National Institute for Public Health
and the Environment
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Minerals Policy Monitoring Programme report 2015–2018

Methods and procedures

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R. van Duijnen (author), RIVM
T.C. van Leeuwen (author), Wageningen Economic Research
M.W. Hoogeveen (author), Wageningen Economic Research

Contact:
Richard van Duijnen
Centre for Environmental Monitoring
Richard.van.duijnen@rivm.nl

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Synopsis

Minerals Policy Monitoring Programme report 2015-2018

This report describes the methods and procedures used by the Dutch Minerals Policy Monitoring Programme (LMM) in the years 2015-2018. A similar report is produced every four years. The LMM provides the Dutch government with, among other things, information on the effects of mineral policies on water quality in and under farms in relation to farm management practices. The LMM is therefore important for the evaluation of Dutch and European policies on the use of minerals (nitrates and phosphates).

The LMM also tracks the effects of derogation on water quality and farm management / crop yields. Derogation means that the Netherlands, under certain conditions, is allowed to apply more nitrogen from animal manure than is allowed by the European Nitrates Directive. Countries with a derogation are required to produce an annual report on the effects of applying an increased amount of nitrogen from animal manure.

Between 2015 and 2018 the LMM was adjusted in order to improve and expand it. Among other things, extra measurements were taken in ditches on farms to improve comparability with other monitoring programmes and the Water Framework Directive. Additionally, an increased number of intensive livestock farms, such as pig farms, were sampled.

Wageningen Economic Research and the RIVM cooperate in the LMM to collect information about agricultural practices and water quality on Dutch farms. Wageningen Economic Research collects financial, economic and environmental data on approximately 450 farms. The RIVM measures the quality of groundwater, soil moisture, ditch water and/or drainage water on these farms.

The participating farms are distributed across the four Dutch soil regions (Sand, Clay, Peat, Loess) and four farm types (arable, dairy, intensive livestock and other), which together represent roughly 85 per cent of the agricultural area of these regions.

Keywords: minerals policy, nitrate directive, water quality monitoring, agricultural practices, methods, procedures

Publiekssamenvatting

Minerals Policy Monitoring Programme report 2015-2018

Dit technische rapport beschrijft de werkwijze van het Landelijk Meetnet effecten Mestbeleid (LMM) tussen 2015 en 2018. Dat gebeurt elke vier jaar. Het LMM geeft de Nederlandse overheid onder andere informatie over de effecten van het mestbeleid op de kwaliteit van water onder en op landbouwbedrijven in relatie tot de bedrijfsvoering. Het meetnet is daarmee belangrijk voor de evaluatie van het Nederlandse en Europese beleid over meststoffen (nitraat en fosfaat).

Het LMM houdt ook bij wat de effecten van de zogeheten derogatie zijn op de waterkwaliteit en de bedrijfsvoering / gewasopbrengsten. Derogatie houdt in dat Nederland, onder voorwaarden, meer stikstof met dierlijke mest op het land mag gebruiken dan volgens de Europese nitraatrichtlijn is toegestaan. Landen met derogatie zijn verplicht de effecten van een hogere hoeveelheid stikstof uit dierlijke mest elk jaar bij te houden.

Tussen 2015 en 2018 is het meetnet aangepast om het te verbeteren en uit te breiden. Er zijn onder andere extra metingen gedaan in sloten op landbouwbedrijven. Hiermee sluit het LMM beter aan bij andere meetnetten en de Europese Kaderrichtlijn Water (KRW). Ook is op meer staldierbedrijven, zoals varkensbedrijven, gemeten.

Wageningen Economic Research en het RIVM werken voor het meetnet samen om informatie te verzamelen over de landbouwpraktijk en waterkwaliteit op landbouwbedrijven in Nederland. Wageningen Economic Research verzamelt financiële, economische en milieudata van ongeveer 450 landbouwbedrijven. Het RIVM meet de kwaliteit van het grondwater, bodemvocht, slootwater en/of drainagewater op deze bedrijven.

De bedrijven die aan het LMM meedoen zijn verdeeld over grondsoortregio’s (Zand, Klei, Veen en Löss) en bedrijfstypen (melkvee-, akkerbouw-, staldier- en overige bedrijven).
Ze vertegenwoordigen ongeveer 85 procent van het landbouwgebied in de regio’s.

Kernwoorden: mestbeleid, Nitraatrichtlijn, waterkwaliteit monitoring, landbouwpraktijk, methoden, procedures

Contents

Summary

The Dutch Minerals Policy Monitoring Programme (LMM) has a dual role: evaluation monitoring (EM) to assess the effectiveness of the Dutch agricultural minerals policy; and derogation monitoring (DM) related to the European Nitrates Directive. This derogation allows the Netherlands a higher maximum application of nitrogen from manure. One of the conditions of the derogation is that the effects of the application of higher levels of nitrogen are monitored and reported annually. The LMM is a trend monitoring programme that collects information on agricultural practices and water quality on the participating farms. Government policies influence agricultural practices and therefore also fertiliser application and water quality. This report is a follow-up to the 'Minerals Policy Monitoring Programme report 2007–2010' and the 'Minerals Policy Monitoring Programme report 2011–2014', and describes the methods and procedures used by the LMM in 2015–2018. It is the basis of the reports and websites that present the results of the LMM research.

Approximately 340 of the 450 farms included in the EM and DM programmes are selected from participants in the Farm Accounting Data Network (FADN). Wageningen Economic Research collects financial, economic and environmental data from a sample of approximately 1,500 farms and registers these in the FADN. The other c. 110 LMM farms are specifically selected for the LMM from the Agricultural Census and recorded separately from the regular FADN sample by the FADN administration. The agricultural practice of all farms is described, including the incoming and outgoing flow of nutrients. From the data supplied by farmers, Wageningen Economic Research calculates indicators of agricultural management and environmental pressure, such as the use of and surplus deposits of nitrogen and phosphorus. The RIVM organises the monitoring of groundwater, soil moisture, ditch water and/or drainage water. By monitoring ditch water it is possible to quantify the nitrogen and phosphorus concentrations in surface water on and directly adjacent to farms. The participating farms are spread across the four soil regions (Sand, Clay, Peat and Loess) and four farm types are distinguished by the LMM (arable, dairy, intensive livestock and other animal farms).

In order to optimise the monitoring network and to adapt to changing circumstances, a number of changes were made in the years 2015-2018. The main changes were the measurement of unfiltered ditch water sampled in summer and an increase in the number of intensive livestock farms sampled for the EM programme in the Sand region. Unfiltered ditch water samples are taken to improve the comparison of measurements with those from other surface water monitoring networks. The increased number of intensive livestock farms monitored allows us to better evaluate these farms as a separate category.

Data are checked and analysed, and subsequently presented and reported. The long-term trends in nutrient concentrations are presented on the RIVM website: https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten/trends-in-nutrientconcentraties.

The description of agricultural practices by Wageningen Economic Research can be found on www.wur.nl/lmm.
An overview of the LMM monitoring reports, specific reports and scientific publications published by the RIVM can be found at: https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/publicaties-0.
Those of Wageningen Economic Research can be found at: https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/Economic-Research/Themas/Monitoring-duurzaamheid/Landelijk-Meetnet-effecten-Mestbeleid/Publicaties.htm.

Samenvatting

Het Landelijk Meetnet effecten Mestbeleid (LMM) bestaat uit twee onderdelen: het Basismeetnet (BM) en het Derogatiemeetnet (DM). Het BM monitort de effecten van het Nederlandse mestbeleid. Het DM is nodig om met toestemming van de EU af te wijken van de Europese Nitraatrichtlijn. Aan de derogatie is de opdracht verbonden de effecten van het opbrengen van een hogere hoeveelheid stikstof uit dierlijke mest per hectare te monitoren en jaarlijks te rapporteren. Het LMM is een trendmeetnet dat informatie verzamelt over de landbouwpraktijk en de waterkwaliteit bij het bedrijf. De beleidsmaatregelen van de overheid hebben invloed op de landbouwpraktijk en daardoor ook op het mestgebruik en de waterkwaliteit. Dit rapport is een vervolg op het ‘Minerals Policy Monitoring Programme Report 2007-2010’ en ‘Minerals Policy Monitoring Programme report 2011–2014’ en legt de gebruikte methoden en procedures van het LMM in de periode 2015-2018 vast. Dit rapport vormt de basis voor de rapportages en websites waar de resultaten van het LMM-onderzoek worden gepresenteerd.

Ongeveer 340 van alle 450 bedrijven voor het Basismeetnet en het Derogatiemeetnet zijn geselecteerd uit de deelnemers aan het Bedrijven Informatienet (BIN). In het BIN verzamelt Wageningen Economic Research financiële, economische en milieudata van een steekproef van ongeveer 1500 agrarische bedrijven. De andere 110 LMM bedrijven zijn, voor het grootste deel, specifiek voor het LMM uit de Landbouwtelling geselecteerd en aanvullend op de reguliere BIN-steekproef in de BIN-administratie opgenomen. Van alle LMM bedrijven wordt de landbouwpraktijk vastgelegd, waaronder de binnenkomende en uitgaande nutriëntenstromen. Uit de gegevens van de betrokken agrariërs berekent Wageningen Economic Research kengetallen die de bedrijfsvoering en milieudruk weerspiegelen zoals de gebruiken en overschotten van stikstof en fosfaat. Het RIVM organiseert de bemonstering van grondwater, bodemvocht, slootwater en/of drainagewater. Door de bemonstering van slootwater en drainagewater kunnen ook de stikstof- en fosforverliezen naar het oppervlaktewater in kaart worden gebracht. Door gestratificeerde selectie wordt er voor gezorgd dat de bedrijven evenwichtig over de verschillende grondsoortregio’s en bedrijfstypen verdeeld zijn. De betrokken landbouwbedrijven zijn verdeeld over vier verschillende grondsoortregio’s (Zand, Klei, Veen en Löss). Daarnaast onderscheidt het LMM vier verschillende typen landbouwbedrijven (melkvee, akkerbouw, staldieren en overige dierbedrijven).

In de periode 2015-2018 is een aantal wijzigingen doorgevoerd met als doel het meetnet te optimaliseren en af te stemmen op de veranderende omstandigheden. De grootste veranderingen omvatten het nemen van ongefiltreerde slootwatermonsters in de zomer en bemonstering van een groter aantal staldierbedrijven voor het Basismeetnet in de zandregio. Ongefiltreerde zomerwatermonsters zijn genomen om beter aan te sluiten bij andere oppervlaktewatermeetnetten. De grotere hoeveelheid staldierbedrijven zorgt ervoor dat we deze categorie bedrijven beter kunnen evalueren.

De verzamelde data worden gecontroleerd en geanalyseerd, en vervolgens gerapporteerd. De langjarige trends in de nutriëntenconcentraties worden gepresenteerd op: https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten/trends-in-nutrientconcentraties.

De resultaten voor de landbouwpraktijk worden gepresenteerd door Wageningen Economic Research op: www.wur.nl/lmm.
Een overzicht van de reguliere rapporten, specifieke onderzoeken en wetenschappelijke publicaties die gepubliceerd zijn door het RIVM kan gevonden worden op: https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/publicaties-0.

Voor Wageningen Economic Research zijn deze te vinden op: https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/Economic-Research/Themas/Monitoring-duurzaamheid/Landelijk-Meetnet-effecten-Mestbeleid/Publicaties.htm.

1 Introduction

1.1 The Minerals Policy Monitoring Programme

The Minerals Policy Monitoring Programme (LMM) is a national monitoring programme collecting information on farm management practices and water quality on farms in the Netherlands.

The objectives of the LMM are multiple. Originally, the programme was set up to monitor the impacts of the government's agricultural policies on water quality in farms in relation to farm management practices. The programme also serves as an instrument to meet the monitoring requirements imposed by the European Nitrates Directive (EC, 1991) and derogation decisions (EC, 2005, 2010, 2014, 2018, 2020). In addition, LMM data are used to provide scientific support for mineral use standards, to study and assess the relationship between nutrient use and water quality, and for other scientific research purposes.

1.2 Agricultural policies and the role of the LMM

Agricultural production in the Netherlands has increased sharply since the 1950s. Key to this production increase were mechanisation and the use of (artificial) fertilisers and pesticides in crop production and of feed concentrates in livestock farming.

This intensification of agricultural production resulted in significant environmental impacts (on air quality, soil, and ground and surface water). In the mid-1980s, the Dutch government started formulating and implementing policies and measures to reduce emissions of nutrients from agriculture into the environment. The LMM was initiated in the late 1980s to assess the effectiveness of government policies in limiting the impacts of agricultural emissions on groundwater quality. The origins of the LMM predate the Nitrates Directive and Water Framework Directive (WFD).

Annex 1 presents a more detailed description of the development of sector policies and, in parallel, the development of the LMM network.

1.3 Outline of assumptions and methodology

The underlying assumption of the LMM is that government policies can affect farm practices (including the use of nutrients) and thereby reduce emissions to ground and surface waters.

Changes in water quality can only be detected over an extended period. The monitoring of water quality aims to assess the impacts of fertilising practices as directly as possible (minimum interference), with the shortest possible time delay. To this end, the programme samples, on each farm, the water leaching from the root zone (corresponding to the precipitation surplus). The programme also monitors the quality of surface waters, which is a more indirect indicator of such impacts.

For data reporting, the LMM currently distinguishes four principal soil type regions ('regions' in short) and, depending on the region, three principal farm types (Table 1.1). 'Intensive livestock farming' is distinguished as a separate (fourth) type of farming in the Sand region only. The farm types 'other animal farms' and 'intensive livestock farms' are sometimes, in the case of water quality data, reported together.

Table 1.1 Reporting units for data evaluation

Regions distinguished	**Farm types distinguished**
Sand region	Dairy farms
Clay region	Arable farms
Peat region	Other animal farms*
Loess region	Intensive livestock farms*

* In the case of water quality data, these farm types are often reported together.
Note: Not all region–farm type combinations exist; see Section 2 for details.

Farms are the basic units for monitoring. In order to provide reliable conclusions at the level of the classification units (LMM categories, i.e. combinations of region and farm type) shown in Table 1.1, stratification is used in the selection of farms. The principal parameters for stratification are farm type, farm size, and geographical position expressed in terms of region and area within a region. These three parameters lead to different strata. These aspects are explained in detail in Section 2. However, at the level of the individual strata, it is usually not possible to provide reliable conclusions due to the limited number of farms per stratum. Therefore, reporting is limited to the classification units.

The LMM collects a wide range of data related to agricultural management practices and nutrient management. In addition to financial and economic results, the participating farms provide information on the amount of in- and outgoing manure and nutrients and other aspects of farm management. This information is recorded in the Farm Accountancy Data Network (FADN). On the basis of these data, the environmental impact of each participating farm can be assessed. Important indicators in this respect are nitrogen and phosphorus surpluses on the soil surface balance.

Water quality monitoring takes place by sampling the water leaching from the root zone, ditch water and surface drains. Water leaching from the root zone is investigated by sampling (a) the upper 1 metre of the groundwater, (b) soil moisture or (c) water from subsurface drains, depending on the presence of subsurface drains and the depth of the groundwater table. Surface drain water (only in the Peat region) and ditch water and are sampled on a selected number of farms, depending on their presence. Figure 1.1 is a schematisation of the different sampling types.

The LMM tests various parameters to assess water quality. Important parameters are nitrogen and phosphorus components as indicators of nutrient leaching from agricultural soils.

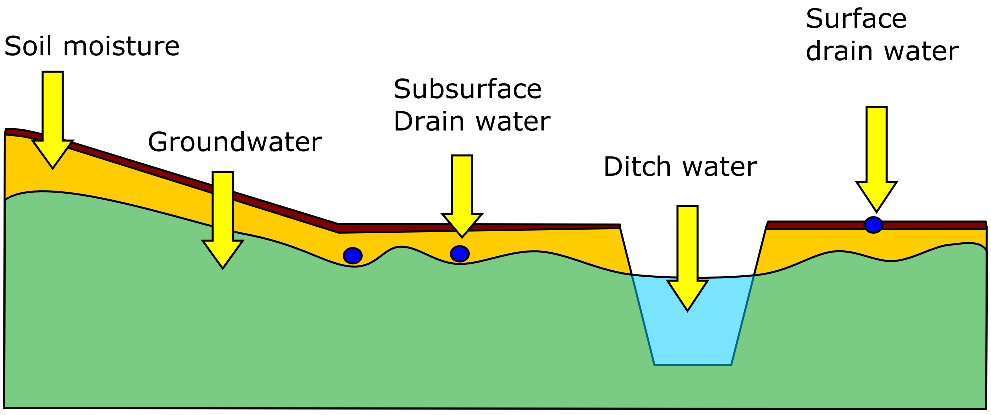


Figure 1.1 Schematisation of the different sampling types: soil moisture, groundwater, drain water and ditch water. The green area represents the water table, the blue dots (sub-)surface drains.

Besides fertilising practices, various other (natural) factors affect the water quality on a farm. Therefore, the LMM also collects information on relevant environmental conditions (meteorology, soil type, groundwater regime, water management practices).

The LMM comprises two main activities. The major activity of the LMM is data collection, processing and validation. The other activity is data analysis, evaluation and reporting.

1.4 Organisations involved in the LMM

Wageningen Economic Research is responsible for collecting and analysing data on farming practices and nutrient management.

The National Institute for Public Health and the Environment (RIVM) is responsible for monitoring and analysing the water quality at participating farms.

The LMM is implemented under the authority of, and financed by, the Ministry of Agriculture, Nature and Food Quality.

1.5 Objective of the report

This report is a background document for the LMM as implemented during the period 2015–2018. It intends to record and present information on the programme’s principles, assumptions, methodology and procedures.

The report covers water quality monitoring during the years 2015–2018 and the monitoring of agricultural practices during the period 2014–2017. It is assumed that farm management practices during year X will affect water quality during year X + ½, + 1 or + 1½, hence the discrepancy between agricultural practice monitoring years (referred to as FADN years) and water quality monitoring years. The connection between farm management practices and water quality varies with the region and season:

- Peat, Clay, Sand (winter): X + ½
- Peat, Clay, Sand (summer): X + 1
- Loess: X + 1½

The results of the LMM are published in other reports and on the relevant websites (see Section 4.3.2).

1.6 Reading guide

This report is structured as follows:

- Section 2: description of the LMM in terms of its set-up and composition.
- Section 3: description of the methodology and planning of data collection activities.
- Section 4: overview of methods of data analysis and presentation of data.

2 LMM set-up and composition

2.1 LMM organisation

2.1.1 Sub-programmes from 2015

In line with the different LMM objectives, data evaluation is carried out in separate sub-programmes.

During the previous reporting period, 2011–2014, the LMM programme was divided into two sub-programmes:

- Evaluation Monitoring (EM): to describe and assess the quality of water at randomly selected farms in relation to current and past environmental stresses from agricultural practices and policy decisions (ex-post evaluation) and to identify long-term trends. The main purpose of this sub-programme was to assess the effectiveness of agricultural policies.
- Derogation Monitoring (DM): to meet the requirements of the EU derogation decisions. DM has similar objectives to EM, but is targeted at grassland farms registered for derogation, which are allowed to apply more nitrogen (up to 230/250 kg nitrogen per ha, depending on the region) through grazing livestock manure than the generally applicable standard of 170 kg of nitrogen per hectare. The DM monitors 300 farms registered for derogation.

Between 2015 and 2018, the set-up of the sub-programmes did not change significantly. From 2015, a distinction has been made in reporting for the DM Sand region. Farms in the southern and central Sand areas that use derogation are allowed only 230 kg N/ha instead of 250 kg N/ha from grazing livestock manure. Other derogation areas are still allowed 250 kg N/ha from grazing livestock manure. This change in derogation condition was implemented in 2014. Thus, the Sand areas that are allowed 230 kg N/ha (Sand 230) and 250 kg N/ha (Sand 250) are reported separately (see Section 2.2.3).

