arise as a result of minor adjustments at farm level or because some farms dropped out.

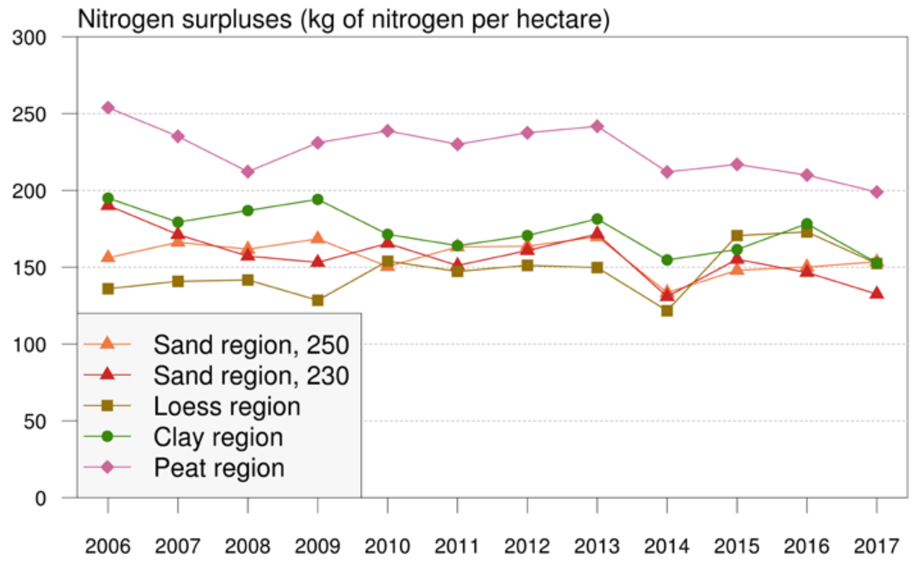

Figure 4.11: average nitrogen surpluses per region (kg N/ha) on derogation farms in the 2006-2017 period

The average phosphate surplus on the soil surface balance in 2017 was slightly negative. During the 2006-2016 period, there was an average positive surplus of 10 kg phosphate/ha (see Figure 4.12; Appendix 4,

Table B4.8). The decrease in the phosphate surplus was primarily due to a reduced use of phosphate fertilisers (see Appendix 4, Table B4.4 and B4.8).

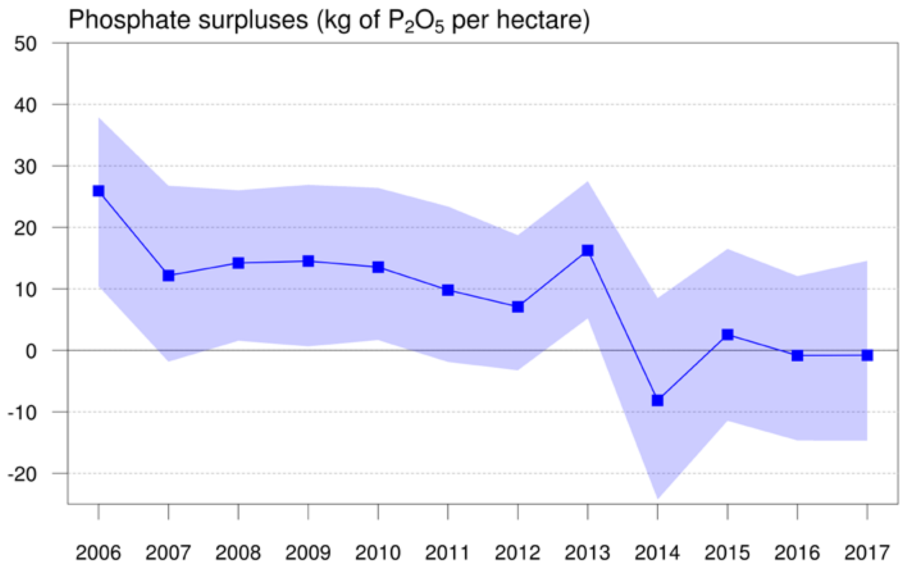

Figure 4.12: Average phosphate surpluses (kg P2O5/ha), and the phosphate surpluses on the 25% of farms with the lowest surpluses (first quartile or 25th percentile), and phosphate surpluses on the 25% of derogation farms with the highest surpluses (third quartile or 75th percentile) during the 2006-2017 period

4.2 Development of water quality

4.2.1 Development of average concentrations during the 2007-2018 period

After a marked decrease since 2014, the average nitrate concentration in the water leaching from the root zone in Sand-230 was higher in 2018 than in 2017 (see Figure 4.13). However, the concentration in 2018 was lower than the average over the entire measurement period (see Appendix 4, Table B4.9). The nitrate concentrations in Sand-250 were practically the same in 2018 as in 2017. After a decrease since 2013, the nitrate concentration in the Loess Region increased slightly during the last measurement year compared to 2016. In Sand-230, Sand-250, and the Loess Region, a decreasing trend can be seen over the entire measurement period.

The nitrate concentration in the Clay Region as well as the Peat Region remained approximately the same since 2016. In the Clay Region, the trend over the entire period is still a decreasing one; in the Peat Region, there is no trend visible.

The peak in 2015 was probably a natural variation caused by variations in the weather and in the sample population, similar to the peak that can also be seen in 2010 (see Appendix 4, Table B4.9). The effect of previous years with below-average precipitation was apparent in the 2010 results for the top metre of groundwater, so that we see higher nitrate concentrations in water leaching from the root zone in Sand-230, the Clay Region, and the Peat Region in 2010 than in previous and subsequent years. The higher concentration in Sand-230 in 2018 could also be related to the relatively dry summers of the last few years.

The highest average nitrate concentrations in water leaching from the root zone were found in the Loess Region and in Sand-230, but the average nitrate concentration in these regions has also remained below 50 mg/l since 2015. The number of farms with nitrate concentrations exceeding the standard has decreased significantly since 2014 (see Figure 4.14). In 2018, more than 90% of the farms in Sand-250 and in the Clay Region and Peat Region had average nitrate concentrations below 50 mg/l. In Sand-230, approximately 70% of the farms had an average nitrate concentration below the standard in 2018. In the Loess Region, this was the case for almost 80% of the farms in 2017.

The higher nitrate concentrations in the Loess Region and Sand-230 compared to Sand-250 can be explained by a higher percentage of soils prone to leaching in these regions. These are soils where less denitrification occurs, partly due to lower groundwater levels (Fraters *et al.*, 2007a; Boumans and Fraters, 2011).

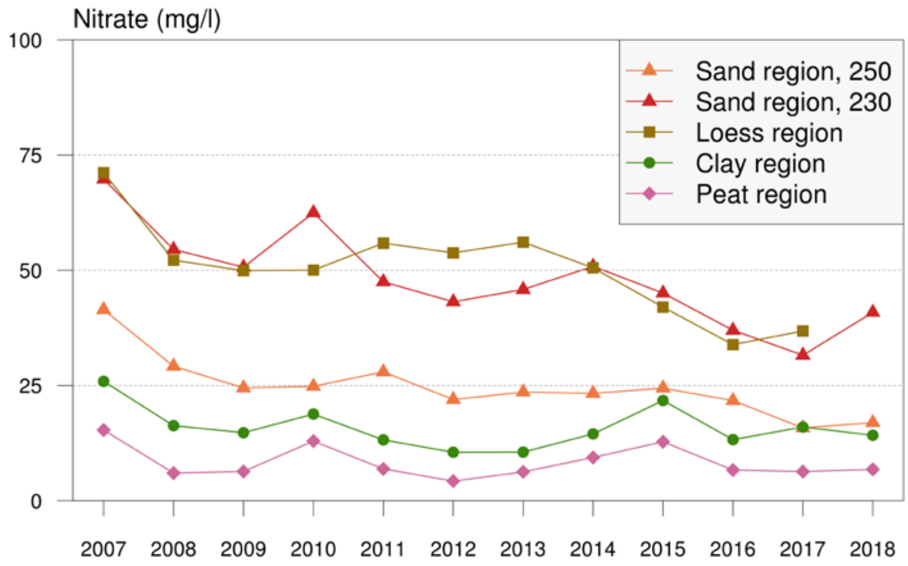

Figure 4.13: average nitrate concentrations in water leaching from the root zone on derogation farms in the four regions during the 2007-2018 period

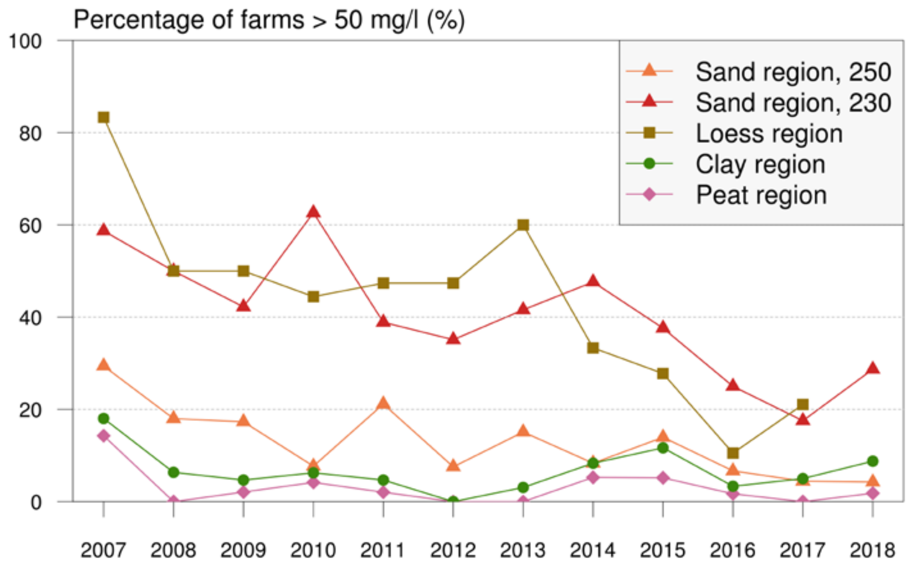

Figure 4.14: Percentage of derogation farms with an average nitrate concentration in the water leaching from the root zone higher than 50 mg/l during the 2007-2018 period

Ditch water nitrate concentrations in Sand-230, Sand-250, and the Clay Region decreased during the measurement period. There was no trend change in nitrate concentrations in the Peat Region. In 2017, the nitrate concentrations in all the regions increased slightly but not significantly. The nitrate concentration in Sand-230 was higher in 2018 than in 2017 but did not diverge significantly from the average values over the entire measurement period (see Figure 4.15; see Appendix 4, Table B 4.9:) We suspect that this is a natural fluctuation resulting from weather effects.

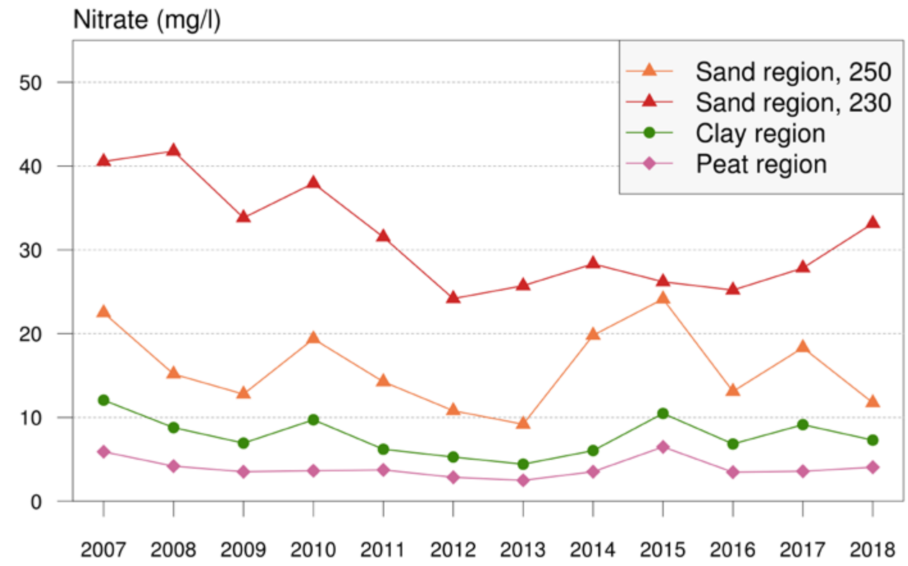

Figure 4.15: Average ditch water nitrate concentrations on derogation farms in the three regions during the 2007-2018 period

The phosphorus concentrations in water leaching from the root zone in the Clay Region and Peat Region decreased during the measurement period (see Appendix 4, Table B4.9). The phosphorus concentration remained stable in the other regions. In the Sand, Clay, and Peat regions, which are the regions containing ditches, the changes in ditch water phosphorus concentration did not follow any particular trend.

The nitrogen concentrations in the water leaching from the root zone decreased in all regions. The ditch water nitrate concentrations decreased in Sand-230 and Sand-250. The changes in ditch water nitrate concentration in the Clay Region did not follow any particular trend. The ditch water nitrate concentration in the Peat Region increased during the measurement period (see Appendix 4, Table B4.9 and B4.10).

Effects of environmental factors and sample composition on nitrate concentrations
Nitrate concentrations in water leaching from the root zone are influenced not only by agricultural practices but also by the precipitation surplus and changes in groundwater levels. Changes in the composition of the farm sample can also have an effect on the average nitrate concentrations, since soil types and groundwater levels vary between farms (Boumans *et al.*, 1989).

A statistical method has been developed for the Sand Region in order to correct the measured nitrate concentrations for the effects of weather conditions, groundwater levels, and changes in the composition of the sample (Boumans and Fraters, 2011). The method was improved in 2016 by making use of more detailed precipitation and evaporation data and by taking into account the sampling month (Boumans and Fraters, 2017). In addition, instead of the measured nitrate*concentration* the measured nitrate*leaching* was standardised. For this purpose, the measured nitrate concentrations are divided by the precipitation surplus in which the nitrate has dissolved. The precipitation surplus is calculated using the SWAP model (Van Dam *et al*., 2008). The standardised nitrate concentration was subsequently derived from the standardised nitrate leaching data. (Boumans and Fraters, 2017). In addition, the new method used more measurement data than the method from 2011. For example, for the farms in the wetter parts of the Sand region, data from the groundwater samples taken during the winter was also used in addition to the data from the summer samples.

This winter data has been collected in a research programme since the winter of 2004-2005 and is not included in the data presented in the previous sections about the derogation monitoring network. Differences may therefore exist between the average concentrations measured as presented in Tables B4.9, B4.11, and B4.12. This method does not take all the processes into consideration that have an influence on the nitrate concentration, and is based only on correlations.

Using this new method, it was found that the standardised nitrate concentrations in the water leaching from the root zone in Sand-230 during the 2007-2018 period decreased from 69 to 39 mg/l. In Sand-250, the nitrate concentration decreased from 34 to 19 mg/l. (see

Figure 4.16 and Tables B4.11 and B4.12). Since 2011, both the measured and the standardised nitrate concentrations have generally been below the nitrate standard. In Sand-230, the standardised nitrate concentration in 2018 was lower than the measured concentration. We suspect that the higher concentrations measured in Sand-230 in 2018 are in part due to natural fluctuations in the weather and the samples. And although the standardised concentration in Sand-230 in 2018 was on average higher than in 2017, it does not differ clearly from previous years (see Table B4.12).

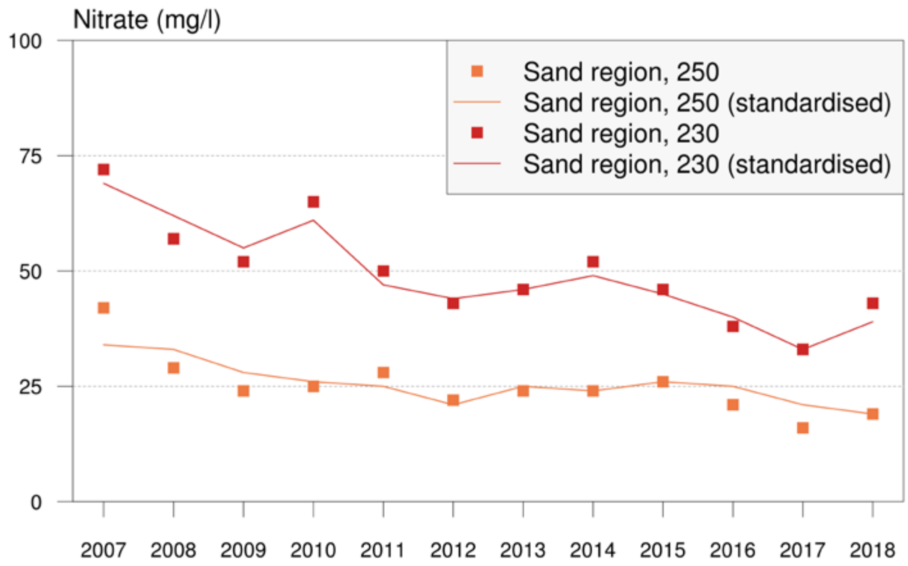

Figure 4.16: Development of the nitrate concentrations in water leaching from the root zone in the Sand Region in the successive measurement years, and the corrected nitrate concentrations The concentrations presented are based on the available summer and winter data of the farms from the derogation monitoring network

4.3 Effects of agricultural practices on water quality

Nitrogen

Between 2006 and 2017, the average nitrogen soil surpluses over all the regions showed a decreasing trend. The nitrate concentrations decreased in all the regions, with the exception of the Peat Region. This meets the expectation that a decrease in soil surpluses results in lower nitrate concentrations.

The strong decrease in nitrate concentrations at the beginning of the measurement series was possibly due to changes in farming operations before the derogation monitoring network was set up. With the exception of Peat soils, the nitrogen soil surplus depends on the balance between the annual input and the annual degradation of organically bound nitrogen. Nitrogen input from the soil is not included in the soil surplus. After-effects can remain noticeable for up to four years (Verloop, 2013).

Starting in 2014, a second downward trend is visible in the nitrate concentrations, particularly in Sand-230 and the Loess Region, which is possibly due to the low nitrogen surplus in 2014. Since 2015, a slight decrease in nitrate concentrations is visible in Sand-250.

In the Clay Region, the nitrate concentration in the water leaching from the root zone fluctuates between 10 and 20 mg/l, and in the Peat Region between 5 and 15 mg/l. These small fluctuations seem to follow the changes in the nitrogen soil surplus in the regions, although with some delay, but they can also be due to weather conditions and changes in the composition of the sample.

There are additional aspects in the operations of the derogation farms that can influence the nitrate concentration but that hardly change the nitrogen soil surplus:

- Since 2014, the derogation farms are required to have a minimum percentage of 80% grassland; in the period before that, the minimum was 70%. This resulted in an increase in the acreage of grassland in 2014 and 2015. The increasing proportion of grassland could also lead to a decrease in the nitrate concentration. The leaching fraction (i.e. the percentage of the nitrogen soil surplus that leaches out) is much higher on land used to cultivate maize than on grassland (Fraters *et al*., 2007a en 2012). However, the effect of this on the water quality cannot be determined independently of all the other developments on the farms and in the soil.
- The assumption is that the decrease in grazing on the derogation farms leads to lower nitrogen leaching. The nitrogen leaching that takes place during grazing in the second half of the growing season is relatively high, as the nitrogen in the urine released onto the surface cannot be completely absorbed by the grass (Corré *et al*., 2014). In Prins *et al*. However, Prins et al. (2015) did not find any relationship between the extent to which grazing takes place on grassland and the nitrate concentration in the groundwater for sandy soils on LMM farms. Still, additional research is needed to examine the influence of additional explanatory variables, such as groundwater level, soil type, and percentage of maize, in greater depth.
- The ploughing-up of grassland has decreased (Van Bruggen *et al.,* 2015), among other reasons because this practice is no longer permitted in autumn on sandy and loessial soils since the introduction of application standards in 2006. In addition, the EU’s agricultural policy as implemented in the Netherlands is also aimed at increasing the area of permanent grassland. This could result in lower nitrate concentrations in the uppermost groundwater. There are indications that the prohibition of ploughing-up grassland in the autumn has led to an increase in catch crops, often silage maize, on dairy farms. However, one cannot exclude the possibility that the targeted reduction of nitrate leaching by placing restrictions on the season when the ploughing of grassland is permitted has been masked by the increase in other types of catch crops (Velthof *et al*., 2017).

Phosphate
The phosphate surplus on the soil surface balance displayed a downward trend during the entire measurement period. The phosphorus

concentrations in water leaching from the root zone in the Clay Region and Peat Region also displayed a downward trend. This is in line with the expectation that a decrease in phosphate soil surpluses would lead to a decrease in phosphate concentration in the water leaching from the root zone.

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Appendix 1 Selection and recruitment of participants in the derogation monitoring network

B1.1. Introduction

This appendix explains the selection and recruitment of the 300 dairy and other grassland farms participating in the derogation monitoring network. As stated in the main text, the derogation monitoring network is part of the Minerals Policy Monitoring Programme (LMM). The selection and recruitment of farms for the derogation monitoring network is comparable to the selection and recruitment of participants in other parts of the LMM programme. Based on the most recent Agricultural Census data at the time (2005), a sample population was defined for each of the four regions. These sample populations were then subdivided into groups of farms (the *strata*) belonging to the same groundwater body and of the same farm type and economic size. Based on this distribution, the required number of sampled farms was derived for each *stratum.* In doing so, the proportion of the total surface area of cultivated land in a given stratum was taken into account (the greater the proportion of cultivated land in a stratum, the larger the number of farms to be included in the sample), as well as a minimum representation for each groundwater body.

The Companies Information Network (BIN) of *Wageningen Economic Research* was established primarily for the national sample of the Dutch part of the *Farm Accountancy Data Network* of the European Commission (FADN). For specific purposes such as the LMM, extra farms are selected and recruited and added to the BIN insofar as is necessary.

The recruitment of farms for the derogation monitoring network was initially targeted at farms participating in the Farm Accountancy Data Network (FADN; reporting year 2006). All suitable FADN farms that had registered for derogation in 2006 were approached. After the FADN farms had been recruited, it was determined which strata required additional farms. Additional farms were selected from a database maintained by the National Service for the Implementation of Regulations of the Ministry of Agriculture, Nature & Food Quality. This database included all farms that registered for derogation in 2006. Sixteen of the additional participants thus selected also participated in the ‘Koeien & Kansen’ (K&K: Cows and Opportunities) research project (see www.koeienenkansen.nl).

Replacements for farms that dropped out during the 2006-2017 period were preferably selected from farms that already participated in the LMM programme and the FADN network. The advantage of this approach is that water quality samples and/or agricultural practice data from previous years are also available for farms newly admitted to the derogation monitoring network.

B1.2. Definition of the sample populations

As with the LMM programme, the sample excludes a small number of farms that had registered for derogation and were included in the

Agricultural Census database. The first group of farms excluded from participation in the derogation monitoring network comprises very small farms with an economic size of less than 25,000 Standard Output (SO) units. Farms using organic production methods were also excluded. By definition, organic farms may not use more than 170 kg of nitrogen from livestock manure per hectare (irrespective of the percentage of grassland or the type of fertiliser). Also, a minimum farm size of 10 hectares of cultivated land was adopted to ensure representativeness with respect to surface area. Finally, only farms where grassland makes up at least 60% of the total area of cultivated land were included in the selection for derogation monitoring purposes. We have opted for a selection requirement that falls short of the 70% minimum prescribed by law (80% as of 2014) because the Netherlands Enterprise Agency (RVO.nl) and Wageningen Economic Research use different operational methods and definitions when registering farm data. Due to these discrepancies, the FADN grassland percentages may differ from the data registered by the Netherlands Enterprise Agency. In addition, farmers may adjust the grassland percentage on their farms from year to year, so that the percentage may exceed the required 70% or 80% in a later year.

The consequences of these selection criteria are illustrated in Tables B1.1 and B1.2. Table B1.1 (farms) and Table B1.2 (acreages) specify how the sample population has been derived from the 2017 Agricultural Census data and a database maintained by the Netherlands Enterprise Agency. This database contains over 19,400 so-called ‘BRS numbers’ of farms that registered for derogation for 2016. BRS numbers are the registration numbers of farms registered with the Netherlands Enterprise Agency. As 716 BRS numbers did not appear in the 2017 Agricultural Census, it was decided not to include absolute numbers of farms and hectares in the tables. Instead, the numbers of excluded farms and hectares of cultivated land are expressed as a percentage of the more than 18,700 farms for which data were available in the 2017 Agricultural Census.

Table B 1.1: Proportion of dairy and other grassland farms (%) represented in the sample population of the derogation monitoring network in 2017

	Distribution of farms		
	Dairy farms	**Other grassland farms**	**Total**
All farms registered for derogation in 2017	76%	24%	100%
Farms smaller than 25,000 SO units	0.1%	6.9%	7.0%
Organic farms	0.3%	0.3%	0.6%
Farms smaller than 10 hectares	1.0%	1.9%	2.9%
Farms where grassland makes up less than 60% of cultivated land	0.6%	0.2%	0.8%
Sample population	74%	15%	89%

Source: Statistics Netherlands Agricultural Census 2017, data processed by Wageningen Economic Research

Table B 1.2: Proportion of cultivated land (%) on dairy and other grassland farms represented in the sample population of the derogation monitoring network in 2017

	Distribution of acreage of cultivated land		
	Dairy farms	**Other grassland farms**	**Total**
All farms registered for derogation in 2017	89%	11%	100%
Farms smaller than 25,000 SO units	0.0%	1.1%	1.1%
Organic farms	0.4%	0.2%	0.5%
Farms smaller than 10 hectares	0.2%	0.3%	0.5%
Farms where grassland makes up less than 60% of cultivated land	0.7%	0.2%	0.9%
Sample population	88%	9%	97%

Source: Statistics Netherlands Agricultural Census 2017, data processed by Wageningen Economic Research

Tables B1.1 and B1.2 show that specialised dairy farms account for 74% of all farms that registered for the 2017 derogation scheme, and account for 88% of the total acreage of cultivated land. Almost all dairy farms also met the selection criteria used to define the sample population for the derogation monitoring network. The excluded farms are mainly other grassland farms with a small economic size (as expressed in SO units) and a small area of cultivated land. Under the adopted selection criteria, 11% of all farms registered for derogation are excluded from the sample population. However, these farms account for no more than 3% of the total acreage for which farmers have requested derogation.

B1.3. Explanation of individual stratification variables

The derogation decision calls for a monitoring network that is representative of all soil types, fertilisation practices, and crop rotations (see Article 8 of the derogation decision). When the derogation monitoring network was designed, the stratification was therefore based on region, as well as farm type, economic size (size class) and groundwater body. With effect from 2012, stratification based on groundwater body was replaced by stratification based on district. These stratification variables are explained below.

B1.4. Classification according to farm type

Since 2011, the LMM programme has used Standard Output (SO) units as a measure of the economic size of farms. This unit replaces the previously used Dutch Size Unit (NGE) (Van der Veen *et al.*, 2012). Standard Output is a measure of the standard value of the production of a farm. The Standard Output of a crop, animal product or other agricultural product is its average monetary value based on the prices received by the agricultural entrepreneur, expressed in euros per hectare or per animal. A regional SO coefficient for each product has been defined as the average value during a specific reference period (five years). The Netherlands is regarded as a single region for this purpose. The total Standard Output of a farm (i.e. the sum of all SOs per hectare of cultivated crops and per animal) is a measure of its total economic size, expressed in euros. A farm is characterised as ‘specialised’ when a particular agricultural activity (e.g. dairy farming, arable farming or pig farming) accounts for a substantial proportion (often at least two-thirds) of its total economic size. Eight main farm types can be distinguished. Five of these types concern one single activity, while three types concern a combination of activities. The five single-activity farm types are: arable farming, horticulture, permanent crops (fruit growing and tree nurseries), grazing livestock, and intensive livestock farming. The three combined-activity farm types are: crop combinations, livestock combinations, and crop-and-livestock combinations. Each main farm type is further divided into a number of subtypes. For instance, the subcategory of specialised dairy farms is part of the overall category of grazing livestock farms.

Within the group of farms that registered for derogation, dairy farms form a large and homogeneous group, which uses almost 89% of the total acreage of cultivated land, as is apparent from Table B1.2; 11% of the acreage is found on other farms types. These farms were also included in the monitoring network in order to obtain a sample that is optimally representative of the different crop rotations and fertilisation practices. Non-dairy farms account for approx. 26% of all farms (see Table B1.1). These farms can be of various types, but are described in this report as ‘other grassland farms’, as most of the cultivated land consists of grassland.

B1.5. Classification according to economic size

Farms are not only classified by type but also according to economic size, with four size classes being distinguished. This prevents over-representation of farms of below-average or above-average economic size. Economic size is also expressed in SO units.

B1.6. Classification according to soil type region and district

The Netherlands has been divided into four soil type regions as part of the Minerals Policy Monitoring Programme. The regions are further subdivided into a number of districts. Fourteen districts were defined in total, based on four-digit postcode districts. The participants in the derogation monitoring network have been selected with a view to achieving optimal distribution and representativeness in each region, in order to cover the most important districts in terms of the area of cultivated land.