The sub-programmes EM and DM are described in more detail in Sections 2.2.2 and 2.2.3. Each programme is defined to meet specific policy requirements or monitoring needs, and data collection is organised differently (see Section 3).

Other changes

In addition to above-mentioned changes, the following changes or additions were made in the years 2015–2018:

- Since 2017, on all farms where ditch water is sampled in summer, unfiltered ditch water samples have additionally been analysed for total N and P. This is done to improve comparisons with measurements made by regional water authorities and other monitoring networks, such as the Monitoring Network for Nutrients in Agriculture-Specific Surface Water. Results of the unfiltered measurements were first reported in 2020 on the LMM EM results website and were made available on the water quality data selection tool on lmm.rivm.nl. See also Section 3.2.4, 3.2.6 and Annex 7.

- In 2018, the number of intensive livestock farms sampled in the Sand region for EM increased from 12 to 17 and from 2019 onwards to 20 farms. This was done in order to improve our ability to evaluate intensive livestock farms as a separate category. See also Section 2.2.1.

2.1.2 *Selection and recruitment of farms*

The LMM focuses on the most common types of agricultural land use and fertiliser practices found in the Netherlands.

Farms participating in the LMM are, as far as possible, recruited from the Farm Accountancy Data Network (FADN), a network managed by Wageningen Economic Research, which gathers detailed financial, economic and environmental data from about 1,500 agricultural and horticultural farms. The farms selected for inclusion in the FADN are a stratified random sample of all the farms within the target population, covered by the annual national Agricultural Census (Roskam et al., 2020). Stratification uses two principal variables: farm type (based on the Netherlands Standard Output classification) and economic size, expressed as standard output (see Annexes 2 and 3). The FADN represents about 95% of total agricultural production in the Netherlands. Poppe (2004) describes the background to and history of the FADN in detail.

The LMM uses 'soil type area' as a third stratification variable. Furthermore, it puts minimum limits on the spatial extent of the farms selected (≥ 10 ha of cultivated land) and on their economic size (≥ € 25,000 standard output). Although two of the stratification variables (farm type and economic size) are identical in the FADN and the LMM, the criteria applied to the variables differ.

For DM, additional selection criteria are applied. Annexes 2 and 3 elaborate on the stratification variables applied in the FADN and the LMM.

With respect to the different soil types and district, fourteen soil type districts make up four main soil type regions in the LMM: seven in the Sand region, four in the Clay region and two in the Peat region (Figure 2.1). The Loess region covers the southern part of the province of Limburg.

Unlike the FADN, the LMM sample does not include all farm types. The decision to include a specific farm type in a certain region depends on the extent of agricultural land occupied by this type. Farm types that cover only a small percentage of the land (or form a heterogeneous group, like specialized horticultural farms) are excluded from the sample. The number of sample farms required per farm type differs, but remains constant over time. These numbers are defined at the start of a sub-programme, taking into consideration vulnerability to leaching, the relative importance of the farm type in land use and the required/desirable number of farms from a policy or statistical perspective (Fraters and Boumans, 2005).

Figure 2.1 Soil type regions with soil type districts distinguished in LMM

In the reporting period 2015–2018, the following general guidelines were used for selecting and recruiting LMM farms:

1. *Overlap between sub-programmes*. Farms already participating in the sub-programme EM and registered for derogation are also included in the sub-programme DM to the extent possible in constituting and maintaining (e.g. for replacement of 'drop-outs') the research sample. Due to this overlap, the information collected at one farm may be used for both sub-programmes.

2. *Sequence of recruitment*. In selecting and replacing farms (see point 3 below), priority is given to an optimal research sample for EM, followed by DM.
3. *Minimum rotation.* The strategy for the monitoring period 2015-2018 (FADN years 2014–2017) is to use a fixed group of participants. Prior to 2006, a 'revolving' sample was used with periodic replacement of participants after 6–7 years (in accordance with the FADN practice). Since 2006, participants are no longer automatically replaced after 6–7 years of participation and are only replaced if they no longer meet the criteria in place, or if they choose to cease participation. This means in practice that each year about 5% of participants 'drop out' and need to be replaced.
4. *Maximum utilisation of the FADN potential.* While in the past (prior to 2006) the selection of LMM farms focused on farms recently added to the FADN, all farms within the FADN are now considered as potential LMM participants as FADN farms are no longer automatically replaced after 6–7 years of participation.
5. *Additional selection takes place only if the FADN potential is insufficient.* If the FADN cannot provide enough LMM candidates, additional farms are selected outside the FADN.
   - Additional farms for the EM and DM sub-programmes are then selected by stratified random sampling from the Agricultural Census, applying the relevant sample criteria.
   - Fifteen dairy farms in the DM sub-programme were not selected by random sampling. These farms were approached because of their participation in the ongoing research project 'Cows and Opportunities' (K&K).
6. *Inclusion in the FADN of additionally selected LMM farms.* All recruited LMM farms are included in the FADN (i.e. those supplementary to the 1,500 regular FADN farms are added) so that all agricultural practice data are uniformly collected.

2.2 The EM and DM sub-programmes

2.2.1 LMM planning for the period 2015–2018

In 2010, the RIVM and Wageningen Economic Research evaluated the organisation and functioning of the LMM (De Klijne et al., 2010). Based on this evaluation, three scenarios for the continuation of the LMM from 2011 onwards were formulated. Each of the three scenarios provided opportunities to reduce costs, but it was the third scenario, which would meet both the reporting obligations to the European Commission, and national policy needs to a limited extent, that was implemented.

This meant that the sub-programmes EM and DM were continued and other sub-programmes like Exploratory Monitoring (VM), in which 16 farms had been intensively monitored because of their participation in the research project 'Cows and Opportunities' (K&K), lapsed. The changes to the set-up of the LMM included a decrease in the number of participating farms and a decrease in the monitoring frequency.

In the 2006–2010 period, the number of intensive livestock farms in the Sand region had been increased from 12 to 20 farms per year. From 2011 onwards the sample was limited to 12 farms again. However, the smaller sample also limited the potential for evaluating intensive livestock farms as a separate category. To improve this potential, it was decided to increase the number of intensive livestock farms in the Sand region for the EM to 20 per year from 2018 onwards. In 2018, 5 extra intensive livestock farms were recruited, making a total of 17 intensive livestock farms. Since 2019, a total of 20 intensive livestock farms have been monitored.

Table 2.1 lists the number of farms that were planned for the different sub-programmes, divided per region and per broad category: 'dairy' and 'non-dairy' farms.

Table 2.1 Number of farms planned for the different sub-programmes for 2018 (FADN year 2017).

Region	**Evaluation Monitoring (EM)**	**Derogation Monitoring (DM)**
Clay	60	60
Loess	50	20
Peat	24	60
Sand	117	160
Total	**251**	**300**

Farm type	**EM**	**DM**
Dairy farms	109	261
non-dairy farms	142	39
Total	**251**	**300**

The composition of the pool of LMM participants and the number of farms in each of the sub-programmes is subject to some fluctuation. This is caused by farms dropping out or by changes in the management of farms that cause them no longer to meet the selection criteria for a sub-programme.

The LMM focuses more strongly on the Sand region than the other regions (Table 2.1). The reasons for this are the greater extent of the Sand region and the higher vulnerability of this region to nitrogen leaching in comparison with the other regions.

2.2.2 *Evaluation monitoring*

EM, the regular trend-monitoring network, is the LMM's longer-standing and more inclusive LMM sub-programme in terms of the categories reported on and representativeness of Dutch agricultural practice. The main purpose of EM is to assess the effectiveness of agricultural minerals policies.
EM fully follows the general procedures for the selection and recruitment of farms, as presented in Annex 2.

The selection criteria for farms are as follows:

- farms must have an economic size of at least € 25,000 standard output (SO).
- farms must have a minimum area of cultivated land of 10 ha.
- the farm type must correspond to one of those listed in Table A3.4 of Annex 3.

Basically, farms are selected from the FADN, using random (stratified) selection, for which 60 strata are applied (15 categories in 4 size classes; see Section 2.1.3).

On a national scale, the research sample of the EM sub-programme represents 86% of the area of cultivated land and 56% of the total number of farms in the Netherlands. The area of grassland and arable land covered by the land-use units discerned in the LMM ranges from 87% to 92%. For ‘other cultivated land’ the coverage (44%) is relatively low (see Annex 2).
Table 2.2 shows the number of farms selected for each region for the EM programme, the DM programme and the combination of both programmes, and the number of farms outside both programmes.

Table 2.2 Number of farms selected for each soil type region per FADN year.*

	Only	**Only**	**Both EM and**	**Other**	**Total**
2014	**147**	**50**	**252**	**3**	**452**
Clay	42	9	53	0	104
Loess	29	1	19	2	51
Peat	7	9	50	0	66
Sand	69	31	130	1	231
2015	**157**	**52**	**249**	**1**	**459**
Clay	43	11	49	0	103
Loess	31	2	18	0	51
Peat	6	11	50	0	67
Sand	77	28	132	1	238
2016	**151**	**48**	**250**	**1**	**450**
Clay	44	10	50	0	104
Loess	30	1	19	0	50
Peat	6	10	49	0	65
Sand	71	27	132	1	231
2017	**151**	**43**	**256**	**4**	**454**
Clay	43	9	51	2	105
Loess	30	1	19	1	51
Peat	5	10	50	0	65
Sand	73	23	136	1	233

* The year is the year the agricultural activities took place (FADN year). The groundwater sampling is performed between 6 and 18 months later, depending on the region.

Currently, a farm may fall into one of four categories: it participates in EM, in DM or in both EM and DM or it falls into the category ‘other’. The category ‘other’ consists of exceptions. For example, a supernumerary farm was initially recruited for a stratum but did not meet the requirements, and a K&K farm that was recruited into DM no longer met the requirements for DM and was not eligible as an EM farm.

2.2.3 *Derogation monitoring*

The DM programme encompasses 300 farms with derogation: 160 in the Sand region, 60 in the Clay region, 60 in the Peat region and 20 in the Loess region (Fraters and Boumans, 2005; Fraters B. et al., 2007). The size of the DM sample is fixed (minimum of 300 farms), having been imposed by the EC in the derogation decision. Some of the farms already participating in EM were included in DM. Table 2.2 shows that the minimum number of farms is reached in 2 out of 4 study years (range of 298–302 farms per year). However, not all farms applying for derogation will actually use it and farms might stop participating in the monitoring programme during the year. The number of farms in the Sand region constitutes more than 50% of the programme's total, since more than 50% of the area of derogation-eligible farms is situated in the Sand region.

Because the derogation decision requires the monitoring network to be representative of all soil types, fertilising practices (manure application practices) and crop rotations, all types of farming using derogation are included. This implies that farm types not represented in EM are eligible for DM.

One of the selection criteria for the inclusion of a farm in DM is that at least 60% of it is grassland. Until 2013, the formal requirement for obtaining derogation was that at least 70% of the farm's area consisted of grassland (Fraters B. et al., 2007). In 2014, the required grassland area was increased to 80% (Lukacs et al., 2016). The difference in percentages between the selection criteria and formal requirement is related to a difference in timing of recruitment for the monitoring programme versus the moment of granting derogation, as well as different methods of calculation of farm size by the authorities (RVO, CBS) and LMM. Only farms with derogation are eligible for DM. By definition, farms operating according to organic farming principles apply a maximum of 170 kg N per ha from manure and are therefore excluded from DM. For DM, the LMM distinguishes two farm types only: specialised dairy farms and other grassland farms.

A limited number of LMM farms consist of multiple 'census farms', according to the administration at the authorities. Some of these 'specific LMM farms are partly registered for derogation. As long as these LMM farms are at least 60% grassland, they can be selected for DM. In 2013, a threshold for participating DM farms was established: if the proportion of grassland on a DM farm falls below 50%, participation in DM will be stopped.

At the start of the programme, the geographical stratification was based on the concept of groundwater bodies, distinguished in the Netherlands within the framework of the WFD. This geographical stratification was used until FADN year 2012. From 2012 onward, geographical stratification, like EM, has been based on the LMM districts.
Farms already participating in EM and applying for derogation form the basis of DM. New farms from the FADN or, in the case of a lack of FADN candidates, the Agricultural Census supplement this base group.

In summary: most DM farms in the LMM are selected randomly from the FADN or the Agricultural Census, in accordance with the previously mentioned criteria. Some derogation farms participating in special programmes (such as K&K, 'Caring Dairy', 'North Frisian Woodlands'), are incorporated in the DM as well. These are not randomly selected. Most 'Caring Dairy' farms were phased out in 2013/2014, whereas farms originally participating in 'North Frisian Woodlands' and K&K farms are still participating in DM. In the current situation, a total of 112 strata are applied: 2 farm types, 4 size classes, and between 1 and 7 soil districts per region.

Figure 2.2 provides an overview of the number of farms in the different monitoring programmes from the start of the LMM in 1991.

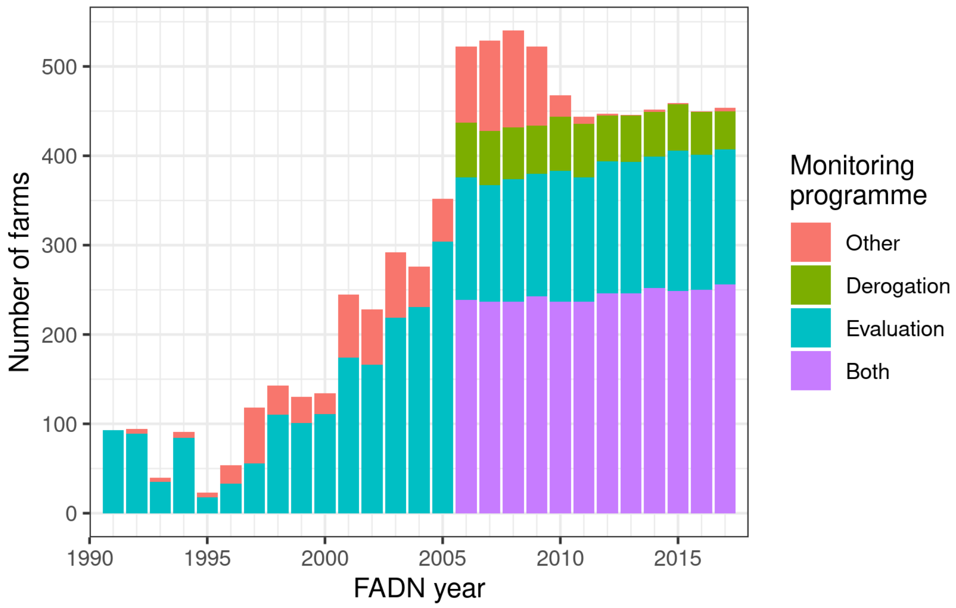


Figure 2.2 Historical overview of the number of farms selected for evaluation and derogation monitoring.

2.2.4 *LMM overview*

Table 2.3 summarises the target number of participating farms, the selection criteria, the number of strata plus the stratification variables, and the mode of selection used in the different sub-programmes (see also Annex 2).

Table 2.3 Selection characteristics of the LMM sub-programmes.

Sub-programme (min. number of participants)*	**Criteria**	**Strata**	**Selection mode**
EM (n=251)	• at least € 25,000 (SO) • at least 10 ha • specific farm type (see Table A3.4, Annex 3)	60 strata (15 categories x 4 size classes)	Fully random selection, from FADN or Agricultural Census
DM (n=300)	• at least € 25,000 (SO) • at least 10 ha • derogation allotted • no organic mode of production	112 strata (2 farm types x 4 size classes x 1–7 soil districts per region)	Random selection from FADN or Agri-cultural Census, except 15 farms parti-cipating in K&K

* Not taking into account overlap between the sub-programmes.

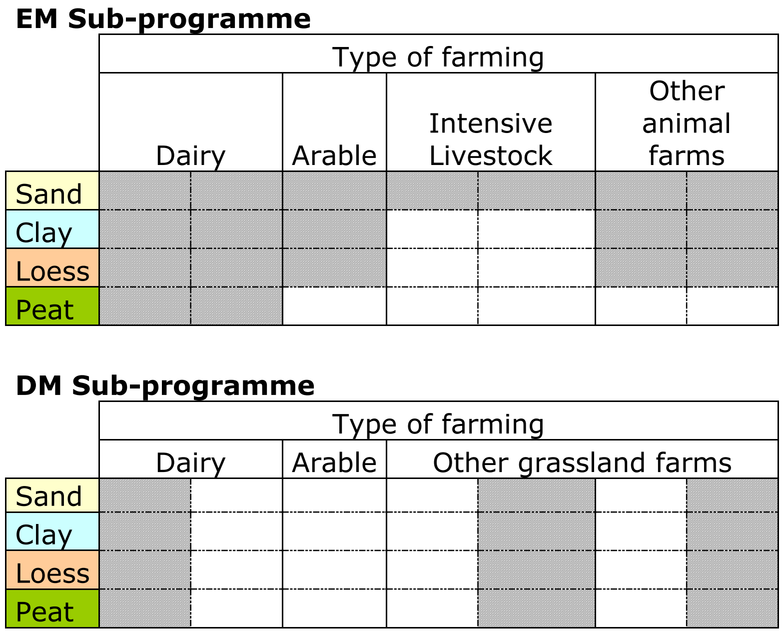
2.2.5 *Farm types for reporting purposes*

The initial focus of the LMM (EM and its predecessor) was on the Sand region. During the 1990s, the Clay and Peat regions were included in the programme. Finally, at the turn of the century, the Loess region was added to the programme. Prior to 2006, the LMM combined the results from the Loess region with those from the Sand region. Since then, the LMM has presented and reported on the Loess region separately.

The LMM started by monitoring dairy farms and arable farms. During the 1990s intensive livestock farms (specialising in granivores like pigs and poultry) and other animal farms (livestock combination farms and crop–livestock combination farms, excluding specialised dairy farms: Table A3.4 of Annex 3) were incorporated into the LMM. Only in the Sand region are intensive livestock farms considered as a separate farm type. In the other soil regions, intensive livestock farms have an insignificant share in the use of cultivated land and are therefore not included in the EM sample.

The LMM reporting categories (combining region and farm type) are not identical to the strata used for the selection of farms. The reporting of results is done at a higher aggregation level. The Netherlands Standard Output (NSO) classification of farm types, used in farm selection, and the corresponding reporting categories are listed in Table A3.5 of Annex 3.

The farm types distinguished in the LMM are aggregated in such a way that the clusters are fairly homogeneous in terms of land use and fertilising practice. For a trend monitoring network like the LMM, limited heterogeneity within the farm type is important. A more homogeneous farm type allows a smaller sample to be used. In all four regions, dairy farms represent a considerable proportion of total land use. In the Peat region, the dominance of dairy farms is such that the EM merely focuses on dairy farms. Figure 2.3 shows the reporting categories in terms of region and farm type for both the EM and DM sub-programmes.



Note: The farm types monitored in the different sub-programmes are hatched. The EM farm types 'Dairy', 'Intensive Livestock' and 'Other animal farms' are divided in two, to address the fact that some EM farms participate in the DM programme as well.

Figure 2.3 Scope of sub-programmes with respect to farm types (simplified).

Figure 2.3 illustrates that EM includes 4 different farm types in the Sand region, 3 types in the regions Clay and Loess and only one farm type (dairy farms) in the Peat region. In the DM, 2 farm types are distinguished: dairy farms, which are the focus of the DM, and 'other grassland farms', which includes all other types of farm that have applied for derogation. Some of the 'other grassland farms' in the DM are participating in the EM as 'intensive livestock farms' or 'other animal farms'.