In the Sand Region, seven districts were distinguished: Peat Districts, Northern Sand Region I, Northern Sand Region II, Eastern Sand Region, Central Sand Region, Southern Sand Region, and Dune Areas and Wadden Sea Islands. The Loess Region has no further districts. The Peat Region is divided into two districts: Northern Peatland Pastures and Western Peatland Pastures. The Clay Region is divided into four districts: Northern Clay, Holland and IJsselmeer Polders, South-Western Marine Clay, and River Clay.

The classification of soil type regions for policy-making purposes is slightly different. The Sand Region is divided into four districts for policy-making purposes: Sand Region – North, Sand Region – Central, Sand Region – South, and Sand Region – West. For policy-making purposes, the Loess Region has not been subdivided. The Peat Region is divided into two districts for policy-making purposes: Peatland Pastures – North and Peatland Pastures – West. The Clay Region is divided into four districts for policy-making purposes: Marine Clay – North, Marine Clay – Central, Marine Clay – South-West, and River Clay (see Figure B1.1).

The distinction between the Sand-250 and Sand-230 districts as used in this report is based on the subdivision of the Sand Region for policy-making purposes. In the districts Sand Region – North and Sand Region – West, the maximum derogation amounts to 250 kg of nitrogen per hectare. In the districts Sand Region – Central and Sand Region – South, the maximum derogation on sandy soils is 230 kg of nitrogen per hectare.

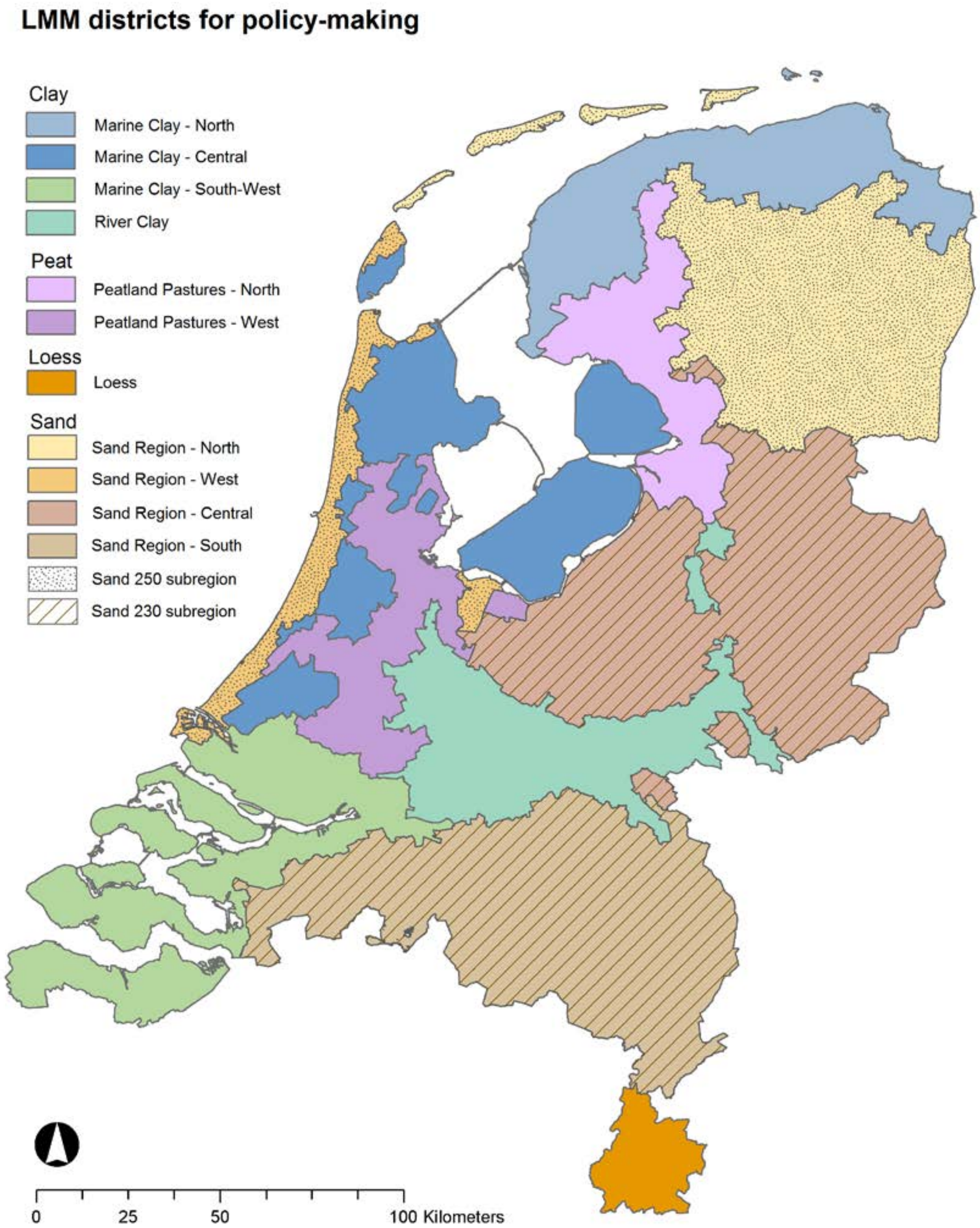

Figure B1.1: Soil type regions and districts for policy-making purposes in the Minerals Policy Monitoring Programme (LMM)

In the 2006-2013 period, stratification within the regions was based on groundwater body (Verhagen *et al.*, 2006). In this period, geographical stratifications (e.g. according to groundwater body) were still based on municipal boundaries. The transition to stratification according to district coincided with the transition from classification based on municipal boundaries to a (more accurate and stable) classification of regions and districts based on postcode districts (from FADN 2013 onward).

The Water Framework Directive distinguishes a total of twenty groundwater bodies in the Netherlands (Verhagen *et al.*, 2006). The derogation monitoring network has been designed with a view to achieving optimal distribution and representativeness in each region, in order to cover the most important groundwater bodies measured in terms of the area of cultivated land. Each farm was assigned to a groundwater body based on the municipality where the farm receives post. In municipalities with multiple groundwater bodies, all farms were assigned to the largest groundwater body.

In the Sand Region, five groundwater bodies were distinguished as sub-regions: Eems, Maas, Rhine Central, Rhine North, and Rhine East. Other farms belonging to other groundwater bodies within the region were assigned to a sixth sub-region termed ‘Other’. The Loess Region only contains the ‘Cretaceous’ groundwater body, and was therefore not subjected to further subdivision. The Peat Region was divided into four sub-regions, namely the groundwater bodies Rhine North, Rhine East, Rhine West, and ‘Other’. The Clay Region was divided into five sub-regions. The entire marine clay area in the south-west of the Netherlands was classified as a separate sub-region because it includes multiple groundwater bodies without one body being clearly dominant. In addition, three groundwater bodies were classified as a separate sub-region: Eems, Rhine North and Rhine West (in so far as the latter is located outside the marine clay area in the south-west of the Netherlands). The fifth sub-region includes farms in other, unallocated municipalities.

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Koeien & Kansen website: http://www.koeienenkansen.nl

Appendix 2 Monitoring of agricultural characteristics

This appendix explains how the agricultural practice data in the FADN network maintained by *Wageningen Economic Research* were monitored, and how these data were used to calculate fertiliser usage (section B2.2), grass and silage maize yields (section B2.3), and nutrient surpluses (section B2.4). Finally, the last section (B2.5) describes which significant changes were implemented in the calculation method and points of departure in comparison to the calculation method and points of departure of the derogation report released in 2015.

B2.1. General

Wageningen Economic Research is responsible for monitoring the agricultural practice data registered in the FADN network. It does so on the basis of a stratified sample of approx. 1500 farms and horticultural enterprises, maintaining a set of detailed financial, economic and environmental data. The FADN represents nearly 95% of total agricultural production in the Netherlands (Poppe, 2004; Binternet, 2013). Approx. 45 full-time *Wageningen Economic Research* employees are tasked with collecting and registering farm data in FADN. They process all the invoices of the participating farms. They also produce inventories of initial and final stocks and gather additional data on crop rotations, grazing systems, and the composition of the livestock population. *Wageningen Economic Research* sends participants a so-called 'participant's report' containing mainly annual totals (e.g. a profit-and-loss account and balance sheet). When data are processed to produce information for participants or researchers, the results are of course checked for inconsistencies as physical flows are registered in addition to financial flows.

Most FADN data are converted into annual totals, which are subsequently corrected for stock mutations. For example, the annual consumption of feed concentrate is derived from the sum of all purchases made during the period between two balance sheet dates, minus all sales, plus initial stocks, minus final stocks. The consumption of fertilisers per crop is also known and is calculated per growing season as well as per year. Fertiliser usage is registered for each crop, and the data allow for calculations of usage per year and per growing season.

Fertiliser usage, yields, and nutrient surpluses are expressed per unit of surface area. The total acreage of land under cultivation in the Netherlands is used for these calculations. This is the land actually fertilised and used for crop cultivation on farms. This acreage does not include rented land, nature areas, ditches, built-up land, paved surfaces, and grassland not used for the production of fodder (e.g. yards, camping sites).

B2.2. Calculation of fertiliser usage

The derogation decision (EU, 2014) stipulates that the report should include data on fertiliser usage and crop yields (Article 10 (1a). This article states (section 1.2):

'The competent authorities shall ... submit to the Commission every year a report containing the following information: data related to fertilisation on all farms which benefit from an individual derogation, including information on yields and on soil types.'

Nutrient usage data are differentiated for five different regions (Clay Region, Peat Region, Sand Region (230 and 250), and Loess Region). Fertiliser usage at farm level is reported, and a distinction is made between the use of fertilisers on arable land and on grassland.

B2.2.1. Calculation of fertiliser usage

On-farm use of livestock manure

In order to calculate the use of nutrients in livestock manure, on-farm production of manure is calculated first. In the case of nitrogen, this concerns net production after deducting gaseous emissions resulting from stabling and 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, 2017, tables 4 and 6). This method does not apply to farms that use the guidance document issued for this purpose (see the section below headed 'Farm-specific use of livestock manure'). Manure production by intensive livestock is calculated based on the standard nitrogen quantities prescribed by law and the phosphate quantities reported by the Working Group on Uniform Mineral and Manure Excretions (WUM). This applies only if the stable balance method cannot be used.

In addition, the quantities are registered for all fertiliser inputs and outputs and all fertiliser stocks (inorganic fertilisers, livestock manure, and other organic fertilisers). The nitrogen and phosphate quantities in inorganic fertilisers and other organic fertilisers are derived from the annual overviews of suppliers. If no specific delivery details are known, the quantities are multiplied by factors derived from data on standard compositions (Nutrient Management Institute, 2013).

In principle, the nitrogen and phosphate quantities in inputs and outputs of organic fertilisers are determined by means of sampling. If sampling has not been performed, standard contents for each type of fertiliser are used (Netherlands Enterprise Agency, 2017, Table 5). If no sampling results are available, the output of on-farm manure is calculated based on the farm-specific mineral content per m^3 of manure, provided that the relevant farm uses the Farm-Specific Excretion (BEX) method or the stable balance method. Standard quantities are used for the other farms.

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

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

Farm-specific use of livestock manure

As of agricultural practice year 2007, the calculation method for manure production has been modified for farms that make use of the guidance document on farm-specific excretion by dairy cattle (Ministry of

Economic Affairs, 2015). For these farms, the manure production is not calculated on the basis of standard quantities but on the basis of farm-specific data, if the farm indicates that it wishes to use the farm-specific excretion method. However, in some cases, the farm-specific calculation of manure production is nevertheless rejected, namely if the criteria mentioned in section B2.3.2 are not complied with. In these cases, the manure production is determined on the basis of standard quantities.

As of 1 May 2015, the guidance document on farm-specific excretion by dairy cattle is used to calculate the farm-specific excretion of the dairy herd (Ministry of Economic Affairs, 2015). The calculation method used deviates from the guidance document in two respects (Ministry of Economic Affairs, 2015):

- The uptake from silage maize expressed in fodder units (*Voedereenheden Melkvee*, VEM) is derived directly from the silage maize yields reported by the farmer, corrected for stocks (the same method used in Aarts et al., 2008). In the guidance document, the uptake is calculated using a correction method.
- The allocation of fodder units to fresh and conserved grass is calculated based on the exact number of grazing hours reported by the farmer, whereas the guidance document (Ministry of Economic Affairs, 2015) and in Aarts *et al*. (2008) define three classes based on reported grazing hours.

Use of fertilisers on arable land and grassland
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 quantities of nitrogen and phosphate applied on arable land are calculated by multiplying the quantity of manure (in tonnes or cubic metres) by:

- the contents derived from sampling results (if available) or
- the farm-specific mineral content if the manure production is calculated separately for each farm (see above); or, if this is not the case
- the applicable standard contents (Netherlands Enterprise Agency, 2017, Table 5).

The quantity of fertiliser applied on grassland is calculated as the closing entry:

Usage on grassland =
fertiliser usage at farm level - fertiliser usage on arable land

In the case of farms where grassland accounts for less than 25% of the total cultivated area[3], fertiliser usage on grassland is calculated based on the quantity of organic fertilisers registered in FADN, and the fertiliser usage on arable land is calculated as the closing entry. The 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

[3] Not relevant for this report, as a minimum of 70% (80% as of 2014) grassland is required for derogation.

each animal category by multiplying the calculated excretion by the percentage of the year that the animals spend grazing.

Use of plant-available nitrogen
The total nitrogen use is expressed in kilogrammes of plant-available nitrogen. The quantity of plant-available nitrogen is calculated by multiplying the total quantity of nitrogen in organic fertilisers by the availability coefficients as stated in Table 3 (Netherlands Enterprise Agency, 2017, Table 3). The quantity of nitrogen from inorganic fertilisers with an availability coefficient of 100% is added to the outcome.

If dairy cows graze on the farm, the availability coefficient is lower (45% instead of 60% since 2008) for all grazing livestock manure produced and applied on the farm. A lower statutory availability coefficient is used if arable land on clay and peat soils is fertilised in autumn using solid manure. In all other cases, the availability coefficient depends solely on the type of fertiliser or manure.

Phosphate use
Phosphate use is expressed in kilogrammes of phosphate. All fertilisers (inorganic fertilisers, livestock manure and other organic fertilisers) are included in the calculation.

Application standards
The average application standards for grassland and arable land are calculated by multiplying the crop areas registered in FADN by the application standards stated in Tables 1 and 2 (Netherlands Enterprise Agency, 2017, Tables 1 and 2). Phosphate differentiation has been applicable since 2010 (depending on the phosphate status of the soil). Soil test results are registered in FADN in order to determine the phosphate status of the soil. If the phosphate status is unknown, a high phosphate status is assumed by default.