The categorisation and stratification used for the selection of farms for the EM sub-programme is shown graphically in Figure 2.4.

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Soil type district</th><th colspan="4">Farm type</th></tr>
<tr><th>Dairy</th><th>Arable</th><th>Intensive livestock</th><th>Other animal farms</th></tr>
<tr><td rowspan="3">Sand</td><td>North</td><td>1*</td><td rowspan="2">4A</td><td rowspan="3">5</td><td rowspan="3">6</td></tr>
<tr><td>Central</td><td>2</td></tr>
<tr><td>South</td><td>3</td><td>4B</td></tr>
<tr><td rowspan="4">Clay</td><td>Marine north</td><td rowspan="4">7</td><td rowspan="4">8</td><td rowspan="4"></td><td rowspan="4">9</td></tr>
<tr><td>Marine central west</td></tr>
<tr><td>Marine south west</td></tr>
<tr><td>River clay</td></tr>
<tr><td>Loess</td><td></td><td>10</td><td>11</td><td></td><td>12</td></tr>
<tr><td rowspan="2">Peat</td><td>North</td><td>13</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>West</td><td>14</td></tr>
</table>

_____ boundary between strata
- - - boundary between sub-strata
* each cell (1,2,…14) contains four SO size classes with the same number of farms (see Table A2.2 in Annex 2)

Figure 2.4 Strata with fixed number of farms used in LMM selection and farm types (numbered) for EM reporting. Strata where number of farms depends on area covered are not shown as separate strata.

3 Data collection and processing

3.1 Data on agricultural practices

3.1.1 Practical aspects of collecting data on farm practice

Wageningen Economic Research collects and records data on agricultural practices in the Dutch Farm Accountancy Data Network (FADN, see also Section 2.1.3 and Annex 2). Data acquisition follows standard procedures and protocols.

An administrative staff of approximately 45 full-time employees at Wageningen Economic Research are responsible for collecting and registering farm data in the FADN. Generally, they have an agricultural as well as an administrative background and so are well qualified to collect information on both financial and technical and economic issues. The administrative staff stay in regular contact with the participating farmers by email, phone and farm visits. Personal contact is of great importance for the staff to be aware of the operation of each farm, to get detailed insights into its characteristics, and to build a relationship of mutual trust with the farmers.

Wageningen Economic Research guarantees participants that data on their farms will be confidential and will not be disclosed or used for tax-collection purposes, but only used anonymously for research purposes. To optimise the efficiency of the data acquisition process, Wageningen Economic Research utilises electronically recorded data as far as possible, e.g. bank data on payments and expenditures.

The data recorded in the FADN are comprehensive, and cover a range of aspects of farm management. Wageningen Economic Research staff members make an inventory of initial and final stocks, and collect supplementary information on, for example, cultivation plans, system of grazing and composition of livestock population. In processing invoices, not only the revenues involved, but also the type of products and/or services, the physical quantities and the suppliers and customers are recorded. Moreover, to verify the completeness of invoices, these are linked to electronic payments. It goes without saying that, while being processed into information for participants or researchers, the data are checked for consistency, using common principles and standards. All data are recorded centrally and are accessible to authorised researchers only.

In return for their cooperation, participating farmers receive amongst other things a Corporate Social Performance (CSP) report and a benchmark assessment report for the relevant farm type. The CSP report contains annual totals (see Section 3.1.2) and covers a wide range of sustainability aspects (such as the annual balance sheet and profit/loss account; use of fertilisers, pesticides, energy and water; the effect of surpluses or deficits of nutrients on the soil surface balance).

Most data in the FADN are converted into annual totals and corrected for stock mutations. For example, the annual consumption of feed concentrates is derived from the sum of all purchases made during the period between the two balance sheet dates (minus all sales) plus initial stock minus final stock. The use of fertilisers is registered for each crop, and the data allow calculations of usage, both per year and per growing season. The growing season consists of the period from harvesting the previous crop up to and including the harvesting of the current crop.

Based on the data on agricultural practices, a large number of derived indicators are calculated, such as indicators for the application and utilisation of minerals.

Annex 4 lists the number of farms per region that are used for data collection. The agricultural practices data in the EM are based on a larger number of farms than the water quality data. All farms in the FADN that meet the selection criteria of EM are taken into account in presenting the results.

3.1.2 *Information gathered*

The information collected by Wageningen Economic Research for the FADN covers a large number of topics and is very detailed (see Van der Veen et al., 2006). The farms are grouped according a number of variables, including the following:

- Type of farm structure (e.g. crop area, cropping plan, soil types, size and composition of livestock population, capacity and characteristics of stables, manure store).
- Type of farm management (e.g. grazing period mowing rate, mode and frequency of grassland renewal, use of clover, irrigation, application for and use of derogation, mode and timing of fertiliser application, crop yields, use of feed concentrates, timing of soil tests, type of feed intake, method of milk production).
- Financial and economic aspects (e.g. transactions for ingoing and outgoing products, costs and benefits allocated to crops and livestock species, valuation of permanently available production assets, stocks at the beginning and the end of the year, input of self-contributed labour and capital).

From the data collected, an extensive body of farm statistics is derived for further research and for use by the farmers themselves. On the one hand, this comprises financial and economic results such as performance analyses, profit and loss accounts, revenue and turnover figures, credit balance and costs at crop level or product level. On the other hand, it consists of technical indicators (such as milk production per cow, the use of minerals in fertilisers, and crop yields). In particular, it generates an overview of the average input and supply of minerals with respect to the soil balance.

For further details of the processing of the farm information covered in the LMM report, see Section 4.

3.1.3 *New/extra data collected in the 2015–2018 period*

Within the LMM programme period of 2015–2018 additional data collection in the FADN on several subjects was initiated.

Band application and precision agriculture techniques (from 2017 onwards)

Row crops are better able to take up fertiliser if it is applied close to the row (this is called band application). Band application results in a crop yield increase and a decrease in nutrient losses to the environment. Precision agriculture techniques include in-furrow fertilising, adjusted fertilising based on sensor information and remote sensing via satellites, and controlled traffic farming. In 2017, a onetime survey was carried out on FADN farms, asking about the use of band application and precision agriculture techniques. As a result of this survey the use of band application was added to the annual FADN data collection.

Expansion of recording of participation to equivalent measures (from 2017 onwards)

Farmers who have had higher than average crop yields for the past 3 years or use band application for maize cultivation on Sand and Loess soils are allowed to use extra nutrients. This is permitted by 'equivalent measures', according to which under certain conditions, e.g. a higher than average yield or low soil nutrient status, an increased amount of fertiliser may be used. As of 2010, one such measure, the beet-fries-cereal regulation, allowed farmers who cultivated these crops on clay soils and achieved very high yields to increase their fertiliser use. Farms that took advantage of this regulation were recorded as such in the FADN.
In 2017, equivalent measures were expanded to include other crops and soil types that qualified for nitrogen differentiation (higher nitrogen application standard). In addition, 3 new equivalent measures were launched, namely:

- higher phosphate application standard for soils with a 'low' soil phosphate status and very high yields;
- higher phosphate application standard for soils with a 'neutral' soil phosphate status and very high yields;
- band application in maize cultivation.

The FADN records which farms take advantage of these regulations and the additional fertiliser allowed (nitrogen or phosphate) per crop type. This information improves the calculation of permitted fertiliser use per farm.

Recording participation of relevant nutrient-related projects/pilots

The nutrient management of a farm is dependent on, among other things, level of knowledge about nutrients and awareness of the effects of the use of fertilisers. Many projects aim to encourage and help farmers to use nutrients more efficiently. Since 2018, Wageningen Economic Research has recorded the projects and pilots in which farmers participate. These projects/pilots relate to nutrient levels and soil and/or water quality. Examples are projects within the Delta Plan for Agricultural Water Management (DAW-projects) and the Farm-Specific Nitrogen Application Standard for Animal Manure pilot (BES-pilot). By collecting this information Wageningen Economic Research is better able to explain variations in nutrient management.

3.2 Water quality data

3.2.1 Introduction

The collection of data on water quality takes the following steps: preparation for sampling, water sampling (different methods for different water and soil types), sample treatment, field testing, storage of samples and transport to laboratory, laboratory testing, data recording and quality control, and data validation.
This process, involving thousands of samples per year, is subject to strict quality control. The RIVM optimises the quality of the work by formulating strict working procedures (to minimise errors), facilitating working conditions as much as possible, and computerising data recording.

3.2.2 Preparation for sampling

Prior to the start of water sampling, RIVM staff visit each new LMM farm. During this first visit, general information is collected through a standardised survey. From this, a so-called field file is prepared containing farm-related information such as a map of the farm parcels and the position of sampling points.
Farmers who have previously participated in the LMM are sent a letter with their current farm-related information, asking whether any changes have taken place the last year.
Additionally, at some farms the drains are cleared annually in advance of the start of the new sampling season.

3.2.3 Water sampling

Fieldworkers contact farmers during sampling, if possible, to record any other relevant changes in the field file.
The method and timing of water sampling is primarily determined by the soil type and the type of water sampled:

- root zone leaching:
  - upper metre of groundwater;
  - soil moisture in unsaturated zone below root zone;
  - tile drain water;
- ditch water;
- surface drain water.

For this reason, water sampling is organised in different 'sampling sub-projects', independent from, and cross-cutting, the sub-programmes described in Section 2. The number of samples per farm, the sampling frequency and the method of sampling may differ per sampling sub-project.

Prior to 2004, the LMM focused on water leaching from the root zone. Root zone leachate was measured by sampling the upper metre of groundwater, water from tile drains or soil moisture in the unsaturated zone below the root zone. Only in the Peat region were ditches sampled as well. From 2004, the scope was broadened to include the quality of surface water (water in ditches and surface drains) and the number of sampling sub-projects grew (Table 3.1). This development was caused by the increased interest in the groundwater–surface water relationship (recommendations of the Spiertz Committee; Velthof, 2000) and the monitoring obligations related to the Nitrates Directive and the derogation decision (see Annex 1). This new approach enables the quantification of nutrient loss from agricultural land and of leaching into the wider environment.

Table 3.1 Sampling periods and frequency in the years 2014–2019 (FADN years 2014–2017).

			winter 2014–2015	summer 2015	winter 2015–2016	summer 2016	winter 2016–2017	summer 2017	winter 2017–2018	summer 2018	winter 2018–2019	Sampling frequency (times per season)
Evaluation and Derogation monitoring												
Sand	Winter	Drains and ditches (wet parts)										4 or 3†
		Groundwater										1
	Summer	Ditches (wet parts)										3
		Groundwater										1
Clay	Winter	Drains and ditches										4 or 3†
		Groundwater										2
		Ditches*										2 or 1†
	Summer	Ditches										3
Peat	Winter	Surface drains and ditches**										4
		Ditches***										3
		Groundwater										1
	Summer	Ditches										3
Loess	Winter	Soil moisture										1

*) Only farms where groundwater is being sampled – ca. 25 of 105 farms
**) Only farms where surface drains are being sampled – ca. 20 of 65 farms
***) Only farms where surface drains are not being sampled – ca. 45 of 65 farms
† Higher number for farms with livestock, lower number for arable farms

Drains and ditches are sampled at the same time if possible. In winter, the interval between the sampling of drains and ditches is three weeks. During summer, the interval between the sampling of ditches is five weeks, whereas drains are never sampled in summer. A conservative approach is followed, whereby the aim is to sample the same location as the year before. When this is not possible, an alternative location is used. Surface drain water and ditch water samples are taken on ca. 20 of the 65 farms in the Peat region.

In the Sand region, groundwater is sampled in preference to soil moisture. However, when the groundwater level is more than 5 m deep, soil moisture is sampled instead.

At 5% of the farms per region, RIVM staff carry out an additional drain and ditch water sampling round (a ‘control round’) as a quality check of the standard sampling. This is done because all of the drain and ditch water sampling is done by external agencies (see Annex 6). Groundwater sampling is done partly by the RIVM in a rotating sampling scheme, thus ensuring quality control. The RIVM performs all soil moisture sampling in the Loess region.

Since 2011, some changes have been made to the sampling frequency. In the winter, drains and ditches on arable farms (without derogation) are sampled three times instead of four times. The summer sampling of ditches has also been reduced from four to three times and the breaks between the rounds in the summer period have increased to five weeks instead of four weeks. However, in the event of long dry periods during winter, the winter sampling interval is reduced (to a minimum of 2 weeks) in order to attain the required number of samplings.

The last column of Table 3.1 lists the sampling frequency for each of the regions. The periods in which sampling is planned to be carried out are shown in Figure 3.1. The annual cycle covers about 15 months: from October (year X) until December (year X + 1), depending on the soil region. An extension to January or February for soil moisture sampling is possible in the event of long periods of frost or rainfall. In the winter, the date when sampling starts in the Peat, Clay and Sand regions depends on the start of the groundwater recharge. Groundwater recharge is assumed to have started when precipitation has been sufficient to start drainage of groundwater via tile drains. However, the sampling of groundwater never starts later than 1 December. The sampling of soil moisture starts in October. Until winter 2015/16 (FADN year 2014) it started in September, but soil moisture sampling requires a temperature of below 20 degrees Celsius and no rainfall. Due to the increase in the number of days in September with temperatures over 20 degrees Celsius for long periods of the day, it was decided to start sampling a month later, in October.

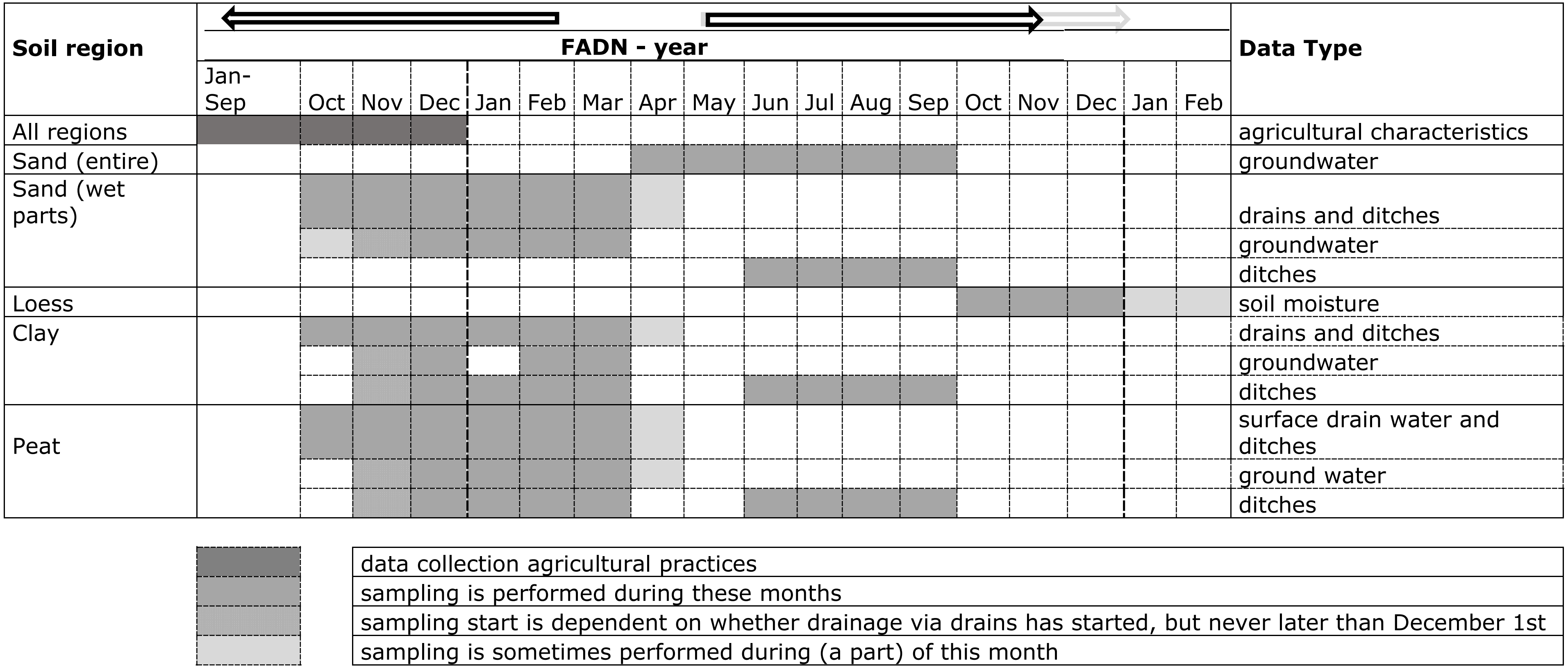


Figure 3.1 Overview of sampling periods, aggregated per region, performed for the period winter 2014/2015-winter 2018/2019 (FADN years 2014-2017)

3.2.4 *Sampling methods and procedures*

The sampling method depends on the water type sampled. Normally, groundwater is sampled from temporary boreholes using the open borehole method (also referred to as the 'sand method'; see Annex 5). However, the method for peat soils is sometimes (but rarely) used. In the peat soils method, a bailer is often used to remove sediment and organic material. Water from tile and surface drains is collected in simple jugs. The same method is used for water from ditches. Until summer 2014, a modified sampling nozzle in combination with a peristaltic pump was used when sampling ditches at the same time as groundwater, but this technique has not been used since. Schematic drawings of the groundwater sampling methods are given in Figure 3.2. Annex 5 provides detailed information on the different sampling methods.

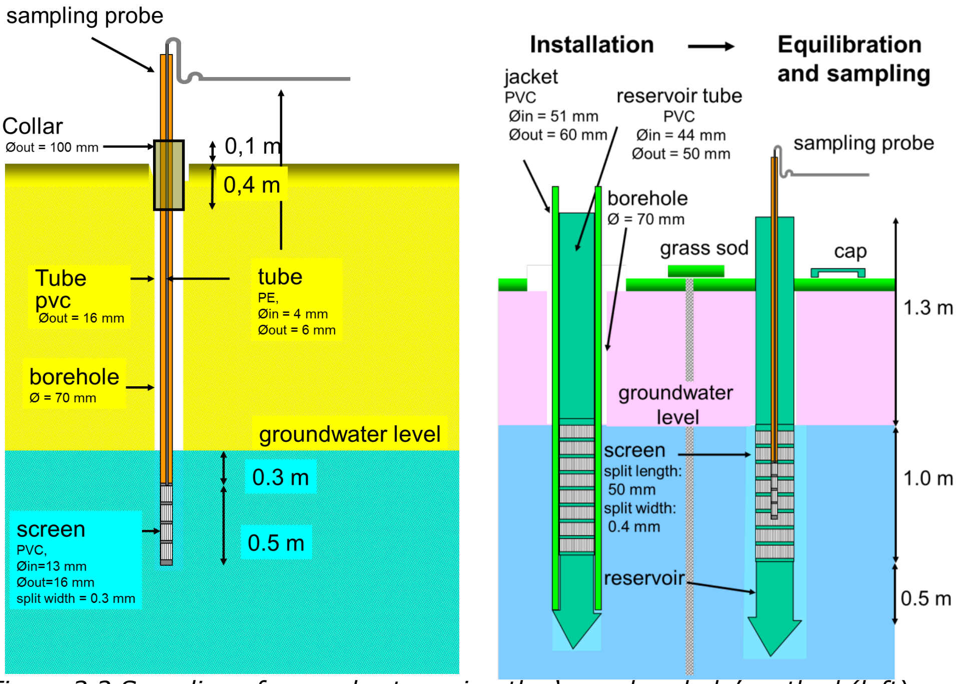


Figure 3.2 Sampling of groundwater using the 'open borehole' method (left) and the 'peat soil' method (right).

The water leaching from the root zone (groundwater, tile drains and soil moisture) and surface drain water is sampled at 16 locations per farm. Water from ditches is sampled at a maximum of 8 locations. The number of samples depends on the number of available ditches.

Sandy soil, with its coarse texture, is usually quite permeable. Consequently, most of the rainwater surplus infiltrates vertically towards the groundwater. For this reason, samples on sandy soils are normally taken in the top 1 metre of the groundwater (Figure 3.3). If the groundwater level is more than 5 metres below the surface, soil moisture is sampled instead.

Routine sampling (of groundwater or soil moisture if the groundwater level is more than 5 metres below surface level) takes place in the summer period (once per year). At a subset of farms – in the wet parts of the Sand region and with 25% of their area drained by tile drains or

50% drained by ditches – additional sampling is done in winter (Buis et al., 2015). At those farms, groundwater (or occasionally soil moisture) is sampled once in winter as well, when drain water and ditch water are sampled 3 times (at arable farms) or 4 times (at all other farm types).

Clay soils are fine grained; usually, they are relatively impervious. Only part of the rainfall surplus infiltrates to the groundwater. The remainder is drained (either overland or through tile drains) towards ditches, and ultimately to larger surface water bodies. In the Clay region, the LMM distinguishes drained farms (with tile drains on more than 25% of their area) and undrained farms (less than 25% of the area drained by tile drains).

At drained farms, the LMM samples the drains and ditches 3 times (at arable farms) or 4 times (at all other farm types) during winter (see Figure 3.4 and Figure 3.5). At undrained farms, the LMM samples the top 1 metre of the groundwater (twice) and ditches (3 or 4 times) during winter.

In the Peat region, with very shallow groundwater table levels (around 0.5 metre below the surface) and a high density of ditches, the rainfall excess partly recharges the groundwater but most of the excess is also drained towards ditches. For that reason, both groundwater (once per year) and ditch water (4 times per year) are sampled (Figure 3.3). The LMM samples surface drains at 20 farms, 4 times per year during the winter season.

In the Loess region (where the groundwater table is usually more than 5 metres below surface level) it is not possible to sample groundwater by hand boring using the open auger method. Here the unsaturated soil is sampled at a depth of between 1.5 m and 3 m below the surface. The quality and quantity of the extracted soil moisture are determined in the laboratory.

Since 2008, ditch water has also been sampled during the summer period in the Clay and Peat regions, as well as on the subset of farms in the wet parts of the Sand region. Since 2011, the number of samples taken has been reduced from 4 to 3. Since 2017, ditch water sampled in summer has also been analysed for total N and P in unfiltered samples.

Sample containers and sample conservation

Field staff responsible for water sampling are equipped with sample containers (bottles) suitable for the different analyses, stickered with pre-printed labels specifying the farm visited, the sampling round and the medium sampled. These pre-printed labels prevent inaccuracies and mistakes in sample identification. If required for conservation purposes, samples are acidified using H_2SO_4 or HNO_3 (depending on the type of analyses planned). The acids are added to the bottles prior to sampling. All water samples, except the unfiltered ditch water samples taken in the summer period, are filtered through a 0.45 µm, 300 mm^2 membrane filter. Groundwater samples are filtered in the field.

Samples of drain water and ditch water are filtered in the laboratory (before winter 2014, ditch water sampled at the time of groundwater sampling was filtered and pre-treated in the field, but since then the groundwater and ditch water sampling have always been performed separately). Unfiltered ditch water samples are not filtered at all. Large particles, however, are removed by straining. Composite samples of soil moisture are combined in the laboratory. Until 2015, composite soil moisture samples were combined in the field. Table 3.2 summarises the sample bottles used and their characteristics per medium sampled. Detailed field and laboratory tests are described in Section 3.2.6.

Table 3.2 Characteristics of sample containers, sample treatment and laboratory analysis package for different water types.

Medium sampled	**Type of bottle**	**Volume (ml)**	**Indivi-dual/composite**	**Filtration in field**	**Acidified**	**Analysis package ***
Ground-water	PE	125	Comp.	Yes	Yes (H_2SO_4)*	A
	PE	100	Comp.	Yes	No	B
	PE	250	Comp.	Yes	Yes (HNO_3)*	C
Drain water	PE	125	Indiv.	No**	No**	D
	PE	125	Comp.	No**	No**	A+B+C
Ditch water (filtered)	PE	100	Indiv.	No**	No**	D
	PE	•500 (3-4 samples) •1000 (2 samples) •1500 (1 sample)	Comp.	No**	No**	A+B+C
Ditch water (un-filtered)	PE	100	Comp.	No	Yes (H_2SO_4)*	E
Soil moisture	PE	500 g (870 ml)	Indiv.	Not appl.	No	F
	Glass	188 g (550 ml)	Comp.	Not appl.	No	A+B+C

A = DOC, ortho-phosphate, nitrate, total nitrogen and ammonium
B = chloride, nitrate, nitrite, sulphate, specific conductivity and pH
C = metals and total phosphorus
D = EC, pH, NO_3 and NO_2
E = Kjeldahl-nitrogen and total phosphorus
F = Cl, NH_4, NO_3 and SO_4
* The acids are added to the bottles by the supplier.
** Filtration and acidification are done in the laboratory.

3.2.5 *Storage and transport of water samples*

The storage and transport of water samples is done in accordance with standard Work Instructions (Annex 5). A portable cool box with cooling elements is used for temporary storage of samples in the field and for transport between two or more sampling points. The samples are

transferred to a fixed or mobile fridge in the fieldwork vehicle during, or latest at the end, of the sampling day.
Normally, the samples are transported to the laboratory on the day of sampling itself. Either the fieldworker does this herself or one or more cool boxes are sent by courier. If same-day transport is not possible, the fieldworker is responsible for keeping the samples in a refrigerator at a constant temperature of +4 °C and a warning system that is activated if the temperature drops below +1 °C or rises above +7 °C.

Responsibility for water sampling
The bulk of the fieldwork is outsourced to external parties. The RIVM remains the principal agent with respect to overall planning, first-time visits to new participants, the sampling of groundwater, quality control and carrying out a control round of ditch and drain water sampling. Annex 6 provides a summary of the agents responsible for the different sampling sub-projects.

Number of samples taken
The effort involved in visiting participating farms for water quality sampling is substantial. The number of farm visits (rounds) ranges from 1,930 to nearly 2,000 per year, and the number of individual water samples taken from roughly 22,100 to 22,700 per year. Of the individual samples, approximately 6,675 are measured in the field and 15,770 in the laboratory per year. Individual samples are combined into composite samples, which results in between 4,175 and 4,275 composite samples per year for laboratory testing.

Information about water quality for participating farms
After sampling, participants receive a written report. In addition to the measured parameters on their own farm, the average results of the other farms in the same region are given for comparison.

Figure 3.3 Sampling of groundwater in the Sand region using a temporary bore-hole.

Figure 3.4 Sampling of drain water.


Figure 3.5 Sampling of ditch water using a jug.

3.2.6 *Testing of water quality*

Field testing

Samples of groundwater are tested in the field for temperature, pH, specific electrical conductance (EC), dissolved oxygen content and nitrate. The fieldworkers use the following equipment:

- Nitrachek-reflectometer (type 404) for nitrate;
- Multimeter WTW Multi 350i with accessory electrodes, namely;
  - WTW Sentix 41 for pH;
  - ConOx for EC, dissolved oxygen and temperature.

In addition, a log of the soil layers perforated, the groundwater level and sampling point coordinates is made. For soil moisture soil layers only a simple log of the soil layers perforated and the sampling point coordinates is made. In water samples taken from ditches, the height, width and depth of the ditch are measured, as well as the visual clarity and the direction of the water flow. In water samples taken from tile and surface drains, the flow rate and distance to the ditch are recorded.

Laboratory testing

Individual samples

Chemical parameters for individual soil moisture, ditch water and drain water samples are measured in the laboratory, not in the field. Separate samples are taken for the analysis of these individual samples (see Table 3.2).

Composite samples

Individual samples taken for the purpose of making composite samples are transported to the laboratory. A laboratory assistant makes up the composite samples according to field information (output from a hand-held computer). An equal amount of each individual sample is used for each composite sample. Since 2016, soil moisture samples have been combined in the laboratory instead of the field. Table 3.3 gives a list of possible numbers and types of composite samples per farm.

Table 3.3 Number and types of composite samples per farm.

	Individual samples	**Composite samples**
Groundwater	16 gw	2 gw
	15–1 gw and 1–15 sm*	1 gw and 1 sm*
Maize**	1–16 gw	1 gw
Drain water	16 drw	1 drw
Ditch water	1–4 diw type 1	1 diw
	1–4 diw type 2	1 diw
Soil moisture	16 sm	2 sm
	15–1 gw and 1–15 sm	1 gw and 1 sm

gw = groundwater, sm = soil moisture, drw = drain water, diw = ditch water
* only possible for groundwater in the Sand region
** extra groundwater samples on permanent maize plots at farms with dairy stock (for explanation see text below)

On permanent maize plots extra groundwater samples are taken from the borehole used for the standard sampling:

- if the farm is in the Sand region;
- in the case of dairy farms or crop–livestock combination farms with dairy stock;
- if maize has been grown there for at least 3 consecutive years.

The maize groundwater samples are put together into a separate composite sample. These individual samples are also used to make a ‘normal’ composite sample representing the entire farm.

Analysis

For each farm and per sampling round composite samples are prepared and tested for a wide range of components. The parameters analysed in filtered water samples are:

- dissolved organic carbon (DOC);
- nitrogen compounds: NO_3, NH_4 and total nitrogen (N-total);
- phosphorus compounds: ortho-phosphate (PO_4) and total phosphorus (P-total);
- macro-elements: Na, K, Mg, Ca, SO_4, Cl;
- trace elements: Fe, Al, As, Ba, Cd, Cr, Cu, Mn, Ni, Pb, Sr, Zn.

The parameters analysed in unfiltered ditch water samples taken in summer are:

- Kjeldahl nitrogen;
- P-total.

Concentrations of N-organic are calculated as follows:
N-organic = N-total - NO_3 - NH_4 (mg N/l)

Individual samples of ditches, tile drains and surface drains are tested for EC, pH, and NO_3 and NO_2.
Individual samples of soil moisture are tested individually for Cl, NH_4, NO_3, and SO_4.

Annex 7 gives details of analysis techniques and detection limits.

3.2.7 *Data recording and quality control*

Implementation of Simplemanager and Field Application
In April 2017, newly developed software was deployed for recording farm information, field sampling data and laboratory analyses. The software consists of 2 parts: Simplemanager (a database and web application) and Field Application (an android application for recording data during field sampling; from now on referred to as 'Field App'). This resulted in major improvements in (speed of) data flow and quality control. For a detailed description of the methods in use up to April 2017 see the previous method report (van Vliet et al., 2017).

Simplemanager consolidates multiple steps. Previously, multiple databases (MS Access) were used for information on the farms themselves, whereas locations of drains, planning of field sampling and laboratory analysis results were stored in LIMS (Laboratory Information Management System). Currently, Simplemanager provides one database for all information available that is accessible using SQL. Additionally, an online interface tailored to each user (field worker, laboratory employee, sub-project coordinator, etc.) is available.

Field App has several advantages over the previously used hand-held computer with pre-formatted menus for recording field data. First, the recorded data is send instantly to Simplemanager via an internet connection, thus removing the need to physically transfer data. Second, input by the fieldworker is automatically checked for impossible values (e.g. minimum/maximum permitted values) or is simply a redefined list of possible options. Third, GPS coordinates are automatically recorded for drain and ditch water sampling points. Previously, coordinates were recorded only at ditch water sampling points that were simultaneously sampled with groundwater as well as at soil moisture and groundwater sampling points.

Error prevention
Because the work in the field is often repetitive, extra efforts have been made to prevent errors. To this end, the following provisions are made:
- use of pre-printed labels for sample bottles;
- use of pre-formatted menus for recording field data (Field App);
- strict quality control of recorded information. Before storage in the central database, data are automatically checked for completeness and consistency by a validation module in Simplemanager. Data that are suspected of errors are flagged and checked by an RIVM employee. Any issues are then checked with the corresponding fieldworker.

Quality control system
Water sampling fieldwork and the treatment and transport of samples are embedded in a strict quality control system. Elements of this system are:
- work Instructions for all elements of fieldwork;
- a kick-off meeting between fieldworkers and supervising staff at the start of each monitoring sub-project. In addition, several evaluation meetings are held during the year. Usually, fieldworkers visit the head office once a week for new supplies and to discuss progress and programmes;
- auditing of fieldwork by RIVM staff (fieldwork supervisors and field coordinators) according to a pre-established programme of spot checks; the programme defines the number of spot checks per fieldworker or field team. RIVM staff visit the external fieldworkers every two or three months and the RIVM fieldworkers once a year. The principal objectives of these field audits are:
  - to verify working methods and ensure that Work Instructions are adhered to;
  - to identify and report on deviations from the Work Instructions, and to register the wishes and suggestions of fieldworkers;
  - to identify and communicate to fieldworkers actions to correct deviations;
  - to improve the efficiency of fieldwork by evaluating practice and procedures, and adjusting procedures if required.

The laboratory analyses are also embedded in a strict quality control system with Work Instructions and audits. The laboratory analyses in the period 2015–2018 were done by TNO, which is certified by the Dutch Accreditation Council (registration number L 026) according to EN ISO/IEC 17025:2005. Because of the improvement in data flow, raw laboratory results are now checked for global inconsistencies with computer scripts in R (R Core Team, 2019), while the sampling is still ongoing. This helps to spot inconsistencies much faster. More detailed data validations are also performed at the end of a sub-project, as described in the next paragraph.

3.2.8 Data validation
Data validation uses of two types of test: (a) tests on samples' internal chemical consistency and (b) tests on consistency in space and time. First, the internal chemical consistency of a sample is tested by comparing the laboratory analysis results of the composite sample with

the results of the corresponding field or laboratory tests on individual samples (for NO_3 and EC). The EC values of composite samples are calculated from the major ions in Dutch ground and surface water, as bicarbonate is not measured. Therefore, the EC values of individual and composite samples are compared to ensure that they are of the same order of magnitude. Second, an outlier analysis is performed to check whether the new data fit within the data set for the specific water type of each individual farm.

If inconsistencies or deviations are found, all available information is checked to detect the possible cause. Checks are made on the laboratory test results to detect any internal chemical inconsistency. The parameters checked include:

- The value of N-total, which should equal or exceed the sum of the individual N-compounds (NO_3, and NH_4).
- The value of P-total, which should equal or exceed the amount of orthophosphate.
- In the case of unfiltered samples (only for ditch water sampled in summer, from 2017 onwards), the value of N-total and P-total unfiltered, which should equal or exceed the value of N-total and P-total filtered, respectively.
- The equivalent sum of cations (mEq/l), which, as no bicarbonate is analysed, must be equal to or exceed the equivalent sum of anions.
- The ratio between chloride and the other ions, such as sodium, magnesium, sulphate or strontium.
- The concentration of some heavy metals, in relation to the pH.

The outliers with deviant results are communicated to the laboratory and, if relevant, to the field workers. If the laboratory confirms that the results of the analyses were incorrect, then the data are replaced with the proper data or marked as 'not available'. If the laboratory cannot confirm that the data are wrong and there are no reasons to assume that something went wrong in the field, then the data will stay in the database. In the case of inexplicable extreme outliers or physically/ chemically impossible data, records are marked as such in the database. These marked data can be excluded during data analysis, and are excluded from the data used in reports.

3.3 Use of secondary data

3.3.1 Map material

To locate and describe the farms participating in the LMM, the RIVM uses topographical maps, scale 1:25,000. The planning of the fieldwork also utilises these maps. For the purpose of interpreting the water quality data, other maps are utilised:

- soil map of the Netherlands (1:50,000), aggregated into 7 main soil types, with grid cells of 50 x 50 m resolution (source: Van Drecht and Schepers, 1998). As of 2020, the 2006 version of the soil map of the Netherlands (Alterra, 2006) is used for reports such as the Derogation Network report (Lukács et al., 2020) and the Nitrates Directive report (Fraters B. et al., 2020);
- groundwater regime map (1:50,000) derived from the above soil maps;

- map of soils prone to nitrate leaching (*Droge grondenkaart*) prepared by Wageningen Environmental Research, which is the outcome of the Government decree 'Besluit zand- en lössgronden' (Decree to Identify and Define Policies for Soils Prone to Leaching) issued in 2001.

To optimise data analysis, each farm participating in the LMM is schematised in a polygon representation, defining individual plots. This is made using auxiliary software (Didger) on the basis of the 1:25,000 topographical maps, and stored in GIS (using ArcGIS). After each monitoring visit, the plot/parcel properties of the farms, such as location and surface area, are checked against the properties recorded earlier and adjusted, if necessary, to represent new field (ownership or use) conditions. This information is combined with the soil maps and groundwater regime maps. The resulting overlays are interpreted and used to produce tables listing fractions with respect to soil type and groundwater regime. These data are incorporated in the programme's database.

3.3.2 Meteorological data

Meteorological data in the form of daily averages of precipitation and evaporation are collected from the data made available by the Royal Netherlands Meteorological Institute (KNMI). These data are available for each coordinate from 1970 onwards, and they are based on interpolation of all weather station data and – from around the year 2000 onwards – also on radar precipitation data.
The RIVM uses this meteorological information to apply net precipitation standardisation of the nitrate concentration data. More detail is given in Boumans and Fraters (2016).

3.3.3 Information sources related to farm management

Annual Agricultural Census in the Netherlands
The annual Agricultural Census, which covers almost all agricultural firms in the Netherlands, describes the structure of the agricultural sector (data on farms, crops grown and animals held/reared). The Agricultural Census, conducted annually by the Netherlands Enterprise Agency (RVO) of the Ministry of Economic Affairs and Climate Policy, and the Ministry of Agriculture, Nature and Food Quality in collaboration with Statistics Netherlands (CBS), can be considered as a complete enumeration.
Data from the Agricultural Census are frequently used within the LMM. First of all, these data are essential for the purpose of identifying and describing the field of observations (target population) that is covered by the LMM sample. For example, the Agricultural Census can be used to compare the characteristics of LMM sample farms with the 'average farm' in the target population. Strata boundaries (size classes per LMM farm type) are defined annually on the basis of the most recent census data, including for the purpose of stratification (preceding the selection of participants). Moreover, where there are insufficient farms of a particular type in the FADN, the selection procedure may draw from the pool of farms in the Agricultural Census.

Netherlands Enterprise Agency (RVO)
The Netherlands Enterprise Agency (RVO) is the agency of the Ministry of Economic Affairs and Climate Policy responsible for the implementation of

agricultural and nature policy. The RVO plays an important role in providing policy information to agricultural firms in the Netherlands, as well as in gathering information from those firms.

In the context of the Fertiliser and Minerals Policies, the RVO issues information on legal standards (e.g. application standards, fixed excretion indicators, operational efficiency coefficients) and prescribes calculation systems (for example, for calculating excretion from intensive livestock production such as pigs and poultry using the 'stable balance').

The RVO utilises a farm registration system (*Bedrijfsregistratiesysteem*, BRS) to gather information, whereby a unique BRS number is allocated to each farm covered. It is therefore important for the LMM to combine the RVO database with the FADN database via the BRS number.

The RVO also provides important information and tools related to manure policies that are be used to calculate data such as the quantities of nitrogen and phosphorus in livestock manure.
Additionally, the RVO provides data about parcels. The FADN incorporates the information from the 'base registration of parcels' recorded by the RVO (*BasisRegistratie Percelen*, BRP). This system records annual data for each farm on their cropped plots (reference date 15 May), and for each cropped plot data are recorded on crop type, area, user type (property, non-recurrent lease, etc.), secondary crop (yes/no; if yes: which crop) and use as pasture (yes/no; if yes: with or without grazing).