B2.2.2. Lower and upper limits
On LMM farms, fertilisation with inorganic fertilisers, livestock manure, and other organic fertilisers must fall within the LMM confidence intervals in order to eliminate any data registration errors. This also applies to total fertilisation (i.e. inorganic fertilisers + livestock manure + other organic fertilisers). Table B2.1 lists the confidence intervals for non-organic dairy farms.

Table B2.1: Lower and upper limits on non-organic dairy farms for applied quantities of inorganic fertilisers, livestock manure, and other organic fertilisers, and total quantities of fertilisers applied (inorganic fertilisers + livestock manure + other organic fertilisers), expressed in kilogrammes of nitrogen and phosphate per hectare[1, 2]

Nutrient and type	Lower or upper limit	Kg N/ha
Nitrogen		
Inorganic fertilisers[3]	Lower limit	0
Inorganic fertilisers	Upper limit	400
Livestock manure	Lower limit	0
Livestock manure	Upper limit	500
Other organic fertilisers	Lower limit	0
Other organic fertilisers	Upper limit	400
Total fertiliser usage	Lower limit	50
Total fertiliser usage	Upper limit	700
Phosphate		
Inorganic fertilisers	Lower limit	0
Inorganic fertilisers	Upper limit	160
Livestock manure	Lower limit	0
Livestock manure	Upper limit	250
Other organic fertilisers	Lower limit	0
Other organic fertilisers	Upper limit	200
Total fertiliser usage	Lower limit	25
Total fertiliser usage	Upper limit	350

[1] If a value falls outside the upper and lower limits listed in Table B2.1, the nutrient flows of the relevant farm are considered incomplete and the farm is not included for the purpose of nutrient flow calculations.
[2]This table only states the lower and upper limits for fertiliser usage at farm level on non-organic dairy farms. Other limits are applied to other types of farms. Lower and upper limits are also applied to other quantities and indicators.
[3] The lower and upper limits for inorganic fertilisers on organic dairy farms are 0 and 100 kg/ha respectively.

B2.3. Calculation of grass and silage maize yields

B2.3.1. Calculation procedure

The calculation procedure for determining grass and silage maize yields in FADN is largely identical to the procedure described in Aarts *et al.* (2005, 2008). First, the energy requirement of the dairy herd is determined based on milk production and growth achieved. All transactions and stock changes of feed products are registered in FADN. These data are used to determine the proportion of the energy requirement covered by purchased feedstuffs. The energy uptake from farm-produced silage maize and other fodder crops (other than grass) is subsequently determined based on measurements and content data for silage supplies, insofar as these are available. The silage maize yield is subsequently determined by adding conservation losses to the ensilaged quantity of silage maize. If no reliable silage supply measurements can be obtained, the farmer and/or a consultant is asked to provide an estimate of the yields of farm-produced silage maize and other fodder crops.

It is subsequently assumed that the remaining energy requirement is covered by grass produced on the farm. The number of grazing days registered in FADN is used to calculate a ratio between the energy uptake from fresh grass and the uptake from conserved grass. This procedure can be used to determine the quantity of energy (expressed in fodder units) obtained by the animals from farm-produced feed. The nitrogen (N) and phosphate (P) uptake are subsequently calculated by multiplying the uptake in fodder units (VEMs) by the N:VEM and P:VEM ratios. Finally, the N, P, kVEM and dry-matter yields (in kilogrammes) for grassland are calculated by adding to the uptake the average quantities of N, P, kVEMs and dry matter lost during feed production and conservation.

B2.3.2. Selection criteria

The calculation procedure described above cannot be applied to all farms. On mixed farms, it is often difficult to clearly separate the product flows between different production units. The method is applied in accordance with Aarts *et al.* (2008).

The following selection criteria for application of the method were not adopted from Aarts *et al*. (2008):

- At least 15 hectares used for cultivation of fodder crops
- At least 30 persons
- Annual milk production of at least 4500 kg of Fat and Protein Corrected Milk (FPCM) per cow

These criteria were not taken into consideration because they were used in the study of Aarts *et al*. (2008) to make statements about the population of ‘typical’ dairy farms. These criteria can be ignored because the population data have already been registered in the permanent derogation monitoring network (comprising 300 farms). In line with Aarts *et al.* (2008), the following additional confidence intervals for yields were applied with respect to the outcomes:

- silage maize yield: 5,000 to 25,000 kg of dry matter per hectare
- grassland yield: 4,000 to 20,000 kg of dry matter per hectare

If the yield falls outside this range, it is assumed that this must be caused by a book-keeping error. In that case, the grass and silage maize yields of the farms concerned are also excluded from the report.

B2.3.3. Deviations from procedure described in Aarts et al. (2008)

In a few cases, we deviated from the procedure described in Aarts *et al*. (2005, 2008) because more detailed information was available, or because the procedure could not be properly incorporated into the LMM model.

This concerns the following data:

1. Composition of silage grass and silage maize pits
2. Mobility factor for grazing based on actual number of grazing days
3. Ratio of conserved grass to fresh grass, based on the actual number of grazing days
4. Conservation and feed production losses

Re 1

Aarts *et al.* (2008) base the composition of silage grass and silage maize pits on provincial averages supplied by the Netherlands Laboratory for Soil and Crop Research (BLGG). A slightly different method is used in the FADN network. Since 2006, the composition of silage grass and silage maize pits per farm is also registered in FADN. The FADN calculation procedure uses these farm-specific composition data if at least 80% of all silage pits have been fully sampled. The average pit composition for each soil type is used if less than 80% of pits have been sampled and/or if data are missing (i.e. dry-matter yields, VEM uptake, nitrogen or phosphate content). Data on average silage grass and silage maize pit composition are obtained annually from Eurofins Agro (formerly BLGG).

Re 2
A so-called ‘mobility factor’ is taken into account when calculating the energy requirement. This mobility factor depends on the number of grazing days, among other things. Aarts *et al.* (2008) distinguish three grazing categories: no grazing (0 grazing days), less than 138 grazing days, and more than 138 grazing days. The exact number of grazing days have been registered in FADN since 2004 and it was decided to use these data for the calculation, in accordance with Appendix 2 to the guidance document (Ministry of Economic Affairs, 2015).

Re 3
Deviating from Aarts *et al.* (2008), the ratio of energy uptake from fresh grass vs. uptake from silage grass was calculated based on the number of grazing days and/or ‘zero grazing’ days registered in FADN. The percentage of fresh grass varies between 0 and 35% for zero grazing, between 0 and 40% for unlimited grazing, and between 0 and 20% for limited grazing. This calculation is also performed in accordance with the method described in Appendix 2 to the guidance document (Ministry of Economic Affairs, 2015).

Re 4
The information in Appendix III in Aarts *et al.* (2008) is not complete with respect to the percentages adopted for conservation losses. To avoid any misunderstandings, all percentages used in FADN to calculate conservation and feed production losses are stated in Table B2.2.

Table B2.2: Percentages used to calculate conservation losses and feed production losses[1]

Category	**Conservation losses**				**Feed production losses**
	Dry matter	**VEM**	**N**	**P**	**Dry matter, VEM, N and P**
Wet by-products	4	6	1.5	0	2
Additional roughage consumed	10	9.5	2	0	5
Feed concentrate	0	0	0	0	2
Milk products	0	0	0	0	2
Silage maize	4	4	1	0	5
Silage grass	10	15	3	0	5
Meadow grass	0	0	0	0	0
Minerals	0	0	0	0	2

[1] The percentage for conservation losses is a percentage of the quantity put to or in the feed storage facility.
The percentage for feed production losses is a percentage of the same quantities after deducting the conservation losses In other words, 100 kg (dry matter) of silage grass in the silage pit corresponds to 90 kg of dry matter after conservation and 85.5 kg of dry matter consumed by the animal.

B2.4. Calculation of nutrient surpluses

In addition to fertiliser usage and crop yields, the report also states the nitrogen and phosphate surpluses on the soil surface balance (in kg of nitrogen and P_2O_5 per hectare, respectively). These surpluses are calculated by applying a method derived from the approach used and described by Schröder *et al*. (2004, 2007). This means that, alongside the input quantities of nitrogen and phosphate in organic and inorganic fertilisers and the output quantities in crops, allowance is also made for other sources of input, such as net mineralisation of organic substances in the soil, nitrogen fixation 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 immobilisation of nitrogen and phosphate in the soil is equal to the mineralisation of nitrogen and phosphate in the soil. An exception to this rule is made for peat soils and reclaimed peat subsoils. With these soil types, an input due to mineralisation is taken into account: 160 kg of nitrogen per hectare for grassland on peat soils, and 20 kg of nitrogen per hectare for grassland on reclaimed peat subsoils or other crops on peat soils and reclaimed peat subsoils. It is known that net mineralisation occurs on these soils as a result of groundwater level management, which is necessary in order to use the land for agriculture. Schröder *et al*. (2004, 2007) calculate the surplus on the soil surface balance by using the release of nutrients to the soil as a starting point. In this study, a bookkeeping method was employed that uses farm data to calculate the surplus on the soil surface balance.

The calculation method used to determine the nitrogen surplus is summarised in Table B2.3. The surplus at farm level is first calculated by determining the total input and output of nutrients as registered in the farm records. Stock changes are taken into account when calculating this surplus.
The calculated nitrogen surplus at farm level is subsequently corrected to account for a number of input and output items on the soil surface balance. The phosphate surplus on the soil surface balance is equal to the surplus at farm level. A more detailed explanation of the calculation methods can be found in Table B 2.3 below.

Table B 2.3 Calculation methods used to determine the nitrogen surplus on the soil surface balance (kg N/ha^{-1} year^{-1})

Description of items	**Calculation method**	
	Quantity	**Contents**
Farm inputs		
Inorganic fertilisers	Balance of all inputs, outputs and stock changes of inorganic fertilisers	Data obtained from suppliers' annual overviews. If these are not available, standards are used (Nutrient Management Institute, 2013).
Livestock manure and other organic fertilisers	Balance of all inputs, outputs and stock changes of livestock manure and other organic fertilisers in the case of net consumption (input)	Sampling results or standard quantities (Netherlands Enterprise Agency, 2017, Table 5). If farm-specific manure production is known, the output of on-farm manure is corrected accordingly (see section B2.2).
Feedstuffs	Balance of all inputs and stock decreases of all feed products (feed concentrate, roughage, etc.)	Data obtained from suppliers' annual overviews. If these are not available, standards are used (Centraal Veevoederbureau, 2012). Standards for compound feed in 2006-2009 based on data compiled by Statistics Netherlands (2010, 2011). As of 2010, all compound feed data are calculated for each farm. Standards for silage grass and silage maize are based on annual averages for the different soil type regions (data supplied by Eurofins).
Animals	Only imported animals	Standard quantities based on Ministry of Economic Affairs, 2015, and Netherlands Enterprise Agency, 2017, Table 7).
Plant products (sowing seeds, young plants and propagating material)	Only imported plant products	Data based on Van Dijk, 2003
Other	Balance of all inputs, outputs and stock changes of all other products in the case of net consumption (input)	
Farm outputs		
Animal products (milk, wool, eggs)	Balance of all inputs, outputs and stock changes of all milk and other animal products	Netherlands Enterprise Agency (2017), Tables 7 and 8
Animals	Balance of outputs and stock changes of animals and meat	Netherlands Enterprise Agency (2017), Tables 7 and 8

Description of items	Calculation method	
	Quantity	Contents
Livestock manure and other organic fertilisers	Balance of all inputs, outputs and stock changes of livestock manure and other organic fertilisers in the case of net production (output)	Sampling results or standard quantities (Netherlands Enterprise Agency, 2017, Table 5). If farm-specific manure production is known, the output of on-farm manure is corrected accordingly (see section B2.2).
Crops and other plant products	Balance of outputs and stock changes of plant products (crops not intended for roughage), stock increases and sales of roughage	Data based on Van Dijk, 2003 and CVB, 2012
Other	Balance of all inputs, outputs and stock changes of all other products in the case of net production (output)	
Nitrogen surplus at farm level	Farm input minus Farm output	
Input on soil surface balance		
+ Mineralisation	For grassland on peat soils: 160 kg of nitrogen per hectare per year (Van Kekem, 2004); other crops on peat soils and reclaimed peat subsoils (irrespective of crop): 20 kg of nitrogen per hectare per year. All other soil types: 0 kg. In the case of FADN farms, the surface areas are registered according to the four soil types defined by the Netherlands Enterprise Agency (sand, clay, peat and loessial soils). Mineralisation in reclaimed peat subsoils was estimated based on the overall soil classifications of each farm (based on postcode), in accordance with the Alterra soil map, version of 2006 (2006).	
+ Atmospheric deposition	The basic data are derived from National Institute for Public Health and the Environment (2016).	
+ Nitrogen fixation by leguminous plants	Clover on grassland (Kringloopwijzer, 2013): the quantity of nitrogen fixation depends on the proportion of clover (relationship between proportion of clover and clover density = 0.82; correction takes place) and the grassland yield, and is based on a nitrogen fixation per kg of dry-matter yield in the form of clover of (4.5/100). Other crops (Schröder, 2006): Lucerne: 160 kg per hectare Peas, broad beans, kidney beans and French beans: 40 kg per hectare	
Output on soil surface balance		
Volatilisation resulting from stabling, storage and grazing	The calculation method is based on Velthof *et al.* (2009). Calculations are based on the Total Ammonia Nitrogen (TAN) percentage. If the farm uses a farm-specific calculation method to calculate manure production, the emissions resulting from grazing, stabling and storage are calculated as follows: Ammonia emission resulting from stabling and storage: the stable codes under the Regulations on the Use of Ammonia in Livestock Farming (Regeling Ammoniak en Veehouderij, RAV) are used as a starting point. The total nitrogen emitted is calculated as a	

Description of items	Calculation method	
	Quantity	Contents
	percentage of the total ammonia nitrogen (TAN) excreted (based on the RAV emission factor). The TAN excreted is determined on the basis of the TAN percentages in the manure (Van Bruggen *et al*., 2017). The calculations take into account mineralisation and immobilisation of nitrogen in solid manure and slurry manure (Van Bruggen *et al*., 2017). Ammonia emission during grazing is calculated as a percentage (4%) of the TAN excreted during grazing (Van Bruggen *et al.,* 2017). If a farm calculates excretion based on standard quantities, the emissions resulting from grazing, stabling and storage are calculated as follows: First, the gross standard-based excretion is calculated by adding the standard-based emission factor to the net standard-based excretion (Groenestein *et al.,* 2005, Tamminga *et al*., 2014, Oenema *et al*., 2000, Groenestein *et al*., 2015). This factor depends on the type of animal. The emissions resulting from grazing are subsequently calculated by multiplying the quantity of nitrogen- excreted in grassland manure (net standard-based excretion for grassland fraction) by the emission percentage of the TAN excreted on grassland (Van Bruggen *et al.,* 2017). The emissions resulting from stabling and storage are calculated as the gross standard-based excretion minus the net standard-based excretion.	
Volatilisation resulting from application	The ammonia emission factors for the application of livestock manure and inorganic fertilisers are based on Velthof *et al*. (2009) and Van Bruggen *et al*. (2017). Other gaseous nitrogen emissions during application are not taken into consideration. Emissions resulting from application are calculated as a percentage of the applied ammonia nitrogen based on the emission factors as reported in Appendix 14 in Velthof *et al.* (2009). If no information on the application method is available (this has not been the case in the LMM framework since 2010), an average percentage for each soil type is applied. This standard is derived using the MAMBO method (De Koeijer *et al.*, 2012). Agricultural Census data on application methods are used for this purpose. The methods are classified according to soil type and land use type, and linked to an emission factor and a TAN factor.	
Nitrogen surplus on the soil surface balance	Nitrogen surplus on farm + input on soil surface balance – output on soil surface balance	

B2.5. Changes in calculation method and points of departure

This section provides an overview of the most important changes that were implemented in the calculation method and points of departure in comparison to the calculation method and points of departure of the derogation report released in 2018. The changes are included in the descriptions provided in the previous sections. The changes in the calculation method and points of departure are as follows:

- The ammonia emission factors for grazing animals have been adjusted in accordance with Groenestein *et al*. (2015). This adjustment has been carried out since 2015 and applies only to

farms for which the nitrogen excretion was determined based on standard quantities.
The above adjustment results in an increase in the calculated values for the nitrogen surplus on the soil surface balance of approximately 1.5 - 2 kg N/ha). This is due to a lower ammonia emission, as a result of which the nitrogen surplus increases somewhat.