Finally, the LMM uses the RVO's annual surveys to identify the farms that have applied for derogation.

Working Group on Uniform Data for Animal Excretion (WUM)
Each year, the Working Group on Uniform Data for Animal Excretion (WUM) calculates and publishes the standards for manure production and mineral excretion per animal category (van Bruggen et al., 2018). The WUM comprises representatives from the Ministry of Economic Affairs and Climate Policy, Statistics Netherlands (CBS), the Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving, PBL), Wageningen University & Research (WUR) and the RIVM.

The calculation methodology takes the mineral balance per individual animal as its starting point. The excretion of minerals is determined from the difference between the intake of minerals in forage and the amounts of minerals in animal products.

In the day-to-day implementation of the Minerals Policy, dairy farms must apply different standards for different categories of grazing livestock. Since 2015, the WUM excretions have been the basis for the different standards.

For intensive livestock farm animals such as pigs and poultry, the calculation of manure production has to be based on a stable balance. From the LMM data, this stable balance cannot be determined for each individual farm and, where information is inadequate to apply the method of stable balances, WUM phosphate excretion defaults are used.

Working Group on National Emission Model for Agriculture (NEMA)
Each year, the NEMA working group calculates emissions to the air from agricultural activities in the Netherlands on a national scale (Van Bruggen et al., 2019). Emissions of ammonia (NH_3) and other N-compounds (NO_x and N_2O) from animal housing, manure storage, manure application and grazing are assessed using a Total Ammoniacal Nitrogen (TAN) flow model. More information about this model can be found in Lagerwerf et al. (2019). NEMA comprises representatives from the CBS, PBL, WUR and RIVM. In calculations of emissions to the air on farms within the FADN, the LMM uses, as far as possible, NEMA emission and TAN factors.

Feed suppliers, research laboratories and ANCA
Most of the analyses of soil and silage performed in the Netherlands are carried out by organisations like Eurofins (previously BLGG-agroXpertus). The LMM uses the data from such laboratories in two ways. First, the laboratories pass on the results of the analyses on LMM farms in digital format to Wageningen Economic Research. This procedure facilitates the registration of the results in the FADN.
Second, to calculate the farm-specific composition of grass/corn silage, the LMM sometimes uses data published by the laboratories themselves. Where silage is not (fully) analysed, the LMM uses average composition data from laboratories such as Eurofins.
Information from feed suppliers about the composition of feed and values of specific raw materials of other feedstuffs is gathered in the FADN and used in the LMM when needed.

Additionally, within the LMM programme, a one-time 10-year data set (2008–2017) of soil analyses per parcel of FADN farms was obtained from Eurofins. This information was then linked to the BRP data, the FADN data (farm structure and nutrient management) and the water quality data of the RIVM.

The calculation tool, Annual Nutrient Cycling Assessment, abbreviated as ANCA (*Kringloopwijzer* in Dutch), is used by Dutch dairy farms to estimate the efficiency of dietary phosphorus and nitrogen utilisation at farm level. Farmers that use the ANCA provide the ANCA data to the staff of Wageningen Economic Research. Some input data from ANCA are also used by the FADN to check the information already in the FADN.

4 Data analysis and presentation of data

4.1 Introduction

Information and data deriving from the LMM are disseminated in different ways: via newsletters (paper or digital), (digital) reports, scientific papers, data selection tools and websites.

LMM data are used for many products. The RIVM website provides an overview of the most important frameworks and the related products (https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/organisatie-van-lmm/gebruik-resultaten).

The following section describes the data analysis. The presentation of the data and the reports are discussed in Section 4.3.

4.2 Data analysis

4.2.1 Data on agricultural practices and mineral management (FADN)

Farms differ in farm management (individual choices of a farmer) and in physical conditions (farm size, hydrology and soil conditions).
Section A8.1 in Annex 8 describes in more detail the indicators of farm dimensions and the nutrient management approach.

LMM publications present and discuss the agricultural practices at participating farms in different ways. The annual DM publication summarises the most recent results using unweighted data. In the EM, the agricultural practice results of participating farms are weighted and compared with national average values. Both averages are established using a weighting procedure. This section gives a brief description of the procedures.

In depicting the impacts of manure policy on agricultural practice, the LMM focuses on long-term developments in nutrient use and nutrient surpluses in each of the LMM farm types.

The results for dairy farms (in all regions) and arable farms in the Clay, Sand and Loess regions are published on a yearly basis. The results presented in bar charts and line graphs and other data are updated annually. The results for the farm type 'intensive livestock' in the Sand region were published for the first time in 2020 on www.agrimatie.nl. Those for the farm type 'other animal farms' are awaiting publication.

For the evaluation of agricultural practices, data on the nutrient use of individual farms in the sample are adjusted (processed) by allocating weights based on the weighted average value of the average farm in the research population (see box below).

The agricultural farms covered by the annual Agricultural Census accurately represent the full population of agricultural firms in the Netherlands. The LMM covers a sub-set of this full population, called the LMM research population.

A sub-set of the LMM target population is included in the FADN. These 'LMM research farms in the FADN' are called the 'research sample' (the FADN sample covers about 1,500 farms, while the LMM research sample consists of about 600 farms). It should be noted that only part of this research sample is monitored for water quality.

Data on agricultural practices, such as those for nutrient use, are available for the research farms (because of their participation in the FADN). For the remainder of farms in the LMM research population, no data on agricultural practices are available; only general corporate characteristics from the Annual Census.

The reason for applying a weighting process is the LMM sample design. Like the FADN, the LMM uses a stratified, disproportional sample for selecting farms. 'Disproportional' means in this case that, even for the same farm type, there are differences in the probability of inclusion (see Annex 2 Section A2.2). This sample design necessitates the application of a weighting procedure when considering individual farms.

The weighting process ensures maximum use of the available data. For reasons of reliability, the process not only uses corporate data on farms that are monitored for water quality; all FADN farms that have been part of the LMM target population since 1991 are taken into consideration. This group of LMM research farms is considerably larger and less susceptible to change than the sample of LMM farms at which water quality is monitored.

The trends investigated in the LMM refer to sub-samples of specific farm types in specific regions and sub-regions. With higher levels of zooming-in (lower aggregation levels) the number of sample farms will be smaller. In order to draw conclusions, in spite of the limited number of sample farms, Wageningen Economic Research generates additional information.

To generate additional information and to weight the available farm data, the research sample data are projected on the available data within the target population. For this purpose Wageningen Economic Research has developed the software tool STARS (Statistics for Regional Studies, see Vrolijk et al., 2005: appendix 1). The input for this tool is a file comprising available FADN data (results of agricultural practices and characteristics of individual farms) and corresponding characteristics of the farms in the target population (available from the Agricultural Census). The corresponding farm characteristics (known as imputation variables) are the basis for comparing and matching farms in the research sample with farms in the target population. The core assumption in statistical matching is that farms showing a resemblance in the imputation variables will also be comparable with respect to the target variables.

Statistical matching uses farm characteristics known for both the research sample farms and farms in the target population, in order to identify for each farm in the target population a number (ranging from 3 to 5) of 'most similar' farms. For this purpose, a distinction is made between characteristics that are identical and characteristics that closely resemble the corresponding characteristics of the farm in the target population. The characteristics used for best possible resemblance are differentiated in terms of their relative importance by assigning different weights. All weights allocated to a sample farm are added up in order to calculate a final weighting factor. The weighting factors obtained in this way (the sum of which should equal the number of farms in the target population) are subsequently used for weighting the sample results.

4.2.2 *Data on water quality*

Aggregating analysis results to calculate averages for reporting purposes

Water quality data are normally reported on an annual basis for each water type and farm type. For some combinations of region and water type a distinction is also made between results from samplings in winter and summer.

Depending on the water type, multiple composite samples and/or multiple sampling rounds are performed per farm. The average per farm is calculated as follows:

- The results for each water type, per round and per farm, are averaged to a 'round average' value.
- The round average values are aggregated to a 'farm average' value.

Further aggregations depend on the specific analysis and report. Usually, annual farm averages are further aggregated by farm type and soil region. These data are then reported in tables and graphs.

As of 2020, farm type and region averages of EM data on https://lmm.rivm.nl/ and in the Nitrates Directives report (Fraters B. et al., 2020) are retroactively weighted by the area of specific strata. This is done because the number of farms in a specific stratum is not always proportional to the area they represent.

Minimum number of farms to estimate an average

To determine an average, a minimum of 10 farms is required. If fewer farms are used, both reliability and confidentiality are compromised. If there are fewer than 10 farms of a particular farm type, this group is not represented. However, these farms are included when determining the average of the region (farm type = all).

Detection limits

The detection limit is the lowest concentration of a substance that can be measured with the laboratory equipment in use. Below this value (i.e. with measured concentrations of between 0 and the detection limit), it cannot be concluded that the substance is present.

Concentrations below the detection limit: use output of analyser

Up to 2017, the following formula was normally used when dealing with concentrations below the detection limit: corrected concentration = factor * detection limit, where this factor is a value between 0 and 1 (in the rule

0, ½ or 1). In the LMM, in both EM and DM, we generally used the factor 0 (zero). So, if the concentration was less than the limit of detection, the concentration was considered to be zero. If most data were under the detection limit, the calculated average might also be below the detection limit. In that case, the percentage of farms with a value below the detection limit was often reported as additional information.
Since 2017, we have used the actual output of the analyser when reporting on both EM and DM. Thus, if the concentration is below the detection limit, the actual output of the analyser is used as the measured value. Because all analysers work with a calibration curve, it is possible to obtain negative values this way. If there are a large number of measured values below the detection limit, it is possible that the mean value is below the detection limit. This method is now used for data from 2006 onwards, which means that historical values in previous reports might show slight differences when compared with reports released from 2017 onwards. For data obtained before 2006 it is only known whether the measured value is below the detection limit, and the value is generally set to the factor 0 (zero).

Presentation of detection limit in charts and graphs
In tables, percentile values that are below the detection limit are shown as '<dg'. Average values below the detection limit are similarly reported. The detection limits used are indicated in the table or graph.

Trend determination
In addition to the presentation of the parameters measured during a specific year, the long-term trends for the principal nutrients are reported. Long-term trends are presented using annual average data as measured – calculated as the weighted or unweighted average (depending on the report) of the annual farm averages – and standardized nitrate concentration data (standardized for variations in net precipitation, sample size and sample composition). This method is currently used for presenting standardised regional average nitrate concentrations for the Sand and Clay regions, and farm-type averages in those regions.

Standardisation of measured data
To distinguish the effects of government policies on groundwater quality (notably nitrate concentrations) from the possible impacts of the weather and changes in the composition of the group of farms participating in the LMM, a statistical model is used. This allows the measured data to be 'standardised' for environmental conditions, thereby filtering temporary fluctuations in the long-term trend (see Boumans and Fraters, 2017).
The method takes into account variables that may affect the nitrate concentrations measured. The variables considered are precipitation surplus (or groundwater recharge), groundwater level, date of sampling, soil type, drainage class (three classes have been distinguished, on the basis of different classes of groundwater regime and farming characteristics/farm type). In addition, the model takes into account the prevalence of each farm type in a region.

4.3 Presentation of data

Currently, many of the LMM data are reported online rather than in traditional reports:

- Since 2011, the results of the EM sub-programme have not been included in reports. The data on water quality can be found on the RIVM-LMM website (https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten). The results on agricultural practice (period 1991–2018) can be found on the Wageningen Economic Research website, www.wur.nl/lmm.
- The main results on agricultural practice from DM for the years 2006–2018, along with the annual DM reports, can be found on www.wur.nl/lmm (since 2017).
- LMM data on water quality derived from the EM sub-programme can be obtained by using the ‘Selection tool LMM’ on the RIVM website, https://lmm.rivm.nl.

The next section describes the data selection tools. Sections 4.3.2 and 4.3.3 present the different reports on monitoring results and specific investigations.

4.3.1 Data selection tools

Selection tool

Since 2015, it has been possible to obtain LMM data on water quality derived from the EM sub-programme by using the ‘Selection tool LMM’ on the RIVM website, https://lmm.rivm.nl.

Data are presented:

- in tabular form;
- as trend figures;
- as boxplot figures.

Selections can be made by:

- year;
- farm category;
- region type (Sand, Clay, Loess or Peat);
- water type;
- period (summer or winter);
- parameter.

It is also possible to export data in CSV format. Results are given per group (region, farm category, water type and period). Only the results of groups of at least 10 farms are provided.

Data on www.wur.nl/lmm

The WUR-LMM website (www.wur.nl/lmm) uses the publication tool Agrimatie.nl. This tool gives insight into the people, profit performance and environmental impact of the Dutch agricultural sector. It combines the best available data sources and presents long-term developments in various indicators of profit (e.g. farm income), people (e.g. spatial quality, animal welfare) and environmental impact (e.g. biodiversity, nutrient uses and losses, and plant health). In short, this website contains all relevant data on Dutch agriculture. Visitors can navigate easily through the site due to interactive charts and clear search and filter functions. The charts can also be downloaded by visitors for their own use. As an example, Figure 4.1 shows the nitrogen soil balance surplus for dairy farms in the Sand region for the period 1991–2018.

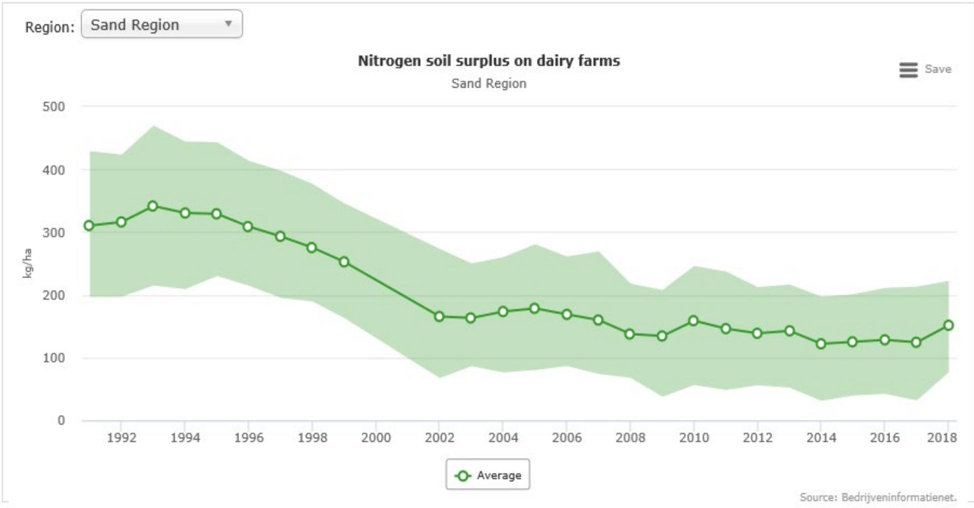


Figure 4.1 Nitrogen soil balance surplus for dairy farms in the Sand region, 1991–2018.

4.3.2 *Reports on monitoring results*

As well as the current background report, reports on monitoring results are published within the context of the LMM periodically. The objective of these reports is to present the most important results of the monitoring activities. In-depth interpretation and explanation of the results is outside the scope of the reports, but these do include the identification of differences between years and/or reporting categories, and extreme values.

The reports often present information for different combined years, with reference to the most recent year of the previous report, which allows a quick comparison of the results between the different years.

In terms of agricultural practices, the emphasis is on the area of agricultural land, classification of farmland, stocking density, milk production, use of organic manure and non-organic fertilisers, mineral surpluses and crops yields for grassland and silage maize.

The section on water quality focuses on the nitrogen and phosphorus components.

The following are publications of monitoring results directly within the LMM programme, or reports that use the data and results from the LMM programme.

- Each year, EM water quality results are published on the RIVM website (https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten/basismeetnet). The results for 2011–2017 are currently given, as well as the trend up to 2017. The results for 2018 will be published in 2021. Before 2011, these results were published in regular results reports (e.g. De Goffau et al., 2013). For the results per year for 2011–2017, see the left navigation pane on https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten/basismeetnet.

- Each year, EM and DM results of agricultural practices are published on the WUR website (www.wur.nl/lmm). The DM results are posted after the report on DM (e.g. Lukács et al. 2020) has been published. The EM results are published twice a year: first in preliminary form and a couple of months later the final results.
- Each year, a report on 'Agricultural practices and water quality on farms registered for derogation' (e.g. Lukács et al., 2019, 2020) is published. These annual reports are produced to meet the EC reporting requirements related to the derogation ruling and provide the European Commission with information – monitoring data and model-based calculations – about the quantities of fertiliser applied to each crop per soil type and about the evolution of water quality.
- Every four years, the data generated within the LMM programme contributes to the publication of a report with background information on the 'Status and trends of the aquatic environment and agricultural practice'. This report supports the Netherlands Member State Report within the framework of the Nitrates Directive. It provides an overview of current agricultural practices and the status of groundwater quality and surface water quality in the Netherlands. It also outlines trends in water quality evolution and assesses the time scale of changes in water quality due to modified farm practices. The report evaluates the implementation and impacts of the measures in the Nitrate Action Programmes and forecasts developments in water quality (e.g. Baumann et al., 2012; Fraters B. et al., 2016, 2020).
- Every four to five years, the data generated within the LMM programme contributes to a report for the ex-post evaluation of the Dutch manure and fertilisers act (Hooijboer and de Klijne, 2012; Van Grinsven and Bleeker, 2017). The results are similar to the results included in the State Report for the Nitrogen Directive.

4.3.3 *Specific research*

During 2015–2018, specific research was carried out and published. The results of this research are not described in this report. Here we provide only a summary of each and a reference to the report in which details can be found:

Farms participating in the K&K programme are among the pioneers of dairy farms. A study comparing these farms with Dutch dairy farms in the FADN research population showed that as of 2008 the nitrogen surplus is no longer lower on the K&K farms. Details can be found in Doornewaard et al. (2016).

Wageningen Economic Research investigated the best performing dairy farms in their economic results and nutrient management. The study shows that proper nutrient management can be achieved together with favourable economic results, and that management is an important factor (Doornewaard et al., 2019).

The RIVM and Wageningen Economic Research explored the research possibilities of linking data on soil parameters (Eurofins), nutrient management such as fertilisation and yields (FADN) and nitrate concentration in the groundwater (RIVM). An article investigating the relation between organic matter content in the soil and nitrate concentration in the groundwater was published in the journal Bodem (Van der Wal et al., 2019).

The RIVM and Wageningen Economic Research developed a method for calculating Nitrate Leaching Fractions (NLFs) using LMM data. NLFs quantify the fraction of the N surplus on the soil balance that leaches from the root zone to groundwater and this fraction represents the N available for leaching and denitrification. This was done for specific crop types as well as specific soil types and soil drainage statuses in the Sand region. Results show that almost the entire N surplus leached from the root zone for arable cropping on deep, well-drained sandy soils, whereas only half of the N surplus leached from grassland (Fraters D. et al., 2015).

The RIVM investigated the effect of grass–maize rotations on nitrate concentrations in the upper groundwater in the Sand region. The cultivation of maize after grass resulted in significantly higher nitrate concentrations, even several years after the change took place (Hooijboer et al., 2017).

The Loess soils sampled in the LMM often have deep groundwater levels, which is why soil moisture is extracted from soil cores. The RIVM performed an experiment to test the effect of centrifugal force and centrifugation time on the recovery of soil moisture from soil cores, and subsequent solute concentrations. Centrifugal force was found to have a greater effect on soil moisture recovery than centrifugation time, but solute concentrations did not show a change with increased soil moisture recovery (Fraters D. et al., 2017).

Over the long duration of water quality monitoring in the LMM, methodological changes are inevitable. The RIVM investigated the effect of certain monitoring methods, such as sample conservation, slit width, and pre-rinsing of the temporary borehole, on the measurements of water quality (Boumans et al., 2016).

The RIVM has updated the model used to determine the effect of farming practices on the amount of nitrate in the upper groundwater. The nitrate concentration is influenced not only by farming practices, but also by precipitation and changes in the group of farms participating in the LMM. The update makes it possible to filter out the effects of these two influences (Boumans and Fraters, 2017).

An overview of all LMM reports from its inception till 2020 is given in Annex 9.

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ANNEX 1. History of the LMM

An extensive overview of the context, methodical concept and historical development of the LMM until 2010 is given in the 'Minerals policy monitoring programme report 2007–2010, methods and procedures' (De Goffau et al., 2012), and for the period 2011–2014 in the report 'Minerals policy monitoring programme report 2007–2010, methods and procedures' (Van Vliet et al., 2017). The present report describes only the important changes in the period 2015–2018.

Figure A1.1 shows a historical overview of the number of farms in each soil region. The monitoring of the farms is performed 6–18 months after the data acquisition, depending on the region, on the assumption that it generally takes one year for changes in farm management to have an influence on leaching water. The water quality of the farms in the Loess region is sampled 18 months after the data acquisition. Figure A1.2 shows the number of farms per farm category monitored in the LMM.

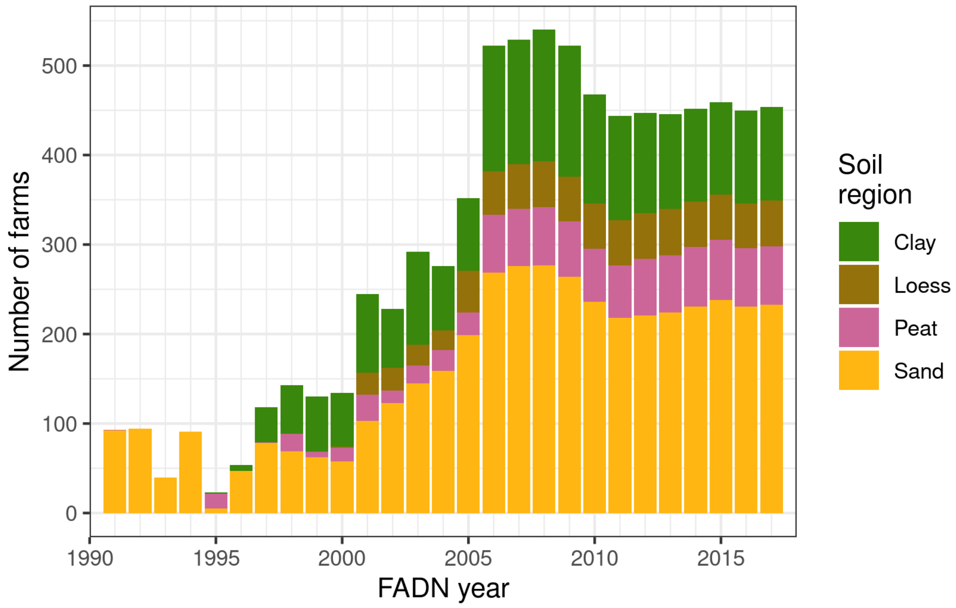


Figure A1.1 Number of farms per soil region monitored in the LMM.

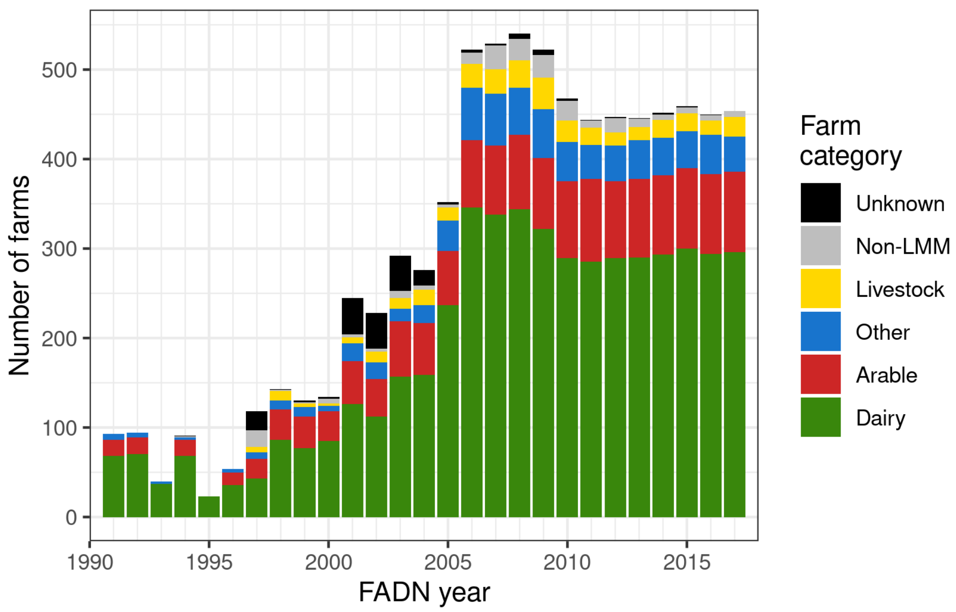


Figure A1.2 Number of farms per farm category monitored in the LMM.

A1.1 Major changes 2015–2018

The major changes in the set-up of the LMM as implemented since 2015 are:

- Since 2015, an additional distinction in areas has been made in DM reporting for the Sand region. Farms that use derogation in certain Sand districts (mostly the southern and central districts) are allowed 230 kg N/ha instead of 250 kg N/ha from grazing livestock manure on sandy soils. This change in derogation condition was implemented in 2014.
- Since 2017, additional unfiltered ditch water samples have been taken in summer and analysed for Kjeldahl N and total P. This is done to improve comparability of N-total and P-total in ditch water with those in regional surface waters monitored by regional water authorities, including results of the Monitoring Network for Nutrients in Agriculture-Specific Surface Water.
- In 2018, the number of intensive livestock farms sampled in the Sand region increased from 12 to 17, and from 2019 onwards to 20 farms. This was done in order to be able to evaluate intensive livestock farms as a separate category.

Other changes include changes in the collection, handling and reporting of data, namely:

- implementation of Simplemanager and the Field App (see Section 3.2.4);
- use of the analyser output for results below the detection limit for reporting, from 2017. This method is applied retroactively for data from 2006 onwards (see Section 4.2.2);
- increase in minimum size of groups for average values to be reported from 7 to 10 farms;

A1.2 Overview of LMM programme changes in relation to policy developments

Table A1.1 provides a summary of the changes in the LMM that are related to policy developments.

Table A1.1 Chronological outline of evolution and changes in the LMM linked to policy decisions and regulatory changes (Fraters B. et al. 2012) and completed with new information.

Year	Changes	Policy impetus	Substantiation	Remarks
1986	Sand region: scouting programme at 10 NMI dairy farms and some arable farms	Preliminary results of evaluation of first phase of Minerals Policy	Preliminary investigation of measuring methods, temporal and spatial variability	Use of temporary boreholes within plots, instead of permanent wells next to a plot
1992	Sand region: start of 3-year scanning programme on FADN farms; 20 arable farms (only in the North) and 80 dairy farms	Evaluation of first phase of Minerals Policy	Study into set-up of monitoring programme	Sampling of upper groundwater, once per summer, with 48 boreholes per farm
1993	Clay region: scouting programme at 20 farms within existing research programmes	Evaluation of first phase of Minerals Policy	Preliminary investigation of measuring methods, temporal and spatial variability	Sampling of drain water at 2 locations/farms during winter, with continuous monitoring of discharge
1994	Sand region: scale-down of scanning programme to 40 farms, with 2 x sampling during summer instead of 1 x		Study of measuring strategy; no difference from preceding years	Discussion about appropriate time for sampling during summer season
1995	Sand region: 1-year extension of scanning programme on 100 farms		50% reduction of nitrate content in 1994, without change in fertiliser use	16 boreholes per farm instead of 48

Year	Changes	Policy impetus	Substantiation	Remarks
1995	Peat region: combined scouting and scanning programme at 20 LMB farms, also participating in FADN (LMB is national soil monitoring network)	Evaluation of first phase of Minerals Policy	Preliminary investigation of measuring methods, temporal and spatial variability	Sampling of groundwater (16 boreholes) and ditch water (8 ditches) during winter
1996	Clay region: start of scanning programme, targeting 60 farms	Evaluation of first phase of Minerals Policy	Study into set-up of monitoring programme	Aim to realise a national monitoring network
1997	Sand region: start of monitoring programme, conversion to revolving network	Evaluation of first phase of Minerals Policy, Nitrates Directive	FADN is a revolving network	Desire to link water quality with agricultural practices
1997	Sand region: adjust sample of arable farms and dairy farms, and complement with intensive livestock farms and crop–livestock combination farms	Nitrates Directive	Better coverage of Sand region; sample more representative	Monitoring of increased number of types of farm costly due to increased heterogeneity
1998 + 2001	Peat region: repeated sampling within programme initiated in 1995	Evaluation of first phase of Minerals Policy, Nitrates Directive	Scouting programme sufficiently advanced	Aim to realise a national monitoring network
1999	Loess region: scouting programme at 1 dairy farm (participating in ‘Cows and Opportunities’)	Evaluation of first phase of Minerals Policy	Preliminary investigation of measuring methods, temporal and spatial variability	Sampling of soil
2002	Clay region: continuation of programme, switching to revolving network	Evaluation of first phase of Minerals Policy, Nitrates Directive	FADN is a revolving network	Desire to enable a direct link between water quality and agricultural practices

Year	Changes	Policy impetus	Substantiation	Remarks
2002	Clay region: additional sampling of groundwater and ditch water; improved sampling of drain water	Nitrate Directive, eutrophication	More representative picture of impacts from Minerals Policy	Better coverage by sampling of groundwater, especially in the River Clay District
2002	Peat region: continuation of programme; initially 12 farms; switching to revolving network	Evaluation of first phase of Minerals Policy, Nitrates Directive	FADN is a revolving network	Desire to link water quality with agricultural practices
2002	Loess region: continued monitoring, as part of combined Sand–Loess region	Evaluation of first phase of Minerals Policy, Nitrates Directive	Scouting programme sufficiently advanced	Aim to realise a national monitoring network, in combination with Sand region
2004	Sand region: extension to 54 dairy and other livestock farms	Perspective of derogation	Coverage of soils prone to leaching	Aim to attain 300 (potential derogation) farms within 4 years
2004	Sand region: extension with specific monitoring in wet parts	Nitrates Directive, eutrophication	More representative picture of impacts from mineral policies	
2004	Peat region: extension of monitoring from 12 to 24 farms	Perspective of derogation	More representative picture of impacts from mineral policies	Striving for more reliable information on Peat region. Aim to attain 300 derogation farms within 4 years
2004	Peat region: specific monitoring of surface drains on selected farms (10)	Nitrates Directive, eutrophication	More representative picture of impacts from mineral policies	Research showed a clear influence of surface-drain water on ditch water quality
2006	General: start of derogation monitoring network, within LMM	Derogation		Integrated execution of LMM monitoring networks

Year	Changes	Policy impetus	Substantiation	Remarks
2006	General: change from revolving to stationary network; no active replacement of farms	Derogation	FADN transformed from revolving network to stationary network	Replacement of participants only in case of termination by participant or non-compliance with selection criteria
2007	General: sampling frequency of drain water and ditch water increased to 4 times/season	Derogation	Target frequency	Frequency informally required by EC was 12 times/year
2007	Sand region: extension of group of arable farms (40)	Heightened interest in arable farms	Current number of 12 inadequate to make reliable assessment	
2007	Loess region: set-up of stand-alone monitoring network	Heightened interest in Loess region	Current number of 6 inadequate to make reliable assessment	In period 2002–2005 water quality info based on scouting programme. Farms not yet included in FADN
2008	General: start of sampling of ditch water during summer season (4 times)	Nitrates Directive, eutrophication, derogation	Eutrophication is a summer phenomenon, while sampling so far done during winter	Frequency informally required by EC was 12 times/year
2010	Discontinuation of ‘Dry soils’ monitoring programme	Cutback in expenditure		‘Dry soils’ programme ran from 2006 to 2009 and included extra farms on Sand/Loess soils with a low groundwater table
2010	Sand and clay regions: discontinuation of sampling at 60 additional derogation farms (Reference Monitoring network)	Derogation 2010–2013 secured	Adequate data expected to be available to underpin the derogation 2014–2017	

Year	Changes	Policy impetus	Substantiation	Remarks
2010	Definition of intensive livestock farms and other farms changed		Other farms in all regions similar in type	Programme to report on intensive livestock farms as a separate farm type only in the Sand region
2011	General: discontinuation of exploratory programmes such as K&K and TmT	Cutback in expenditure		Some K&K farms continued in derogation network, therefore sampled at lower intensity than previously
2011	General: discontinuation of monitoring at non-LMM groups (scouting of outdoor market gardening crops in the Sand region)	Cutback in expenditure		Information lost on water quality at 20% of areas not covered
2011	General: sampling frequency of drain water and ditch water reduced to 3 times per season at arable farms in winter, and at all farm types in summer	Cutback in expenditure	Sampling frequency corresponds to frequency before 2006 (for winter sampling)	Arable farms excluded from derogation. Summer sampling less important than winter sampling for goals of LMM
2011	Loess area recognised as a separate region		Sufficient participants recruited	
2012	Adapt and intensify arable farming in Southern Sand region	Focus on specific policy	Sufficient new participants recruited	In Southern Sand region more arable farmers
2012	New stratification method for derogation network		Uniform selection of farms for EM and DM	DM distinguishes two farm type categories only: specialised dairy farms and other grassland farms

Year	Changes	Policy impetus	Substantiation	Remarks
2013	Soil region identified by postcode instead of municipality		Fixed borders instead of continually changing (more stable grouping)	Better representation of dominant soil type
2013	Definition of sub-region ‘Dunes and islands’		Removal of sandy coastal area from Clay region	Better representation of dominant soil type
2014	Sampling of ditches disconnected from groundwater monitoring programme		All ditch water is sampled following one method; no differences in conservation method and timing	From winter 2014/2015
2015	Distinction in reporting between ‘230’ and ‘250’ kg N/ha in the DM Sand regions	Derogation	Derogation conditions changed in 2014, with certain areas in the sand region allowed 230 instead of 250 kg N/ha from grazing livestock manure	Water quality measurements relate to the previous agriculture year, hence change in reporting took place from 2015 onwards
2017	Unfiltered samples taken for Kjeldahl N and total P analyses in ditch water sampled in summer	Water Framework Directive	Able to compare LMM measurements with measurements made by regional water authorities and other monitoring networks	From summer 2017
2017	Increase of intensive livestock farms sample in the Sand region to 20 per year		To be better able to evaluate intensive livestock as a separate category in the Sand region	From 2017/18 onwards

ANNEX 2. Farm Accountancy Data Network (FADN) and LMM farm selection

A2.1 Composition of the FADN

Through the Farm Accountancy Data Network (FADN), Wageningen Economic Research collects detailed financial, economic and environmental data from about 1,500 agricultural and horticultural companies. The FADN represents about 95% of the total agricultural production in the Netherlands. Detailed background information and the history of the FADN are described in Poppe (2004).

The primary aim of the FADN is to monitor farm incomes and business activities of agricultural holdings (farms); farm data are collected with this purpose in mind. The FADN is an important data source for the evaluation of the income of farms and the impacts of the EU Common Agricultural Policy (Roskam et al., 2020).

The farms in the FADN are selected from the Agricultural Census, a comprehensive annual census of almost all agricultural and horticultural holdings in the Netherlands. The selection of farms is made using stratified random sampling. The selected farms in the FADN therefore constitute a representative sample of nearly all commercially operated farms in the Netherlands.

This section provides a description of the FADN farm selection strategy and the stratification criteria in the FADN. These stratification criteria were adopted by the Dutch Minerals Policy Monitoring Programme (LMM).

The subdivision into strata is based on two parameters: the farm type and the economic size of a farm. To identify the farm type, the NSO system is applied. The NSO farm typology is described in Annex 3. The economic size of farms is expressed in Standard Output (SO[1]).

The target population of the FADN is limited to an SO of € 25,000; farms with an SO smaller than € 25,000 are excluded. Taking 2014 as an example year, the total number of farms in the Annual Census was 65,508. The FADN target population (meeting the size criterion) in 2014 was 48,509 farms. This number accounted for 99% of the total agricultural production capacity expressed in SO (Ge et al., 2017).

The recruitment of farms for participation in the FADN takes place each year, according to the annual selection plan. Taking the accounting year 2014 as an example again, 1,515 farm reports were delivered to the European Commission. The legal obligation of 1,500 farms was fulfilled.

[1] Standard output, a measure of the economic size of agricultural activities and farms, refers to the standard value of gross production. The standard output of an agricultural product (crop or livestock) is the average monetary value of the agricultural output at farm gate price, in euros per hectare or per head of livestock. There is a regional SO coefficient for each product, which is the average value over a reference period of 5 years. The Netherlands consists of one region. The sum of all the SOs per hectare of crop and per head of livestock in a farm is a measure of its overall economic size, expressed in euros.

FADN data are of major importance for the evaluation of agricultural policies and the monitoring of economic developments in the agricultural sector. In the design of the selection plan, a stratification based on farm type and size class has been used. Stratification enables better control over the representativeness of the sample and contributes to more reliable estimates (Ge et al., 2017).

A2.2 Criteria for selection of farms in the LMM

The monitoring objectives determine the type of data needed and thus the required composition of the groups of farms examined. The LMM focuses on the most common types of land and fertiliser use practices in the Netherlands.

The goals of the LMM differ from those of the FADN. Therefore, the LMM uses its own target population and stratification criteria.

In addition to the stratification parameters of ‘farm type’ and ‘economic size’, farms participating in the LMM are grouped and selected on the parameter of ‘region’. Although two of the stratification variables (farm type and economic size) are identical in the FADN and the LMM, the definitions of the parameters within each variable differs.

In principle, LMM farms constitute a randomly selected sub-sample of FADN farms. However, the actual selection of farms for the LMM deviates slightly from this principle. There are five main explanations for this deviation:

- The LMM has grown to an extensive programme with two sub-programmes – derogation monitoring (DM) and evaluation monitoring (EM), each with specific goals and selection criteria.
- To reduce costs to the LMM of collecting farm data, existing FADN farms are preferred. However, for some farm categories (combinations of farm type and region), more farms are needed in the LMM sub-sample than are available in the FADN sample. In these cases, additional farms have to be added to achieve the required number of farms for the LMM. The data collection and registration on these additional farms are identical to those on FADN farms. The accompanied costs are fully charged to the LMM budget.
- To reduce costs, the DM programme maximally uses the potential farms participating in the EM programme.
- During the participation period, farms within the sample may change in size and even business activities. For instance, farms that are selected for the programme as dairy farms might turn out to be ‘other animal farms’ in the year of sampling. In the yearly selection plans, changes in participating farms are considered as carefully as possible. Participation in the LMM has greater impact for a farmer, as water samples are taken in addition to the data collected for the FADN. Not all farmers in the FADN are willing to participate in the LMM.

Given these considerations, the sample of farms for the LMM programme is not always fully in line with the sampling design, but the result of practical considerations regarding the constraints of farms available in the FADN sample and the available LMM budget.

Selecting LMM farms from the FADN was a policy decision made at the start of the LMM project. A major advantage of selecting farms from the FADN is the reduced cost of monitoring agricultural practices. Moreover, by recruiting LMM participants from the FADN sample, the evolution in water quality and environmental pressure on farms can be linked to the nutrient management practices and economic performance of the farms that are part of the research.