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Appendix 3 Sampling of water on farms in 2017

B3.1. Introduction

The derogation decision (EU 2014, see section 1.3) states that a report must be produced on the development of water quality, and that this report must be based, among other things, on monitoring of water leaching from the root zone as well as surface and groundwater quality (Article 10, paragraph 1(f) and 1(g)). The monitoring of the quality of shallow groundwater, soil water, and streams on farms belonging to the monitoring network yields data about the nitrate and phosphorus concentrations in water leaving the root zone and ending up in the groundwater and surface water system (Article 8 (5)).

B3.1.1. Water sampling

In the Netherlands, the groundwater level is often located just below the root zone. The average groundwater level in the Sand Region is approximately 1.5 metres below surface level. The average groundwater level in the Clay Region and Peat Region is higher. The average groundwater level is usually more than five metres below surface level only in the Loess Region and on the push moraines in the Sand Region. In most situations, therefore, water leaching from the root zone or leaching into groundwater can be analysed by sampling the top metre of phreatic groundwater. In situations where the water table is more than five metres below surface level and the soil retains sufficient moisture (in the Loess Region), the soil moisture is sampled below the root zone. There is little agricultural activity on push moraines in the Sand Region where the water table is far below ground level. Where these agricultural activities do occur, the soil moisture below the root zone is also sampled if possible.

The surface water is loaded with nitrogen and phosphorus via run-off and groundwater. In the latter case, the travel times are usually longer. In the High Netherlands, only water leaching from the root zone is monitored by sampling the top metre of groundwater or by sampling soil moisture below the root zone. In areas drained by means of ditches in the Low Netherlands (possibly in combination with tile drainage), the travel times are shorter. Here, the concentrations in surface water are analysed by sampling ditch water, the top metre of groundwater, and/or water from tile drainage (drain water).

B3.1.2. Number of measurements per farm

On each farm, groundwater, soil moisture, and drain water were sampled at sixteen locations, while ditch water was sampled at up to eight locations. The number of measurement locations was based on the results of previous research carried out in the Sand Region (Fraters *et al*., 1998; Boumans *et al*., 1997), in the Clay Region (Meinardi and Van den Eertwegh, 1995, 1997; Rozemeijer *et al*., 2006) and in the Peat Region (Van den Eertwegh and Van Beek, 2004; Van Beek *et al*., 2004; Fraters *et al*., 2002).

B3.1.3. Measurement period and measurement frequency

In the Low Netherlands, samples are taken in winter. In this region of the country, shallow groundwater flows in winter transport a significant portion of the precipitation surplus to the surface water. In polders in the dry season, water from outside the polder is often let in to maintain groundwater levels and water levels in ditches. Samples can be taken in summer as well as winter on sand and loessial soils in the High Netherlands. As the available sampling capacity must be utilised throughout the year, sampling in the Sand Region is carried out in summer and sampling in the Loess Region in autumn. The measurement period (see Figure B3.1) has been chosen in such a manner that the measurements are properly representative of water leaching from the root zone, and thus reflect the agricultural practices of the previous year as accurately as possible. Due to weather conditions, sampling campaigns may need to be extended or started at a later time.

Month	Jan-Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Agricultural data															
Soil moisture in Loess Region															
Total groundwater in Sand Region															
Groundwater in Sand Region in Low Netherlands															
Groundwater in Clay Region[1]															
Groundwater in Peat Region[1]															
Drain water and ditch water in all regions															

[1] The exact date on which sampling is started depends on the amount of precipitation. Sufficient precipitation must have fallen before leaching into groundwater occurs. Sampling never starts later than 1 December.

Figure B3.1: Relationship between data on agricultural practices in a specific year and the water sampling period that has provided the data linked to these agricultural data, for all regions defined in the Minerals Policy Monitoring Programme (LMM)

In the High Netherlands, groundwater and soil moisture are sampled once a year on each farm. The average precipitation surplus in the Netherlands is approximately 300 mm. This quantity of water spreads throughout the soil with a porosity of 0.3 (typical for sandy soils) over a soil layer of approx. 1 metre (saturated soil). Therefore, the quality of the top metre of groundwater is expected to be representative of the water leaching from the root zone every year, and of the loading of the groundwater. Other types of soil (clay, peat, loess) generally have higher porosity. In other words, a sample from the top metre will contain, on average, water from more than just the previous year. A measuring frequency of once every year is therefore sufficient. Previous research has shown that variations in nitrate concentrations in a single year and between years can be eliminated when dilution effects and groundwater level variations are taken into account (Fraters *et al.*, 1997).

From the start of the first sampling period in the Low Netherlands after the granting of derogation (1 October 2006), the sampling frequency for drain water and ditch water was increased from two to three rounds per winter period (the LMM sampling frequency until then) to approximately four rounds per winter (the intended LMM sampling frequency). This higher sampling frequency allows for better distribution during the leaching season. The feasibility of four sampling rounds depends on the weather conditions. It may be impossible to sample drains during periods of frost or insufficient precipitation. The intended LMM sampling frequency was based on research carried out in the early 1990s (Meinardi and Van den Eertwegh, 1995, 1997; Van den Eertwegh, 2002). A review of the LMM programme in the Clay Region in the 1996-2002 period produced the conclusion that there was no reason to change the existing relationship between the number of sampling rounds per farm and per year (actual sampling frequency) and the number of drains sampled on each farm and during each sampling round (Rozemeijer *et al.*, 2006). The sampling frequency was increased in response to a request from the European Commission. A frequency of four times a year corresponds to the proposed sampling frequency for operational monitoring of vulnerable phreatic groundwater with a relatively fast and shallow run-off (EU, 2006).

In addition to the compulsory components of nitrate content, total nitrogen content and total phosphorus content, other water quality characteristics were also determined as part of the chemical analysis of water samples. This was done to explain the results of the measurements of the compulsory components. These additional components include ammonium nitrogen, orthophosphate, and a number of general characteristics such as conductivity, pH value, and dissolved organic carbon concentration. The results of these additional measurements have not been included in this report.

The sections below describe the sampling procedure for each region in greater detail. Sampling was performed in accordance with the applicable work instructions. The text below refers to the applicable work instructions by stating the relevant document number. An overview of the work instructions concerned is provided at the end of this appendix.

B3.2. Sand Region and Loess Region

B3.2.1. Standard sampling procedure

Groundwater sampling on derogation farms in the Sand Region was carried out from April 2017 up to and including October 2017 (see Figure B3.2). In the Loess Region, samples were taken from September 2017 up to and including January 2018 (see Figure B3.2). Each farm was sampled once during these periods.

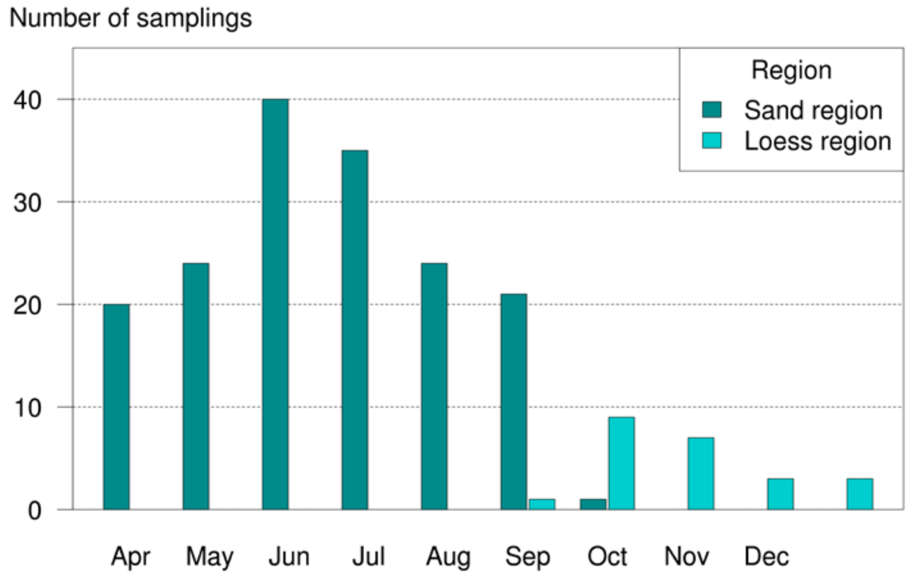

Figure B3.2: Number of samples taken of groundwater and soil moisture in the Sand Region and Loess Region per month in the period from April 2017 up to and including January 2018

The samples were taken in accordance with the standard sampling method. On each farm, samples were taken from bore holes drilled at sixteen locations. The number of locations per plot depended on the size of the plot and the number of plots on each farm. The locations in the plot were selected at random. The locations were selected and positioned in accordance with the applicable protocol (MIL-W-4021). The top metre of groundwater was sampled using the open bore hole method (MIL-W-4015). The groundwater levels and nitrate concentrations were determined in situ at each location (Nitrachek method, MIL-W-4001). The water samples were filtered and stored in a cool dark place prior to transport to the laboratory (MIL-W-4008). Acidification has been deployed as a method of conservation since 1 November 2010, using sample bottles which have been previously acidified in the laboratory or by the manufacturer. Acidification was previously carried out in situ using sulphuric acid or nitric acid (MIL-W-4009). Soil moisture samples were taken by collecting drill cores at depths ranging from 150 to 300 cm, using an Edelman drill. The samples were subsequently transported to the laboratory in untreated form and packed in tightly sealed containers (MIL-W-4014). In the laboratory the samples were centrifuged to collect the soil moisture. In the laboratory two compound samples were prepared (each consisting of eight separate samples) and analysed for nitrate content, total nitrogen content, and total phosphorus content. Bound phosphorus is filtered out when the water samples are filtered. Consequently, the phosphorus concentrations in the LMM programme only concern dissolved phosphorus. These concentrations are lower than the total phosphorus concentrations which include bound as well as dissolved phosphorus (Vrijhoef *et al.*, 2015).

B3.2.2. *Additional sampling in low-lying sandy areas*

On farms in the Sand Region, additional ditch water samples were taken during the period from October 2016 up to and including March 2017 (see Figure B3.3). Samples were taken in accordance with the standard method. On each farm, no more than two types of ditches were distinguished: farm ditches and local ditches. Farm ditches only transport water originating on the farm itself. Local ditches carry water from elsewhere, so that the water leaving the farm is a mixture.

If farm ditches were present, samples were taken downstream (i.e. where the water leaves the farm or ditch) in up to four of these ditches. Furthermore, samples were taken downstream in up to four local ditches to gain insight into the local ditch water quality. If there were no farm ditches, samples were taken both upstream and downstream in four local ditches. This method provides insight into the local water quality and the impact of the farm's activities on water quality. Three types of samples may therefore be distinguished: farm ditch, local ditch (upstream), and local ditch (downstream). The locations for ditch water sampling were selected in accordance with the applicable protocol (MIL-W-4021). The selection was aimed at gaining insight into the impact of the farm's activities on ditch water quality, and excluding as far as possible any effects external to the farm.

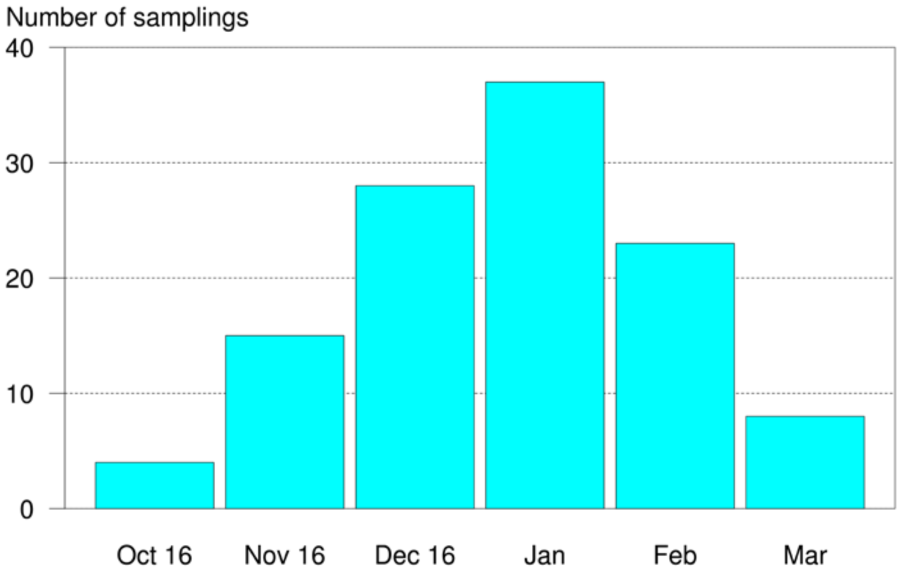

Figure B3.3: Number of ditch water samples in the Sand Region per month during the period from October 2016 up to and including March 2017

Three to four ditch water samples were taken on these farms in the winter of 2016-2017. The ditchwater samples were taken using a measuring beaker attached to a stick or 'fishing rod' (MIL-W-4011). Water samples were stored in a cool, dark place prior to transport to the laboratory (MIL-W-4008). The ditchwater samples were filtered in the laboratory on the next day, and two compound samples were prepared (one for each ditch type). The individual ditch water samples were analysed for nitrate content, and the compound samples were also analysed for total nitrogen and total phosphorus content. Bound phosphorus is filtered out when the water samples are filtered. Consequently, the phosphorus concentrations in the LMM programme only concern dissolved phosphorus. These concentrations are lower than the total phosphorus concentrations which include bound as well as dissolved phosphorus (Vrijhoef *et al.,* 2015).

B3.3. The Clay Region

In the Clay Region, a distinction is made between farms where the soil is drained using drainage pipes and farms where this is not the case. A farm is considered to lack drainage if less than 25% of its acreage is drained using drainage pipes, or if less than 13 drains can be sampled. Different sampling strategies are used on farms with drainage and farms without drainage.

B3.3.1. Farms with drainage

On farms with drainage, drain water and ditch water were sampled during the period from October 2016 through to March 2017 (see Figure B3.4). On each farm, 16 drainage pipes were selected for sampling. The number of drainage pipes to be sampled on each plot depended on the size of the plot. Within one plot, the drains were selected in accordance with the relevant protocol (MIL-W-4021). On each farm, two ditch types were distinguished. For each ditch type, up to four sampling locations were selected (see section B3.2). The selection was performed in accordance with the aforementioned protocol, and was aimed at gaining insight into the impact of the farm's activities on ditch water quality, and excluding as far as possible any effects external to the farm.

During the winter of 2016-2017, drain water and ditch water were sampled between one and four times using the method described in the previous section. Samples were taken throughout the winter; the minimum period between two sampling dates was three weeks.

Water samples were stored in a cool, dark place prior to transport to the laboratory (MIL-W-4008). The next day, the samples were filtered in the laboratory and one compound sample was prepared from the drain water samples in the laboratory, and two compound samples were prepared from the ditchwater samples (one for each ditch type). The individual drain water and ditchwater samples were analysed for nitrate content, and the compound samples were also analysed for total nitrogen content and total phosphorus content. Bound phosphorus is filtered out when the water samples are filtered. Consequently, the phosphorus concentrations in the LMM programme only concern dissolved phosphorus. These concentrations are lower than the total phosphorus concentrations which include bound as well as dissolved phosphorus (Vrijhoef *et al.,* 2015).

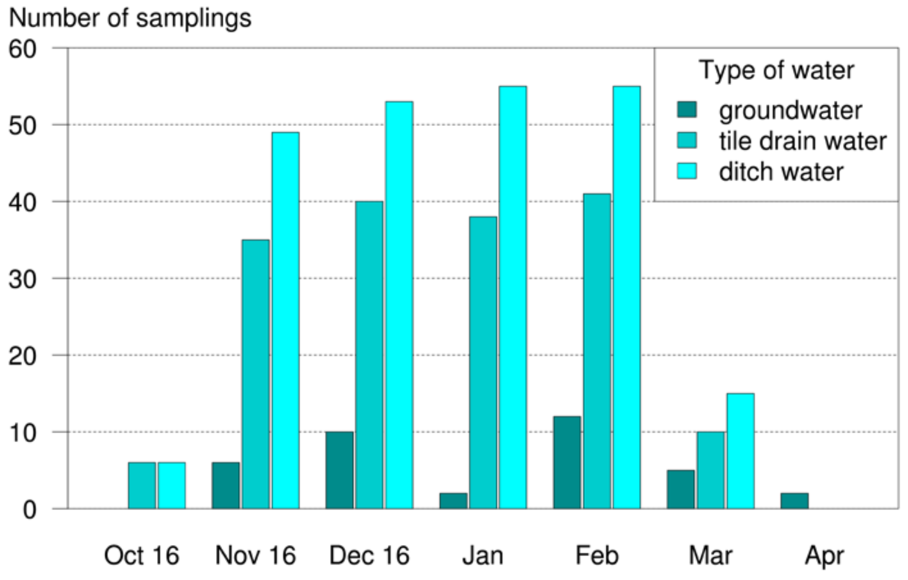

Figure B3.4: Number of groundwater, drain water, and ditch water samples in the Clay Region per month during the period from October 2016 up to and including April 2017

B3.3.2. *Farms without drainage*

On farms without drainage, samples were taken of the top metre of groundwater and ditch water during the period from November 2016 up to and including April 2017 (MIL-W-4021) (see Figure B3.4). On these farms, groundwater samples were taken once or twice, and ditchwater samples were taken a minimum of one time and a maximum of four times.

The groundwater was sampled using a method comparable to the one used in the Sand Region, with the exception that the groundwater was sampled twice in the Clay Region. However, the closed bore hole method (MIL-W-4015) was occasionally used instead of the open bore hole method. The nitrate concentration was determined in situ at each of the 16 locations (Nitrachek method, MIL-W-4001). The water samples were filtered and stored in a cool, dark place prior to transport to the laboratory (MIL-W-4008). Acidification has been deployed as a method of conservation since 1 November 2010, using sample bottles which have been previously acidified in the laboratory or by the manufacturer. Acidification was previously carried out in situ using sulphuric acid or nitric acid (MIL-W-4009). In the laboratory, two compound samples were prepared (each consisting of eight individual samples) and analysed for nitrate content, total nitrogen content, and total phosphorus content. Bound phosphorus is filtered out when the water samples are filtered. Consequently, the phosphorus concentrations in the LMM programme only concern dissolved phosphorus. These concentrations are lower than the total phosphorus concentrations which include bound as well as dissolved phosphorus (Vrijhoef *et al.,* 2015). The ditchwater samples were taken in a manner similar to the method used on farms with drainage, i.e. two ditch types were defined, with up to four sampling locations per ditch type.

B3.4. The Peat Region

In the Peat Region, the top metre of groundwater was sampled once on all farms during the period from October 2016 up to and including March 2017 (see Figure B3.5). In the same period, three to four ditchwater samples were taken on these farms.

The groundwater was sampled using a method similar to the one employed in the Sand Region and Clay Region. However, the reservoir tube method (MIL-W-4015) was generally used instead of the open or closed bore hole method. The nitrate concentration was determined in situ at each of the 16 locations (Nitrachek method, MIL-W-4001). The water samples were filtered and stored in a cool, dark place prior to transport to the laboratory (MIL-W-4008). Acidification has been deployed as a method of conservation since 1 November 2010, using sample bottles which have been previously acidified in the laboratory or by the manufacturer. Acidification was previously carried out in situ using sulphuric acid or nitric acid (MIL-W-4009). In the laboratory, two compound samples were prepared (each consisting of eight individual samples) and analysed for nitrate content, total nitrogen content, and total phosphorus content. Bound phosphorus is filtered out when the water samples are filtered. Consequently, the phosphorus concentrations in the LMM programme only concern dissolved phosphorus. These concentrations are lower than the total phosphorus concentrations which include bound as well as dissolved phosphorus (Vrijhoef *et al.,* 2015).

The ditchwater was sampled using a method similar to the one employed in the Sand Region and Clay Region. The ditchwater samples were taken using a measuring beaker attached to a stick or 'fishing rod' (MIL-W-4011). Water samples were stored in a cool, dark place prior to transport to the laboratory (MIL-W-4008). The ditchwater samples were filtered in the laboratory on the next day, and two compound samples were prepared (one for each ditch type). The individual ditch water samples were analysed for nitrate content, and the compound samples were also analysed for total nitrogen and total phosphorus content. Bound phosphorus is filtered out when the water samples are filtered. Consequently, the phosphorus concentrations in the LMM programme only concern dissolved phosphorus. These concentrations are lower than the total phosphorus concentrations which include bound as well as dissolved phosphorus (Vrijhoef *et al.,* 2015).

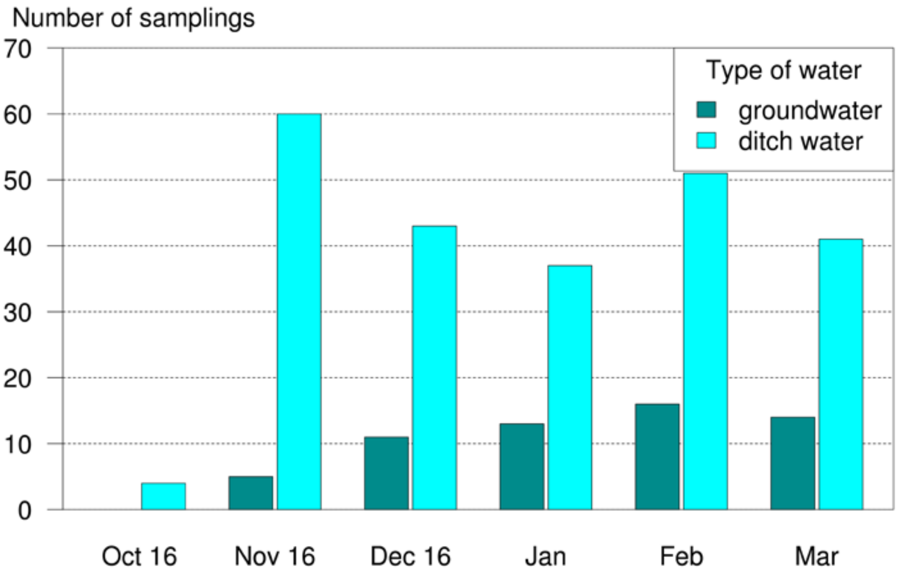

Figure B3.5: Number of groundwater and ditch water samples in the Peat Region per month during the period from October 2016 through to March 2017

The following RIVM work instructions were used

MIL-W-4001	Measuring nitrate concentrations in aqueous solutions using a Nitracheck reflectometer (type 404)
MIL-W-4008	Temporary storage and transportation of samples
MIL-W-4009	Method for conserving water samples by adding acid
MIL-W-4011	Sampling ditchwater or surface water using a modified sampling lance and peristaltic pump
MIL-W-4014	Soil sampling using an Edelman drill for soil moisture analysis purposes
MIL-W-4015	Groundwater sampling using a sampling lance and peristaltic pump on sand, clay or peat soils
MIL-W-4021	Determining sampling locations

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Annex 4. Derogation monitoring network results by year

Table B 4.1: Some general characteristics of farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Farm characteristic	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	2006-2016	Difference	Trend
Number of dairy farms	251	247	253	249	252	255	262	254	250	258	262	259	254		
Number of other grassland farms	43	48	43	44	42	34	33	33	36	30	33	34	38		
Total area of cultivated land (ha)	49	50	51	52	52	53	55	56	56	58	60	61	54	+	+
Proportion of grassland (%)	83	83	82	82	83	83	83	83	86	87	87	87	84	+	+
Proportion of farms with intensive livestock (%)	12	13	12	10	10	8	6	6	6	6	5	5	9	-	-
Total livestock density (LSUs/ha)[1]	3.0	3.1	2.7	2.8	2.9	2.8	2.6	2.7	2.9	3.0	2.9	2.9	2.9	≈	≈
Kg of FPCM per dairy farm (x 1,000)	696	731	779	813	860	869	895	946	983	1,057	1,134	1,179	888	+	+
Kg of FPCM per dairy cow (x 1,000)	8.4	8.4	8.4	8.5	8.7	8.6	8.5	8.5	8.5	8.7	8.8	9.2	8.5	+	+
FPCM production per ha of fodder crop (x 1,000 kg)	14	14	15	15	16	16	16	16	17	18	18	19	16	+	+
Percentage of dairy farms where dairy cows graze:															
• May-October	89	88	86	83	79	78	79	79	77	76	80	81	81	≈	-
• May-June	86	84	82	80	76	76	77	76	76	76	79	80	79	+	-
• July-August	88	88	86	83	79	78	79	78	76	76	79	81	81	≈	-
• September-October	87	87	84	80	74	71	75	76	75	74	77	76	78	≈	-

[1] Phosphate Livestock Unit (LSU) is a unit used to compare numbers of animals based on their standard phosphate production. One adult dairy cow produces 41 kg of phosphate on average, which is equivalent to 1 LSU. One young animal 1-2 years of age produces = 18 kg of phosphate = 0.44 Phosphate LSU. One young animal 0-1 years of age produces = 9 kg of phosphate = 0.22 Phosphate LSU (source: Ministry of Agriculture, Nature & Food Quality, 2000). 15505 Tabellenbrochure MINAS. (MINAS Tables brochure).
Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$). Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.2: Average application of nitrogen in livestock manure (in kg of nitrogen per hectare) on farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Description	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**2006-2016**	**Difference**	**Trend**
Number of farms	273	280	276	272	280	276	278	275	272	275	283	275	276		
Produced on farm	265	272	262	261	286	268	252	269	290	299	299	308	275	+	+
+ Inputs	8	10	10	10	9	11	11	10	8	6	6	7	9	≈	≈
+ stock changes[1]	-4	-8	-7	-1	-8	-5	-5	-6	-13	-8	-2	-5	-6	≈	≈
– Outputs	25	32	28	29	44	33	27	33	46	57	64	64	38	+	+
Total use	240	234	237	238	240	240	231	240	238	237	238	245	238	+	≈
Use on grassland[2]	253	247	254	255	255	253	244	255	251	246	246	256	251	≈	≈
Use on arable land[3]	183	180	171	168	169	175	171	182	185	189	187	180	178	≈	+

[1] A negative change in stocks is a stock increase and corresponds to output of manure.
[2] The average use on grassland is based on the following numbers of farms: 263 (2006), 275 (2007), 263 (2008), 261 (2009), 268 (2010), 262 (2011), 263 (2012), 264 (2013), 265 (2014), 270 (2015), 276 (2016) and 265 (2017), as on a number of farms, the allocation of fertilisers to arable land exceeded the upper limit or fell below the lower limit.
[3] The average use on arable land is based on the following numbers of farms: 195 (2006), 204 (2007), 204 (2008), 200 (2009), 197 (2010), 198 (2011), 198 (2012), 201 (2013), 197 (2014), 202 (2015), 208 (2016) and 202 (2017), since at some farms the allocation of fertilisers to arable land exceeded the upper limit or fell below the lower limit. The allocation of fertilisers to arable land or grassland exceeded the upper limit or fell below the lower limit on the following numbers of farms: 10 (2006), 5 (2007), 13 (2008), 11 (2009), 12 (2010), 14 (2011), 15 (2012), 11 (2013), 7 (2014), 5(2015), 7 (2016) and 10 (2017) farms. Without arable land were 68 (2006), 71 (2007), 59 (2008), 61 (2009), 71 (2010), 64 (2011), 65 (2012), 63 (2013), 68 (2014), 68 (2015), 68 (2016) and 63 (2017) farms.
Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.3: Average application of nitrogen (in kg of client-available nitrogen per hectare) on farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Description	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**2006-2016**	**Difference**	**Trend**
Number of farms	273	280	276	272	280	276	278	275	272	275	283	275	276		
Livestock manure excluding availability coefficient	240	234	237	238	240	240	231	240	238	237	238	245	238	+	≈
Availability coefficient	39	40	48	49	49	49	49	49	49	49	49	49	47	+	+
Animal manure based on statutory availability coefficient	94	93	114	116	117	118	114	117	118	117	117	120	112	+	+
+ Other organic fertilisers	0	0	0	0	0	1	0	0	1	0	0	0	0		
+ inorganic fertilisers	129	127	122	125	123	123	126	125	136	131	130	135	127	+	+
Total use	222	220	236	241	240	242	240	243	255	248	247	255	239	+	+
Nitrogen application standard per farm	291	287	271	263	260	260	258	258	269	273	272	271	269	≈	-
Use on grassland[1]	246	246	265	267	265	267	266	271	279	267	265	278	264	+	+
Nitrogen application standard for grassland	317	314	296	286	282	282	281	281	291	293	291	291	292	≈	-
Use on arable land[2]	108	113	122	123	119	124	123	125	130	130	129	127	122	≈	+
Nitrogen application standard for arable land	157	156	158	153	154	152	143	145	145	141	141	141	150	-	-

[1] The average use on grassland is based on the following numbers of farms: 263 (2006), 275 (2007), 263 (2008), 261 (2009), 268 (2010), 262 (2011), 263 (2012), 264 (2013), 265 (2014), 270 (2015), 276 (2016) and 265 (2017).On a number of farms, the allocation of fertilisers to grasland exceeded the upper limit or fell below the lower limit.