A2.3 Delineation of the LMM research sample

To derive the LMM research sample from the FADN, additional criteria are used. In contrast to the FADN, some farm types are excluded from the LMM research population. In the LMM, a lower limit of 10 ha of cultivated land is applied. Moreover, some farm types (e.g. horticultural farms) are excluded. This makes the LMM sample and target population a sub-sample of the FADN sample and target population. The following differences are noted between the FADN and LMM target populations:

1. The LMM target population does not represent all types of farming, but only the most important farm types in the use of cultivated land area within each (soil) region. Because of this criterion, dairy farms are included in all four regions and horticultural farms are fully excluded.
2. The LMM target population represents only farms equal to or larger than 10 ha. Farms smaller than 10 ha are excluded. Note that farms with an economic size of less than € 25,000 SO are already excluded from the FADN and therefore also from the LMM.

The criteria used for the selection of LMM farms are elaborated below.

a. Geographical position linked to the region
Four main regions, which are named according to their predominant soil types, are distinguished: Sand, Clay, Peat and Loess. These four soil type regions represent respectively 47%, 42%, 10% and 1.5% of the total agricultural area of the Netherlands. The four main soil type regions are subdivided into 14 soil type districts: 7 in the Sand region, 4 in the Clay region and 2 in the Peat region. The Loess region is not subdivided: it covers the Southern part of Limburg. Figure 2.2 in the main text shows the location of the four soil type regions and the 14 soil type district.

The subdivision into soil type regions is linked to the Dutch postcode areas. The dominant soil type within a postcode area determines the soil type region assigned to an individual farm. The soil type within a region is not homogeneous. There are cases where a farm is situated in an area that, according its postcode, is in the Sand region, while the specific farm may, for example, be dominated by peat-rich soils. This variation in soil types within a soil type region affects the water quality.

This aspect and the variability of soil types within a region are taken into account when considering the water quality on farms with soils different from that of the region as a whole.

b. Types of farming

According to the Agricultural Census, circa 55,680 farms were active in agriculture and horticulture in the Netherlands in 2016 (Annex 3, Table A3.2). They cultivated a total area of 1.8 million ha. Grassland dominated the total cultivated area (nearly 51%). About 27% of the cultivated land was in use for arable agriculture and 12% for other fodder crops. The remaining 10% was identified as 'other land' (totalling 174,000 ha, including 92,000 ha of outdoor horticultural crops, 72,000 ha of natural grassland and 9,000 ha indoor horticultural crops). Almost 48% of the 1.8 million hectares of cultivated land was in use by dairy farms, 24% by arable farms and 11% by other grazing animal farms. The rest of the farm types cover 17% of the cultivated land.

Due to budget constraints, the LMM focuses on the dominant forms of land use and fertilising practices in the Netherlands. The decision to include a specific farm type in the farm research population of a certain region depends on the extent of agricultural land of the various NSO types present in that region. Unlike geographical position (i.e. region), farm type is a determining factor for inclusion in the LMM. Due to the limited areas of cultivated land covered by the NSO main types horticulture (type 2), permanent cultures (type 3) and crop combinations (type 6), farms in these categories are not included in the LMM.[2]

c. Size of selected farms

Like the FADN, the LMM distinguishes economic size classes in terms of SO. There are four size classes per LMM farm category. The class boundaries are defined annually on the basis of the most recent Agricultural Census. This stratification on farm size is done in such a way that each size class represents the same area of cultivated land. This implies that each sample farm represents more or less the same surface area and that larger farms are more widely represented than smaller ones.

[2] This statement is not exact, as will be explained later. For example, in the DM, there are 7 non-dairy farms in the Peat region.

The LMM distinguishes four SO size classes. The class boundaries are defined annually per LMM farm category, based on the most recent Agricultural Census. This stratification according to farm size is done in such a way that each stratum represents the same area of cultivated land. From each stratum, an equal number of farms is included in the LMM sample.

The stratification procedure is illustrated by an example from the arable farms category in the Sand region. According to the Agricultural Census, the LMM research population consists (roughly) of 2,500 farms, covering in total 140,000 ha. Forty of these 2,500 farms are monitored in the LMM. In the stratification process, the research population is divided into four strata, each containing 35,000 ha but different numbers of farms. In each stratum, only 10 sample farms are selected. Therefore, each sample farm represents more or less the same surface area but larger farms have a higher chance of being included in the sample than smaller ones.

Table A2.1: Example from 2016 that illustrates the allocation of farms to different size classes for arable farms in the Sand region

Size class	I	II	III	IV
Total area in Agricultural Census (ha)	35,000	35,000	35,000	35,000
Number of farms in Agricultural Census	1,200	700	400	200
Average area per farm (ha)	29	50	88	175
Number of farms in LMM	10	10	10	10
Selection chance	10 in 1,200	10 in 700	10 in 400	10 in 200

In general, large farms are less homogeneous than small ones. In the case of less homogeneous groups, it is important to have a larger number of observations to make reliable estimates. In both the FADN and the LMM, the greater heterogeneity within larger farms is reflected by a higher chance of being included in the sample.

A.2.3 General procedure for selection and recruitment of farms in LMM

In the preceding sections, some differences were indicated between the target population and stratification in the FADN and the LMM. There are also some differences between the LMM and the FADN in the procedures for the selection and the recruitment of farms.

As in the FADN, a stratified sample is used for the selection and recruitment of LMM farms. The sample is made in accordance with a pre-established 'farm selection plan'. For each stratum the annual farm selection plan makes an inventory of:

- the number of LMM farms already available (farms recruited earlier, still meeting the criteria and willing to cooperate);
- the number of LMM farms needed;
- the number of farms potentially available for inclusion in the LMM (farms included in the FADN and meeting the selection criteria for the LMM that have not yet been invited to participate in the LMM).

While a single selection plan is sufficient for the FADN, this is not the case for the LMM, because the LMM consists of two sub-programmes, each with specific sampling scopes, selection criteria and stratification requirements. Moreover, the timing of water sampling at participating farms differs over the four regions. A separate 'annual farm sampling plan' is therefore formulated for each LMM sub-programme and for each region.

The number of sample farms required per farm category is defined for DM and EM in relation to vulnerability (to leaching), the relative importance of the category in land use, and required/desirable numbers of farms from a policy perspective and/or statistical considerations (Fraters and Boumans, 2005).

Unlike the FADN, the LMM does not annually adjust the allocation of sample farms within a farm category (in response to the variation in economic results between farms). Table A2.2 presents the target number of farms per category (60 strata in total: 15 farm types in 4 size classes) for EM.

Table A2.2 Summary of number of farms per sampling stratum.

LMM farm category	**SO class**				**Total**
	I	**II**	**III**	**IV**	
Arable sand - North + Central	5	5	5	5	20
Arable sand - South	5	5	5	5	20
Intensive livestock Sand[3]	5	5	5	5	20
Other animals Sand	3	3	3	3	12
Dairy Sand – North	3–4	3–4	3–4	3–4	15
Dairy Sand – Central	3–4	3–4	3–4	3–4	15
Dairy Sand – South	3–4	3–4	3–4	3–4	15
Total Sand region	***29–30***	***29–30***	***29–30***	***29–30***	***117***
Arable Clay	7–8	7–8	7–8	7–8	30
Dairy Clay	5	5	5	5	20
Other animals Clay	2–3	2–3	2–3	2–3	10
Total Clay region	***15***	***15***	***15***	***15***	***60***
Dairy – Northern Peat	3	3	3	3	12
Dairy – Western Peat	3	3	3	3	12
Total Peat region	***6***	***6***	***6***	***6***	***24***
Arable Loess	5	5	5	5	20
Dairy Loess	5	5	5	5	20
Other animals Loess	2–3	2–3	2–3	2–3	10
Total Loess region	***12–13***	***12–13***	***12–13***	***12–13***	***50***

[3] In 2014–2016, 12 intensive livestock farms were sampled annually. From 2017 onwards, 20 intensive livestock farms per year have been sampled.

The aim is to have an even distribution in terms of cultivated land area within each farm category. In the selection of participants in the Clay region (all types of farms) and the Sand region (intensive livestock farms and other animal farms), the LMM aims at a maximum geographical spread, to avoid over-concentration in parts of the respective regions.

Recruiting LMM participants from separate strata means that the reliability of the random sample survey is higher than that of a non-stratified sample survey of the same size. Moreover, stratification allows representativeness to be maintained in cases where a selected farm declines to participate (or when an existing participant drops out). A replacement can be pursued, corresponding as closely as possible, in terms of farm characteristics (i.e. farm type, farm size and region), with the farm that was replaced.

If a selected farm refuses to participate (or if a participant drops out), the LMM tries to find a replacement, which resembles the replaced farm as closely as possible, i.e. with respect to farm type, size and location. In the event of a shortage of participating farms, the LMM draws candidates from an adjacent stratum. If there is no potential participant in an adjacent stratum, then the LMM tries to find a replacement outside the FADN.

A2.4 Coverage of the LMM research population

Table A2.3 shows for each region the percentage of farms and area represented in the LMM research population. The right-hand column shows the LMM sample area as a percentage of the total area of cultivated land. The numbers at the top of the table are the total population of farms in the four LMM regions in 2016.

From Table A2.3 it can be concluded that:

- over 88% of all farms and all cultivated land are situated in the Sand and Clay regions. With an area of less than 30,000 ha the Loess region is by far the smallest;
- on a national scale, the LMM research population represents 86% of all cultivated land, worked by 56% of all farms. The individual ‘coverage’ is slightly higher for grassland, arable farming and other fodder crops (86–92%); for ‘other cultivated land’ the coverage (44%) is relatively low;
- among the regions, the coverage of total cultivated land varies between 81% in the Peat region and 87% in the Clay and Sand regions. For the category ‘other cultivated land’, the Peat region has the highest coverage (64% compared with 44% overall). In the Peat region, the research population focuses entirely on specialised dairy farms.

Table A2.3 Distribution of farms and their area over LMM regions: for the Netherlands as a whole and for the LMM research population.

	Number farms	**Grassland**	**Other fodder crops**	**Arable farmland**	**Other cultivated land**	**Total cultivated land**	**Share in total extent**
		ha x 1,000	**ha x 1,000**	**ha x 1,000**	**ha x 1,000**	**ha x 1,000**	**(%)**
LMM Sand region	30,400	443	154	174	81	852	47%
LMM Clay region	19,245	324	50	309	79	762	42%
LMM Peat region	5,085	160	12	4	11	188	10%
LMM Loess region	950	9	4	12	3	28	1,5%
Total agri- & horticulture in NL	**55,680**	**936**	**220**	**499**	**174**	**1,830**	**100%**
Research population Sand region							
- Dairy farms	8,506	323	70	11	15	419	23%
- Arable farms	2,587	9	21	108	4	142	8%
- Intensive livestock farms	2,084	19	21	19	3	62	3,4%
- Other farms	3,430	61	20	19	16	116	6%
Total	**16,607**	**412**	**132**	**157**	**38**	**739**	**41%**
(in % of Sand region)	**(55%)**	**(93%)**	**(86%)**	**(90%)**	**(47%)**	**(87%)**	
Research population Clay region							
- Arable farms	4,702	15	12	257	7	291	16%
- Specialised dairy farms	4,842	248	27	8	11	294	16%
- Other farms	1,847	43	6	15	13	77	4,2%
Total	**11,391**	**306**	**45**	**280**	**31**	**662**	**36%**
(in % of Clay region)	**(60%)**	**(94%)**	**(90%)**	**(91%)**	**(39%)**	**(87%)**	
Research population Peat region							
- Specialised dairy farms – North	1,378	72	7	0	3	83	4,5%
- Specialised dairy farms – West	1,382	63	3	0	4	70	3,8%
Total	**2,760**	**135**	**10**	**0**	**7**	**153**	**8%**
(in % of Peat region)	**(55%)**	**(84%)**	**(83%)**	**(0%)**	**(64%)**	**(81%)**	

	Number farms	Grassland	Other fodder crops	Arable farmland	Other cultivated land	Total cultivated land	Share in total extent
		ha x 1,000	ha x 1,000	ha x 1,000	ha x 1,000	ha x 1,000	(%)
Research population Loess region							
- Dairy farms	160	5	2	1	0	8	0,5%
- Arable farms	241	1	1	8	0	10	0,5%
- Other farms	151	2	1	1	1	6	0,3%
Total	**552**	**8**	**4**	**10**	**1**	**24**	**1,3%**
(in % of Loess region)	**(58%)**	**(89%)**	**(100%)**	**(83%)**	**(33%)**	**(86%)**	
Total LMM research population	31,310	861	191	447	77	1,578	86%
% of agri- & horticulture in NL	56%	92%	87%	90%	44%	86%	

Source: Agricultural Census 2016

ANNEX 3. Farm types

A3.1 The Netherlands Standard Output typology

The Netherlands Standard Output (NSO) typology is a Dutch version of the EU system for characterising agricultural and horticultural farms. Based on their activities (production of crops and/or animals), farms are classified in 'farm types'. All cropped areas and numbers of head per animal species are converted into a so-called standard output (SO) (*standaardopbrengst* in Dutch). The SO of a crop or animal refers to its yield (in euros), achievable on an annual basis under normal circumstances. The proportion of the production from specific animals or crops is compared with total production (sum of all SO). This provides a measure of the specialisation of a farm. A farm is defined as 'specialised' if at least two-thirds of its proceeds are derived from one product or mode of production (e.g. dairy cattle, arable farming or pigs). The degree of specialisation is used to define the farm type.

The NSO typology distinguishes eight main types of farming, of which five are single product/production-oriented and three comprise combinations of farm activities. The five single product/production-oriented types of farm types are: arable, horticulture, permanent cultures (fruit and trees), grazing animals, and intensive livestock. The three combined farm types are crop combinations, livestock-rearing combinations and crop–livestock-rearing combinations. Within the 8 NSO main types of farm, a total of 37 more specific NSO types of farm are distinguished (Table A3.1).

A3.2 Recent changes in NSO characterisation

The NSO typology is subject to change. In accordance with EU agreements, the SO standards are redefined every three years. The almost continuous shift in ratios between prices and yield among products is the main reason for this triannual redefinition. These changes affect the SO value of each crop and animal.

In addition, minor modifications occur in the list of products and animals used. These modifications relate to animal species or crops that have appeared or disappeared. Since 2006, the number of products in the Agricultural Census has increased considerably; this is partly due to changes in manure and minerals legislation (plant available nitrogen application standards per hectare per crop).

Changes in the NSO characterisation have a limited impact on the size and distribution of the cultivated area within the LMM research population. A modified characterisation, however, may change the allocation of sample farms to LMM strata. When a farm needs to be replaced, the selection of a new farm is made using the most recent Agricultural Census and FADN data. In this way, developments in farm type and changes in the NSO characterisation are taken into account.

Table A3.1 Summary of types of farm in the NSO characterisation.

1 Arable – field crops			
1500	Specialising in cereals (other than rice), oilseeds and protein crops	1602	Specialising in field vegetables
		1603	Specialising in feed crops
1601	Specialising in starch potatoes	1604	Other arable farming
2 Horticulture			
2111	Specialising in vegetables indoor	2210	Specialising in outdoor vegetables
2121	Specialising in flowers and ornamentals indoor	2221	Specialising in outdoor flowers and ornamentals
2122	Specialising in pot and bedding plants	2310	Specialising in mushrooms
		2320	Nursery specialist
2131	Specialising in indoor mixed horticulture	2331	Various horticulture
3 Permanent cultures			
3500	Specialising in vineyards	3699	Various permanent crops combined
3610	Specialising in fruit		
4 Grazing animals			
4500	Specialising in dairying	4830	Specialising in goats
4611	Specialising in cattle-rearing and fattening	4841	Specialising in horses and ponies
4612	Other cattle	4842	Grazing animals, mainly feed crops
4810	Specialising in sheep		
		4843	Other grazing animals
5 Intensive livestock (poultry, pigs, fattening calves)			
5111	Specialising in pig-rearing	5221	Specialising in poultry meat
5121	Specialising in pig-fattening	5231	Layers and poultry meat combined
5131	Pig-rearing and fattening combined	5301	Various granivores combined
5211	Specialising in layers		
6 Mixed cropping			
6100	Mixed cropping		
7 Mixed livestock			
7300	Mixed livestock, mainly grazing livestock	7400	Mixed livestock, mainly granivores
8 Mixed crop–livestock			
8300	Field crops and grazing livestock combined	8400	Various crops and livestock combined

A3.3 Number and area of farm types

Table A3.2 gives a summary of all agricultural and horticultural farms in the Netherlands (both in numbers and size), based on the Agricultural Census of 2016 (see also Annex 2). The categorisation of farms is based on the eight main types of farming in the NSO characterisation, in which category 4 (grazing animals) is divided further into 'dairy farms' (type 4a) and 'other grazing animal farms' (type 4b). The total area of cultivated land has been represented in terms of four forms of land use: grassland, other fodder crops (primarily silage maize), arable farming products and 'other cultivated land' (comprising, for example, market gardening crops – outdoor and under glass).

Table A3.2 Summary of farm categories in the Netherlands (2016).

Farm category	Number of farms	Grassland (ha x 1,000)	Other fodder crops (ha x 1,000)	Arable farmland (ha x 1,000)	Other cultivated land (ha x 1,000)	Total cultivated land (ha x 1,000)	Share in total extent (%)
1) Arable	10,821	32	42	363	9	446	25
2) Horticulture	7,389	5	5	16	66	92	5
3) Permanent cultures	1,612	1	1	2	18	22	1
4a) Dairy	16,503	712	108	21	33	875	48
4b) Other grazing	11,407	135	28	8	28	198	11
5) Intensive livestock	4,837	17	17	24	2	61	3
6) Mixed cropping	1076	4	4	32	10	49	2
7) Mixed livestock	607	14	4	2	1	21	1
8) Mixed crop–livestock	1,429	16	11	32	7	66	4
Total (ha x 1,000)	***55,681***	***936***	***220***	***500***	***174***	***1,830***	***100***
Share of land use (%)		51	12	27	10	100	

Table A3.3 Developments in the area per main farm type, per region.