[2] The average use on arable land is based on the following numbers of farms: 195 (2006), 204 (2007), 204 (2008), 200 (2009), 197 (2010), 198 (2011), 198 (2012), 201 (2013), 197 (2014), 202 (2015), 208 (2016) and 202 (2017).The allocation of fertilisers to arable land or grassland exceeded the upper limit or fell below the lower limit on the following numbers of farms: 10 (2006), 5 (2007), 13 (2008), 11 (2009), 12 (2010), 14 (2011), 15 (2012), 11 (2013), 7 (2014), 5(2015), 7 (2016) and 10 (2017) farms. Without arable land were 68 (2006), 71 (2007), 59 (2008), 61 (2009), 71 (2010), 64 (2011), 65 (2012), 63 (2013), 68 (2014), 68 (2015), 68 (2016) and 63 (2017) farms.

Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$). Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.4: Average application of phosphate (in kg P_2O_5/ha)) on farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Description	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**2006-2016**	**Difference**	**Trend**
Number of farms	273	280	276	272	280	276	278	275	272	275	283	275	276		
Livestock manure	87	85	87	87	85	84	81	81	81	78	77	77	83	-	-
+ Other organic fertilisers	0	0	0	0	0	0	0	1	1	1	0	1	0		
+ inorganic fertilisers	10	7	6	3	3	3	3	3	2	0	0	0	4	-	-
Total use	98	92	93	91	88	88	84	84	84	79	78	78	87	-	-
Phosphate application standard per farm	108	106	101	102	91	91	88	87	86	84	84	84	94	-	-
Use on grassland[1]	100	94	97	93	91	90	87	86	87	82	80	81	90	-	-
Phosphate application standard for grassland	111	110	104	106	94	94	92	92	91	88	88	88	97	-	-
Use on arable land[2]	89	86	82	77	74	77	74	76	78	67	64	62	77	-	-
Phosphate application standard for arable land	95	90	85	85	78	75	69	64	63	59	59	60	75	-	-

[1] The average use on grassland is based on the following numbers of farms: 263 (2006), 275 (2007), 263 (2008), 261 (2009), 268 (2010), 262 (2011), 263 (2012), 264 (2013), 265 (2014), 270 (2015), 276 (2016) and 265 (2017), as on a number of farms, the allocation of fertilisers to arable land exceeded the upper limit or fell below the lower limit.

[2] The average use on arable land is based on the following numbers of farms: 195 (2006), 204 (2007), 204 (2008), 200 (2009), 197 (2010), 198 (2011), 198 (2012), 201 (2013), 197 (2014), 202 (2015), 208 (2016) and 202 (2017), as on a number of farms, the allocation of fertilisers to arable land exceeded the upper limit or fell below the lower limit. The allocation of fertilisers to arable land or grassland exceeded the upper limit or fell below the lower limit on the following numbers of farms: 10 (2006), 5 (2007), 13 (2008), 11 (2009), 12 (2010), 14 (2011), 15 (2012), 11 (2013), 7 (2014), 5(2015), 7 (2016) and 10 (2017) farms. The numbers of farms without arable land were as follows: 68 (2006), 71 (2007), 59 (2008), 61 (2009), 71 (2010), 64 (2011), 65 (2012), 63 (2013), 68 (2014), 68 (2015), 68 (2016) and 63 (2017) farms.

Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$). Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.5: Calculated crop yields for grassland and estimated crop yields for silage maize (in kg of dry matter, nitrogen, phosphate and P_2O_5 per hectare) on farms participating in the derogation monitoring network that meet the criteria for application of the grassland yield calculation method (zie Bijlage 2), for the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Description	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**2006-2016**	**Difference**	**Trend**
Estimated silage maize yield															
Number of farms	174	167	173	183	180	181	179	190	178	186	196	187	181		
Tonnes of dry matter per hectare	15.2	15.5	16.0	16.6	16.2	16.7	17.2	16.3	17.9	17.6	16.8	18.8	16.5	+	+
kg N/ha	189	180	188	192	190	197	182	183	193	192	175	203	187	+	≈
kg P/ha	30	30	31	31	30	32	32	30	35	32	32	32	31	≈	+
Kilogrammes of P_2O_5 per hectare	69	69	70	71	70	73	73	68	81	73	74	74	72	≈	+
Calculated grassland yield															
Number of farms	235	231	228	231	241	239	240	248	238	244	251	242	239		
Tonnes of dry matter per hectare	10.1	10.2	9.9	10.0	9.70	10.5	10.4	9.8	11.2	10.6	11.0	10.0	10.3	-	+
kg N/ha	279	274	276	261	253	264	252	267	301	270	276	292	270	+	+
kg P/ha	35	40	39	35	35	37	38	35	46	37	38	37	38	-	+
kg P_2O_5/ha	79	92	90	81	80	86	88	80	105	85	88	84	87	-	+

Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.6: Nitrogen surplus on the soil surface balance (in kg N/ha) on farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Description	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	2006-2016	Difference	Trend
Number of farms	276	280	276	273	280	276	278	275	272	275	283	275	276		
Inputs of (organic and inorganic) fertilisers, feedstuffs, animals and other products	329	341	324	326	365	332	320	339	347	370	378	382	343	+	+
Outputs of milk, animals, feedstuffs, manure and other products	143	159	152	148	179	161	145	150	193	198	205	220	167	+	+
Deposition, mineralisation and nitrogen fixation	64	64	63	63	53	60	59	56	59	56	56	55	59	-	-
Gaseous emissions resulting from stabling, storage, grazing and application	58	65	61	62	63	60	56	58	59	58	60	62	60	≈	≈
Surplus on soil surface balance															
average	193	182	174	178	176	171	178	186	153	169	168	155	176	-	-
25th percentile[1]	133	120	124	130	127	124	129	140	101	119	117	113	124		
75th percentile[2]	243	239	217	217	218	210	213	222	197	209	210	199	218		

[1]Upper limit of the 25% of farms with the lowest surplus on the soil surface balance.
[2]Lower limit of the 25% of farms with the highest surplus on the soil surface balance.
Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.7: Nitrogen surplus on the soil surface balance (in kg N/ha) on farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016, period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Region	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**2006-2016**	**Difference**	**Trend**
Sand-250 sub-region (n = 45-56)	156	166	162	168	151	163	164	170	134	148	150	154	157	≈	-
Sand-230 sub-region (n = 83-104)	190	171	157	153	166	151	161	172	131	155	147	133	159	-	-
Loess Region (N = 15-20)	136	141	142	129	154	147	151	150	122	171	173	152	147	≈	≈
Clay Region (N = 56-69)	195	179	187	194	171	164	171	181	155	162	178	153	176	-	-
Peat Region (N = 47-59)	254	235	212	231	239	230	238	242	212	217	210	199	229	-	-
All farms (N = 272-283)	193	182	174	178	176	171	178	186	153	169	168	155	176	-	-

Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.8: Phosphate surplus on the soil surface balance (in kg P_2O_5/ha) on farms participating in the derogation monitoring network (DMN) in the 2006-2017 period: average values for the 2006-2016 period, differences between 2017 results and the average values for the 2006-2016 period, and trends identified for the 2006-2017 period

Description	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	2006-2016	Difference	Trend
Number of farms	273	280	276	272	280	276	278	275	272	275	283	275	276		
Inputs of (organic and inorganic) fertilisers, feedstuffs, animals and other products	87	84	80	78	93	79	70	79	77	85	84	86	81	≈	-
Outputs of milk, animals, feedstuffs, manure and other products	61	72	66	64	79	69	63	63	85	83	84	87	72	≈	+
Surplus on soil surface balance															
average	26	12	14	15	14	10	7	16	-8	3	-1	-1	10	-	-
25th percentile[1]	10	-2	2	1	2	-2	-3	5	-24	-11	-15	-15	-3		
75th percentile[2]	38	27	26	27	26	23	19	28	9	17	12	15	23		

[1] Upper limit of the 25% of farms with the lowest surplus on the soil surface balance.
[2] Lower limit of the 25% of farms with the highest surplus on the soil surface balance.
Difference: direction and significance of difference between 2017 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2006-2017 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.9: Average nutrient concentrations (in mg/l)# in the water leaching from the root zone in the 2007-2018 period: average values for the 2007-2017 period, differences between 2018 results and the average values for the 2007-2017 period, and trends identified for the 2007-2018 period*

		'07	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**'18**	**2007-2017**	**Difference**	**Trend**
Sand-250	Number of farms	51	50	52	52	52	53	53	48	43	45	45	47			
	Nitrate	41	29	24	25	28	22	24	23	24	22	16	17	25	-	-
	Phosphorus[1](P)	0.07	0.07	0.07	0.12	0.14	0.12	0.16	0.19	0.21	0.22	0.22	0.17	0.14	≈	≈
	Nitrogen (N)	12	9.9	8.4	8.8	9.5	8.6	8.6	8.6	8.9	8.6	7.2	7.2	9.1	-	-
Sand-230	Number of farms	92	92	90	91	90	94	101	105	109	112	114	108			
	Nitrate	70	55	51	62	47	43	46	51	45	37	32	41	49	-	-
	Phosphorus (P)	0.10	0.09	0.10	0.09	0.11	0.11	0.09	0.12	0.12	0.11	0.12	0.14	0.11	≈	≈
	Nitrogen (N)	19	15	14	16	14	13	13	14	13	11	9.7	12	14	-	-
Loess Region[2]	Number	18	18	20	18	19	19	20	18	18	19	19				
	Nitrate	71	52	50	50	56	54	56	51	42	34	37		52	-	-
	Phosphorus[1](P)	<DT	<DT	<DT	<DT	**	<DT	<DT	<DT	<DT	**	**		<DT	N/A	≈
	Nitrogen (N)	18	13	12	12	14	14	13	12	9.9	8.4	8.8		12	-	-
Clay Region	Number of farms	61	63	64	64	64	60	65	60	60	60	60	57			
	Nitrate	26	16	15	19	13	11	11	15	22	13	16	14	16	≈	-
	Phosphorus (P)	0.36	0.41	0.33	0.25	0.29	0.36	0.26	0.28	0.25	0.29	0.25	0.25	0.30	≈	-
	Nitrogen (N)	9.1	6.2	5.5	6.3	5.2	4.8	4.5	5.4	6.6	4.9	5.4	5.1	5.8	≈	-
Peat Region	Number of farms	49	49	48	48	49	51	57	57	58	59	58	55			
	Nitrate	15	6.0	6.3	13	6.9	4.3	6.3	9.4	13	6.7	6.3	6.8	8.5	≈	≈
	Phosphorus (P)	0.51	0.40	0.33	0.44	0.38	0.42	0.43	0.30	0.35	0.30	0.37	0.33	0.38	≈	-
	Nitrogen (N)	11	9.7	8.2	11	9.4	8.0	8.3	9.3	10	8.4	8.5	8.4	9.2	≈	-

*The concentrations deviate from the final figures that are reported annually (see section 2.4.2 for the calculation method).
#In calculating average concentrations, this report dealt with the detection limits differently than previous reports. Historic figures can therefore deviate a bit from previous reports. **Phosphorus data were rejected in that year
[1] Average phosphorus concentrations below the detection threshold of 0.062 mg/l are indicated by the abbreviation <DT. [2] The data for 2018 are not yet available.
Difference: direction and significance of difference between 2018 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2007-2018 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

*Table B 4.10: Average nutrient concentrations (in mg/l)**# *in the ditch water*[1] *in the 2007-2018 period: average values for the 2007-2017 period, differences between 2018 results and the average values for the 2007-2017 period, and trends identified for the 2007-2018 period*

		'07	**'08**	**'09**	**'10**	**'11**	**'12**	**'13**	**'14**	**'15**	**'16**	**'17**	**'18**	**2007-2017**	**Difference**	**Trend**
Sand-250	Number of farms	11	11	12	13	14	13	12	11	10	10	12	12			
	Nitrate	22	15	13	19	14	11	9.2	20	24	13	18	12	16	-	-
	Phosphorus (P)	0.29	0.24	0.46	0.17	0.13	0.18	0.16	0.18	0.21	0.25	0.17	0.20	0.22	≈	≈
	Nitrogen (N)	7.1	5.8	5.9	6.7	5.4	4.8	4.5	7.0	8.0	5.6	6.7	5.3	6.1	≈	-
Sand-230	Number of farms	21	22	22	21	21	22	23	19	20	19	22	22			
	Nitrate	41	42	34	38	32	24	26	28	26	25	28	33	31	≈	-
	Phosphorus (P)	0.10	0.09	0.09	0.12	0.09	0.09	0.13	0.10	0.15	0.16	0.10	0.18	0.11	≈	≈
	Nitrogen (N)	11	11	9.4	11	9.2	7.7	8.1	8.7	8.3	8.1	8.5	10	9.2	≈	-
Clay Region	Number of farms	60	59	63	63	63	59	64	59	59	59	59	56			
	Nitrate	12	8.8	6.9	9.7	6.2	5.3	4.4	6.0	10	6.8	9.1	7.3	7.8	≈	-
	Phosphorus (P)	0.33	0.36	0.36	0.23	0.27	0.26	0.27	0.27	0.22	0.29	0.24	0.26	0.28	≈	≈
	Nitrogen (N)	4.3	4.0	3.7	4.1	3.5	3.1	3.4	3.4	4.2	3.6	4.0	3.6	3.8	≈	≈
Peat Region	Number of farms	49	48	47	47	48	50	56	56	57	59	57	57			
	Nitrate	5.9	4.2	3.5	3.6	3.7	2.9	2.5	3.5	6.5	3.5	3.6	4.0	3.9	≈	≈
	Phosphorus (P)	0.22	0.14	0.16	0.15	0.16	0.16	0.20	0.19	0.20	0.21	0.17	0.20	0.18	≈	≈
	Nitrogen (N)	3.7	4.2	4.3	4.1	4.6	4.0	4.1	4.3	5.2	4.3	4.3	4.6	4.3	≈	+

*The concentrations deviate from the final figures that are reported annually (see section 2.4.2 for the calculation method).
#In calculating average concentrations, this report dealt with the detection limits differently than previous reports. Historic figures can therefore deviate a bit from previous reports.
[1] There are no LMM farms with ditches in the Loess Region.
Difference: direction and significance of difference between 2018 and average for previous years. ≈: insignificant difference ($p > 0.05$), +/-: significant difference ($p < 0.05$).
Trend: direction and significance of trend in 2007-2018 period. ≈ insignificant trend ($p > 0.05$), +/- significant trend ($p < 0.05$).

Table B 4.11: Average nitrate concentration [*] *(mg/l), measured and corrected for weather conditions and variation in sampling population, in the water leaching from the root zone in Sand-250; in addition, the average relative groundwater suppletion, the groundwater level, the percentages of wetland and dry soils, the average month of sampling, and the differences between the years are presented in standardised concentrations.*

Sand-250									
Year	**Number of farms**	**Relative groundwater suppletion**	**Groundwater level (cm below surface level)**	**Wetland soils (%)**	**Dry soils (%)**	**Average sampling month**	**Nitrate**		**Difference**[1]
							measured	**standard**	
2007	52	1.4	143	34	7	9.0	42	34	C
2008	51	1.0	144	34	5	9.7	29	33	BC
2009	54	1.0	165	33	6	9.3	24	28	ABC
2010	54	1.2	158	33	6	9.9	25	26	ABC
2011	54	1.4	151	34	4	8.6	28	25	AB
2012	53	1.3	145	34	4	8.6	22	21	A
2013	53	1.1	152	33	4	8.5	24	25	AB
2014	48	1.2	147	34	4	8.6	24	24	A
2015	43	1.2	153	34	2	8.4	26	26	ABC
2016	45	1.1	151	36	3	8.5	21	25	ABC
2017	45	1.0	177	36	3	9.2	16	21	A
2018	45	1.3	175	37	3	8.8	19	19	A

[*] The summer sampling as well as winter sampling data for the farms in the derogation monitoring network were used to calculate the average measured and standardised nitrate concentrations.
[1] Average standardised nitrate concentrations with the same letters do not clearly differ from each other.

Table B 4.12: Average nitrate concentration (mg/l), measured and corrected for weather conditions and variation in sampling population, in the water leaching from the root zone in Sand-230; in addition, the average relative groundwater suppletion, the groundwater level, the percentages of wetland and dry soils, the average month of sampling, and the differences between the years are presented in standardised concentrations.*

Sand-230									
Year	**Number of farms**	**Relative groundwater suppletion**	**Groundwater level (cm below surface level)**	**Wetland soils (%)**	**Dry soils (%)**	**Sampling month**	**Nitrate**		**Difference[1]**
							measured	**standard**	
2007	96	1.5	125	9	12	9.5	72	69	F
2008	96	1.2	139	8	12	8.6	57	62	EF
2009	94	1.2	151	8	12	8.7	52	55	DE
2010	95	1.6	134	8	11	8.7	65	61	EF
2011	95	1.7	137	9	12	8.6	50	47	BCD
2012	94	1.4	140	8	12	8.6	43	44	BC
2013	101	1.4	148	7	14	8.8	46	46	BC
2014	105	1.5	138	7	14	8.8	52	49	CD
2015	109	1.4	133	7	14	8.9	46	45	BC
2016	112	1.3	126	8	13	9.0	38	40	B
2017	113	1.2	169	7	14	9.3	33	33	A
2018	107	1.5	175	7	14	8.9	43	39	AB

* The summer sampling as well as winter sampling data for the farms in the derogation monitoring network were used to calculate the average measured and standardised nitrate concentrations.

[1] Average standardised nitrate concentrations with the same letters do not clearly differ from each other.

Appendix 5 Comparison of data on fertiliser usage at derogation farms as calculated by RVO.nl and LMM

B5.1. Introduction

Since 2006, the Netherlands Enterprise Agency (RVO.nl), formerly known as the National Service for the Implementation of Regulations (DR), as well as the Minerals Policy Monitoring Programme (LMM) have reported the calculated fertiliser usage on farms participating in the derogation scheme. Because the calculated data sometimes showed significant discrepancies in the past, *Wageningen Economic Research* has analysed these differences since 2010 at the request of the Ministry of Agriculture, Nature and Food Quality.

One important cause of the calculated differences between the LMM data and the RVO.nl data is related to the different purposes for which fertiliser usage on derogation farms is calculated. The LMM calculations are aimed at calculating the fertilisation rates as accurately as possible, using as much farm-specific information as possible. The fertiliser usage calculations performed by RVO.nl serve a different purpose, namely to discover possible offenders.
There are also differences in the population. The LMM population is a sample of the Agricultural Census data that excludes very small farms. The RVO.nl data concern all farms included in the Agricultural Census that have applied for derogation.

This Appendix compares the fertiliser usage as calculated based on LMM data and stated in this report, with the fertiliser usage as calculated by RVO.nl (see Table B5.1). In addition, an explanation is provided of any differences that were found.

Table B5.1 Fertiliser usage in kg/ha on farms to which derogation has been granted according to RVO.nl data, fertiliser usage in kg/ha on farms according to LMM derogation monitoring results, and differences between these source data in 2017 for both nitrogen and phosphate in kg/ha and in percentages

Item	LMM (kg/ha)	RVO (kg/ha)	Difference between LLM and RVO (basis) (kg/ha)	(%)
Nitrogen				
Livestock manure	245	239	6.1	2.6%
Inorganic fertilisers	136	116	20	17.1%
other organic fertilisers	0	3	-3	-86.1%
Total	382	358	23	6.5%
Phosphate				
Livestock manure	77	81	-4	-5.5%
Inorganic fertilisers	0	0	0	0.0%
other organic fertilisers	1	2	-1	-69.8%
Total	78	83	-6	-6.7%

Source: based on data from RVO and FADN processed by Wageningen Economic Research

B5.2. Approach

The LMM population includes only farms that meet the following criteria:

- Fertilisation with inorganic fertilisers, livestock manure and other organic fertilisers must fall within the LMM confidence intervals. This also applies to total fertilisation (i.e. inorganic fertilisers + livestock manure + other organic fertilisers). The relevant criteria are specified in Appendix 2 (Table B2.1).
- The farm records for the year concerned need to be worked out in detail (that was not possible for 3 farms in 2017).
- Farms may not have an anaerobic digestion plant.
- Farms must actually make use of the derogation in the year concerned (4 farms in the derogation monitoring network did not do so in 2017).

The application of these exclusion criteria meant that the number of LMM farms usable for derogation monitoring purposes in 2017 decreased from 300 to 280.

To enable a comparison with the RVO.nl data, fertiliser usage on these 280 LMM farms was also calculated based on the relevant RVO.nl data. For this purpose, 312 BRS numbers were linked to the 280 LMM farms, as some LMM farms have two BRS numbers (for example due to partners joining or leaving the business during the year), and in those cases the data belonging to the two BRS numbers were combined. Based on their RVO.nl data, 12 LMM farms with 16 BRS numbers turned out to fall outside the confidence intervals specified in Appendix 2. Eventually, the comparison with the RVO.nl data was made for 268 LMM farms with 296 BRS numbers

The following data sources were used to compare the RVO.nl and LMM figures for 2017:

- The Farm Accountancy Data Network (FADN) of *Wageningen Economic Research*: this concerns the 300 farms that qualified for derogation monitoring (DM) in 2017. We mainly analysed the fertilisation data, but also used other FADN data pertaining to these farms where necessary. These farms are all participants in the LMM programme and will therefore be referred to below as 'LMM farms', and the data provided as 'LMM data';
- Data provided by the Netherlands Enterprise Agency (RVO.nl): this concerns 19,024 registration numbers (BRS numbers) of farms that applied for derogation in 2017. Twenty-nine BRS numbers have also been added that were included in the 280 usable LMM farms but not in the 19,024 BRS numbers.
- Data from the 2017 Agricultural Census concerning the 19,053 BRS numbers. In the case of 367 BRS numbers, no number could be found in the 2017 Agricultural Census, leaving 18,686 BRS numbers with Agricultural Census data.

B5.3. Analysis of differences

B5.3.1. Nitrogen in livestock manure

The calculated quantity of applied nitrogen in livestock manure is 6.1 kg per hectare higher according to the LMM data than according to the RVO.nl data (see Table B5.1). Table B5.2 summarises the reasons for these differences.

Differences between the two populations are an important cause of the discrepancies. If the RVO.nl population were to be rendered comparable to the LMM population, the nitrogen use in livestock manure calculated by RVO.nl would increase by 5.7 kg, from 239 (rounded off) to 244 kg N/ha (B in Table B5.2). For this purpose, farms smaller than 10 ha and/or 25,000 SO units have been excluded from the RVO.nl data set in accordance with the LMM population. In addition, the same confidence intervals have been used for the fertiliser quantities as in the LMM data set (see Appendix 2, Table B2.1). By rendering the populations comparable, the difference between the LMM figure and the RVO.nl figure changes from 6.1 kg (A in Table B5.2) to +0.4 kg (A-B in Table B5.2).

The remaining difference of +0.4 kg N/ha (A-B in Table B5.2) may be attributed to the following factors (indicated by a to h):

a. The 268 LMM observations may be regarded as a sample from the much larger RVO.nl population of farms with a size of 10 hectares or more, an economic size of 25,000 SO units or more, and falling within the LMM confidence intervals (i.e. the sample population). If the fertiliser usage on these 268 farms is calculated based on RVO.nl data, the result deviates by 7.6 kg N/ha from the result for this much larger RVO.nl population. This may be considered a sampling difference.
b. The area of cultivated land in use on the above-mentioned 268 LMM farms exceeds the cultivated land area according to RVO.nl data by approximately 0.48 ha. If the RVO.nl results are converted to the area of cultivated land according to LMM data, we get a difference of -1.9 kg N/ha.
c. and d. In addition, the stocks, inputs and outputs registered in the LMM programme sometimes differ from the RVO.nl data. FADN participants are requested to report the actual situation, which may differ from the RVO.nl data. The net effect of these discrepancies in 2017 was that the calculated LMM fertiliser quantities are 0.6 kg N/ha higher than the RVO.nl quantities.
e. The remaining difference (-5.7 kg N/ha; items d through h) can be accounted for by differences in the method used to calculate excretion quantities. The BEX method is used at somewhat more than half of all farms participating in the LMM programme. As a result, the use of livestock manure according to the LMM data is 6.4 kg N/ha less than according to the RVO.nl data. The BEX method is applied in the LMM programme for all farms that report that they use the BEX method, provided that sufficient reliable data are available.
f. The standard-based excretion in the LMM programme is determined with greater accuracy than in the RVO.nl data set. There are a various reasons for this. RVO.nl is not always able to

calculate excretion by dairy cows due to insufficient data on milk supplies or urea levels.
g. Furthermore, the LMM programme takes the stable system into account when determining the standard quantities. Stable system data are not included in the RVO.nl data set, so the lower standard quantities for solid manure are selected in the case of young livestock.
h. In addition, RVO.nl does not classify excretion by hobby animals as 'Excretion', but as 'Other organic fertilisers'.
i. Furthermore, the excretion by intensive livestock is calculated differently, e.g. due to differences in the initial and closing stocks.

Table B5.2 Breakdown of differences in the use of nitrogen in livestock manure on derogation farms according to RVO.nl data and according to LMM data for the year 2017

Item	**Nitrogen kg N/ha**
Difference between LMM and RVO.nl data (A)	6.1
Difference due to different populations (B)	5.7
Difference in comparable populations (A-B)	0.4
The difference (A-B) is caused by:	
a. RVO.nl population ≥ 10 hectares, ≥ 25,000 SO units and within LMM confidence intervals, versus LMM derogation farms with RVO.nl data	7.6
b. Difference in acreage of cultivated land	-1.9
c. Stocks	1.4
d. Inputs and outputs	-0.8
e. Use of BEX* method in LMM programme	-6.4
f. Standard-based excretion by dairy cows	-1.4
g. Standard-based excretion by other cattle	2.4
h. Standard-based excretion by other grazing animals	-0.4
i. Standard-based excretion by intensive livestock	-0.1

Source: based on data from RVO and FADN processed by Wageningen Economic Research.
* The abbreviation BEX stands for Farm-Specific Excretion (National Service for the Implementation of Regulations, 2010).

B5.3.2. *Nitrogen in inorganic fertilisers and other organic fertilisers*

The differences in the use of nitrogen in other organic fertilisers and inorganic fertilisers are minor and can for the most part be attributed to the following factors:

- The farms that were excluded (because of sampling limitations and because they fell outside the confidence intervals) use less fertilisers. The RVO.nl data in Table B5.1 still include farms smaller than 10 ha or 25,000 SO units.
- RVO.nl classifies excretion by hobby animals as 'Other organic fertilisers'.

B5.3.3. *Phosphate in livestock manure, inorganic fertilisers and other organic fertilisers*

The nitrogen-phosphate ratio in cattle manure is reasonably stable. This also applies to other organic fertilisers. The differences in Table B5.1 for phosphate in livestock manure and other organic fertilisers are caused by the same factors as for nitrogen. In the case of phosphate in inorganic fertilisers, there is no difference in the number of kilogrammes stated in Table B5.1. The amount used is also very small: < 0.4 kg phosphate/ha. Derogation farms are not permitted to use phosphate from inorganic fertilisers. LMM farms with more than one BRS number will have at least one BRS number with derogation, whereas the other BRS number or numbers will not be part of the derogation network; on the latter numbers, the use of phosphate from inorganic fertilisers is permitted if they are not part of the derogation network.

B5.4. Conclusion

The differences found do not give cause to adjust the LMM calculation method. This applies to nitrogen as well as phosphate.

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