	2014		2015		2016		2017	
Main farm type	**area (ha)**	**(%)**	**area (ha)**	**(%)**	**area (ha)**	**(%)**	**area (ha)**	**(%)**
1) Arable	151,000	18%	157,000	18%	150,000	18%	153,000	18%
2) Horticulture	54,000	6%	56,000	6%	53,000	6%	55,000	6%
3) Permanent cultures	2,000	<1%	3,000	<1%	3,000	<1%	3,000	<1%
4a) Dairy	395,000	46%	407,000	47%	420,000	49%	418,000	49%
4b) Other grazing	135,000	16%	129,000	15%	112,000	13%	109,000	13%
5) Intensive livestock	52,000	6%	51,000	6%	48,000	6%	47,000	5%
6) Mixed cropping	13,000	2%	14,000	2%	15,000	2%	15,000	2%
7) Mixed livestock	16,000	2%	16,000	2%	16,000	2%	15,000	2%
8) Mixed crop–livestock	34,000	4%	32,000	4%	35,000	4%	41,000	5%
Total SAND region	**853,000**	**100%**	**868,000**	**100%**	**852,000**	**100%**	**856,000**	**100%**
1) Arable	295,000	39%	295,000	38%	281,000	37%	279,000	37%
2) Horticulture	35,000	5%	36,000	5%	37,000	5%	37,000	5%
3) Permanent cultures	17,000	2%	17,000	2%	18,000	2%	17,000	2%
4a) Dairy	277,000	36%	284,000	37%	294,000	39%	293,000	38%
4b) Other grazing	71,000	9%	69,000	9%	59,000	8%	57,000	7%
5) Intensive livestock	12,000	2%	13,000	2%	12,000	2%	11,000	1%
6) Mixed cropping	26,000	3%	29,000	4%	32,000	4%	36,000	5%
7) Mixed livestock	4,000	1%	4,000	1%	4,000	1%	4,000	1%
8) Mixed crop–livestock	27,000	4%	26,000	3%	27,000	4%	29,000	4%
Total CLAY region	**763,000**	**100%**	**770,000**	**100%**	**762,000**	**100%**	**762,000**	**100%**
1) Arable	5,000	3%	5,000	3%	5,000	3%	4,000	2%
2) Horticulture	2,000	1%	2,000	1%	2,000	1%	2,000	1%
3) Permanent cultures	<100	<1%	<100	<1%	<100	<1%	<100	<1%
4a) Dairy	148,000	78%	150,000	78%	153,000	81%	153,000	81%
4b) Other grazing	31,000	16%	29,000	15%	25,000	13%	24,000	13%
5) Intensive livestock	1,000	1%	1,000	1%	1,000	1%	1,000	1%
6) Mixed cropping	200	<1%	500	1%	400	<1%	500	<1%
7) Mixed livestock	1,000	1%	1,000	1%	1,000	1%	1,000	1%
8) Mixed crop–livestock	2,000	1%	1,000	1%	1,000	1%	1,000	1%

	2014		2015		2016		2017	
Main farm type	**area (ha)**	**(%)**	**area (ha)**	**(%)**	**area (ha)**	**(%)**	**area (ha)**	**(%)**
Total PEAT region	**190,000**	**100%**	**192,000**	**100%**	**188,000**	**100%**	**188,000**	**100%**
1) Arable	10,000	36%	10,000	36%	10,000	36%	10,000	37%
2) Horticulture	200	<1%	200	<1%	200	<1%	100	<1%
3) Permanent cultures	1,000	4%	1,000	4%	2,000	7%	2,000	7%
4a) Dairy	8,000	29%	8,000	29%	8,000	29%	8,000	30%
4b) Other grazing	4,000	14%	4,000	14%	3,000	11%	3,000	11%
5) Intensive livestock	400	<1%	400	<1%	300	<1%	300	<1%
6) Mixed cropping	1,000	4%	1,000	4%	2,000	7%	2,000	7%
7) Mixed livestock	<100	<1%	<100	<1%	<100	<1%	<100	<1%
8) Mixed crop–livestock	3,000	11%	3,000	11%	3,000	11%	3,000	11%
Total LOESS region	**28,000**	**100%**	**28,000**	**100%**	**28,000**	**100%**	**27,000**	**100%**
1) Arable	464,000	25%	464,000	25%	464,000	25%	464,000	25%
2) Horticulture	92,000	5%	92,000	5%	92,000	5%	92,000	5%
3) Permanent cultures	20,000	1%	20,000	1%	20,000	1%	20,000	1%
4a) Dairy	830,000	45%	830,000	45%	830,000	45%	830,000	45%
4b) Other grazing	241,000	13%	241,000	13%	241,000	13%	241,000	13%
5) Intensive livestock	66,000	4%	66,000	4%	66,000	4%	66,000	4%
6) Mixed cropping	40,000	2%	40,000	2%	40,000	2%	40,000	2%
7) Mixed livestock	21,000	1%	21,000	1%	21,000	1%	21,000	1%
8) Mixed crop–livestock	65,000	4%	65,000	4%	65,000	4%	65,000	4%
Total Netherlands	**1,839,000**	**100%**	**1,839,000**	**100%**	**1,839,000**	**100%**	**1,839,000**	**100%**

A3.4 The evolution of areas per main farm type

Table A3.3 specifies the main types of farm and the area of cultivated land for the four regions in the period 2006–2009. The specification is based on the eight NSO main types of farm, in which NSO type 4 (grazing animals) is subdivided into three groups: dairy farms (designated as type 4a), calf-rearing and -fattening farms (which were added to 'industrial livestock farming'; type 5) and other grazing animals (designated as type 4b). Between 2014 and 2017, the number of agriculture and horticulture farms dropped by more than 9% (from 72,324 in 2014 to 65,507 in 2017). This reduction had limited effects on the (relative) areas per main farm type.

A3.5 LMM reporting categories

For the purpose of selecting, enrolling and reporting (new) participants, all farming activities represented in the LMM are aggregated into more or less homogeneous farm types. Table A3.4 shows for each region the farm types distinguished in the LMM and the corresponding NSO business characterisation.

Table A3.4 Summary of farm types distinguished within the LMM per region.

Region	LMM reporting categories with respect to type of farm	NSO (main) farm types used in LMM selection
Sand	Arable farms	NSO main type 1: arable farms NSO type 6100: other mixed cropping <u>on condition that</u> the area of horticultural crops does not exceed 20% of total area
	Dairy farms	NSO type 4500: dairy farms
	Intensive livestock farms	NSO main type 5: industrial livestock farms NSO type 4611: calf-rearing and -fattening farms NSO type 7400: livestock combinations, mainly granivores (seed predators)
	Others	NSO main type 4: farms with grazing animals (excluding NSO types 4500 and 4611) NSO type 7400: livestock combinations, mainly grazing animals NSO main type 8: crops/livestock combinations
Clay and Loess	Arable farms	NSO main type 1: arable farms NSO type 6100: other mixed cropping <u>on condition that</u> the area of horticultural crops does not exceed 20% of total area
	Dairy farms	NSO type 4500: dairy farms
	Others	NSO main type 4: farms with grazing animals (excluding NSO types 4500 and 4611) NSO type 7400: livestock combinations, mainly grazing animals NSO main type 8: crops/livestock combinations
Peat	Dairy farms	NSO type 4500: dairy farms

ANNEX 4. Number of farms and locations covered in programme implementation

Table A4.1 shows the number of farms included for data collection on agricultural practice for EM and DM, respectively. In depicting the long-term trends and impact of manure policy on agricultural practice, all available farms in the Farm Accountancy Data Network (FADN) that meet the EM selection criteria are used. The total number of farms exceeds 600, of which roughly two-thirds participate in the RIVM's water quality monitoring programme (see also Table A4.2).

Table A4.1 Farms included for data collection on agricultural practice, EM/DM.

AGRICULTURAL PRACTICE – EM

Clay region

	Arable		Dairy	Other animal	Total
2014	133		66	15	214
2015	134		68	18	220
2016	129		75	15	219
2017	132		75	16	223

Peat region

	Arable		Dairy	Other animal	Total
2014			47		47
2015			46		46
2016			46		46
2017			44		44

Loess region

	Arable		Dairy	Other animal	Total
2014	19		18	10	47
2015	17		21	9	47
2016	18		20	6	44
2017	19		21	7	47

Sand region

	Arable	Int. Livestock	Dairy	Other animal	Total
2014	56	71	155	27	309
2015	62	57	161	25	305
2016	65	52	170	22	309
2017	67	60	166	18	311

All regions combined

	Arable	Int. livestock	Dairy	Other animal	Total
2014	208	71	286	52	617
2015	213	57	296	52	618
2016	212	52	311	43	618
2017	218	60	306	41	625

AGRICULTURAL PRACTICE – DM

	Clay region	**Loess region**	**Peat region**	**Sand region**	**All regions**
2014	61	20	60	157	298
2015	58	20	59	155	292
2016	60	20	60	158	298
2017	60	20	59	158	297

Tables A4.2 and A4.3 show the number of farms included for data collection on water quality for EM and DM, respectively. Farms can be eligible for both EM and DM and counted in both tables. Figures A4.1 and A4.2 show the number of samples taken from different water types. For groundwater these correspond to the number of boreholes drilled. In the Loess area no surface water is available and the groundwater is too deep to sample; therefore, only soil moisture is sampled. The Peat region contains surface and tile drains, while farms in the Sand and Clay regions contain only tile drains. Ditch water is collected in the wet parts of the Sand region, and in the Clay and peat regions.

Table A4.2 Number of eligible farms included for data collection on water quality for EM.

Clay

Year	Arable	Intensive livestock	Dairy	Not LMM	Other animal	Total
2014	30		51		14	95
2015	30		51		11	92
2016	30		51		13	94
2017	29		52		13	94

Loess

Year	Arable	Intensive livestock	Dairy	Not LMM	Other animal	Total
2014	19		19		10	48
2015	19		21		9	49
2016	18		22		9	49
2017	18		21		9	49

Peat

Year	Arable	Intensive livestock	Dairy	Not LMM	Other animal	Total
2014			57			57
2015			56			56
2016			55			55
2017			55			55

Sand

Year	Arable	Intensive livestock	Dairy	Not LMM	Other animal	Total
2014	40	13	134	1	11	199
2015	41	16	136	1	15	209
2016	41	14	133		15	203
2017	42	20	134		13	209

All regions combined

Year	Arable	Intensive livestock	Dairy	Not LMM	Other animal	Total
2014	89	13	261	1	35	399
2015	90	16	264	1	35	406
2016	89	14	261		37	401
2017	89	21	262		35	407

Table A4.3 Number of farms included for data collection on water quality for DM.

Year	Clay	Loess	Peat	Sand	All regions combined
2014	62	20	59	161	302
2015	60	20	61	160	301
2016	60	20	59	159	298
2017	60	20	60	159	299

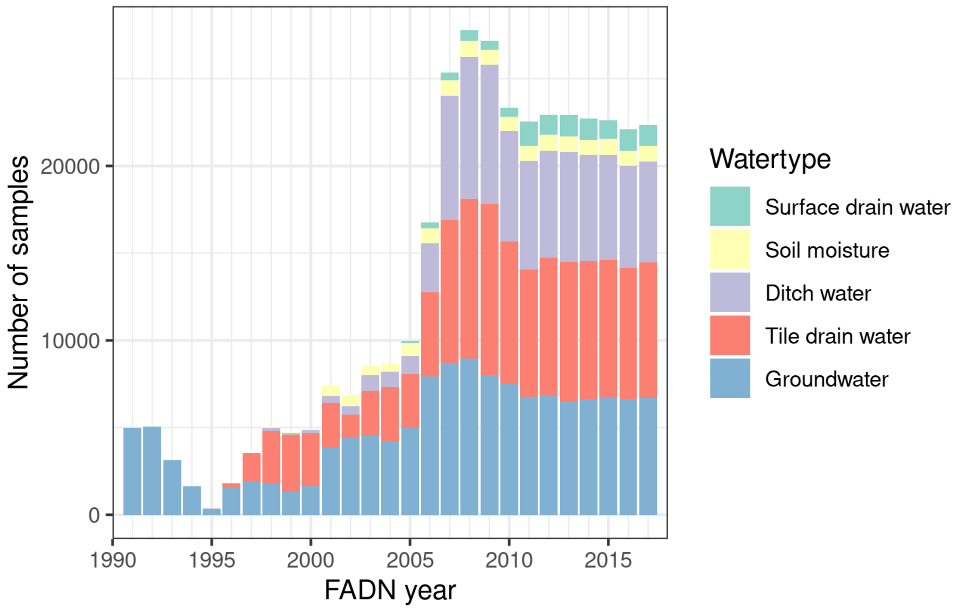


Figure A4.1 Historic overview of the number of individual samples taken from different water types.

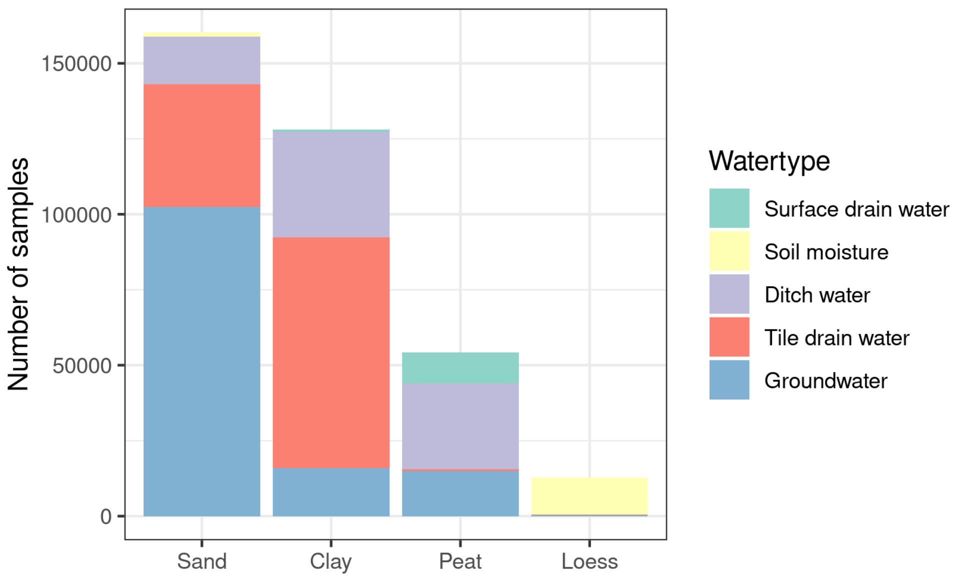


Figure A4.2 Number of individual samples taken from the different water types in the four soil regions during the whole history of the LMM (1992–2018).

ANNEX 5. Work Instructions for field activities

A5.1 Quality control using a system of Work Instructions

All field activities are performed in accordance with written Work Instructions, previously (prior to 2010) called ‘standard operating procedures’ (SOPs). These include instructions for the drilling of boreholes, the sampling of different types of water, field tests (including calibration procedures) and the handling of water samples. A summary of Work Instructions most relevant to the fieldwork related to water sampling and water quality testing is presented in Table A5.1.

Table A5.1 Work Instructions most relevant to fieldwork related to water sampling and water quality testing.

SOP/Doc. No.	Title
MIL-W-4001	Measuring the nitrate concentration in an aqueous solution using a Nitracheck-reflectometer (type 404) [version 5, May 2018]
MIL-W-4002	Use of control sheets for equipment calibration [version 5, September 2018]
MIL-W-4006	Measuring pH, specific conductivity and oxygen content in an aqueous solution using the WTW Multi 350i [version 6, August 2018]
MIL-W-4008	Temporary storage and transportation of samples [version 5, September 2019]
MIL-W-4010	Concise description of the soil profile [version 5, June 2018]
MIL-W-4012	Sampling of surface water/ditch water using a measuring jug [version 6, July 2018]
MIL-W-4013	Sampling of drain water [version 5, May 2018]
MIL-W-4014	Soil sampling for soil moisture testing using an Edelman auger [version 7, January 2019]
MIL-W-4015	Sampling of groundwater in sand, clay and peat using a sampling nozzle and a peristaltic pump [version 6, May 2018]
MIL-W-4016	Preparation of RIVM sampling nozzle for sampling groundwater and ditch water [version 5, May 2018]
MIL-W-4017	Field visits and work site inspections within the Environmental Quality Monitoring (MMK) Department [version 5, June 2019]
MIL-W-4018	Safety during fieldwork [version 6, June 2018]
MIL-W-4020	Compiling and archiving of the business information of agricultural firms [version 5, March 2019]
MIL-W-4021	Identifying the position of sampling points [version 7, April 2018]
MIL-W-4022	Recording the temperature in refrigerators [version 4, April 2018]
MIL-W-4023	Data validation and drafting (written) reports for individual LMM participants [version 5, March 2018]
MIL-W-4025	Drafting a working plan for measurements within the LMM programme [Version 2, August 2018]
MIL-W-4104	Collection of ground, ditch, and drain water or soil samples [version 2, May 2018]

In the ensuing sections a number of these Work Instructions are presented in detail, with reference to the materials and equipment used, as well as to the methodology. The Work Instructions for water sampling (in groundwater, drain water and ditch water) and the storage and transport of samples are presented in particular detail.

A5.2 Sampling of groundwater using a sampling nozzle in combination with a peristaltic pump on sand, clay and peat (Instruction MIL-W-4015)

Material

- location map with all plots and markings of locations where groundwater samples are to be taken (available through the Field App);
- spade;
- sheet of plastic;
- manual drilling equipment of various sizes:
  - edelman auger: Ø 7 cm / Ø 10 cm;
  - sand pump or suction borer (piston sampler): Ø 7 cm / Ø 10 cm;
  - bailer: Ø 7 cm / Ø 10 cm;
  - river side drill: Ø 7 cm / Ø 10 cm;
  - Van der Horst auger (drill for soft clay): Ø 7 cm / Ø 10 cm;
- plastic cylinder (collar): length of about 50 cm, Ø ±11 cm;
- sampling nozzles, in various lengths, of PVC material with a 50 cm perforated section (slot size 0.3 mm) and external graduation (RIVM design, in accordance with Work Instruction MIL-W-4016);
- filter gravel: bag with 25 kg content;
- clay plug material: type Mikolit 00: 25 kg bag;
- reservoir tube with perforated section (slot size 0.4 mm), length 100 cm, reservoir section of 50 cm, with a glued tip at the bottom end; total length 285 cm, $Ø_{int}$ 4.5 cm, $Ø_{ext}$ 5.0 cm;
- external tube: length 300 cm; $Ø_{int}$ 5.2 cm, $Ø_{ext}$ 6.0 cm (PVC, impact-resistant, yellow);
- sealing caps for reservoir tubes (HDPE, 50 mm);
- PE hose/tube: $Ø_{int}$ 4 mm, $Ø_{ext}$ 6 mm;
- peristaltic pump;
- lifting jack (*dompbok*), lever and chain;
- sounding lead;
- ball valve and tube;
- high-pressure water cleaner;
- sampling vehicle (e.g. quad bike);
- Field App;
- GPS with minimum accuracy of 10 metres (available through the Field App).

Procedure/Work method

A. Position of sampling point and sampling preparation

- Proceed to sampling point, using location map with marking of locations available in the Field App. If the position of the sampling point has not yet been established, determine the position using Work Instruction MIL-W-4021.

- If it is necessary to deviate from the point marked on the map, indicate the new point on the map in the Field App and record the reason for the deviation.
- Remove turf, using spade. Keep turf separate, for replacing after sampling. On arable land, drilling can start immediately.
- Put piece of plastic next to borehole, to display material drilled.

Depending on the monitoring sub-project (sand, clay or peat), a selection has to be made of one of the following sampling methods.

B. Sampling in sand and clay; install sampling nozzle according to open borehole method
This method can be used if the soil material in the groundwater-saturated zone is sufficiently loose (not compacted) to cause spontaneous slumping of the borehole. The method also requires a swift and profuse influx of groundwater. The above conditions apply primarily to sandy soils, but the open borehole method is also used for clay soils.

- Drill a hole with the 7 cm or 10 cm diameter auger to a depth of 30 cm (just below the arable soil).
- Install the collar in the hole, fully protecting the hole from intrusion of loose soil. Ensure that the collar protrudes from the surface, facilitating removal after sampling.
- Continue drilling with a 7 cm diameter auger up to a maximum depth of 75 cm below the groundwater level. This depth is reached upon wetting of the first connector cover of the drilling rod. Take into account that in the presence of clay (causing a slower influx of groundwater), the groundwater level may be underestimated.
- At a peat location, use the bailer 1 or several times if necessary, until the slush is almost removed.
- Install the sampling nozzle in the borehole and push it, if necessary with jerking movements, as far as possible into the hole.
- Often sampling can start within half an hour of installing the sampling nozzle. For the sampling methodology, reference is made to section D of this Instruction.

C. Sampling in peat; install sampling nozzle according to 'peat' method
Note: In practice, the sand method often also works well for peat soils and is used instead. This in part due to the use of larger filters with a bigger surface area, which are less easily clogged with organic material, and of a bailer to remove sediment and organic particles. The sand method is less complex and quicker.

- Drill with a 7 or 10 cm diameter auger down to the top of the peat.
- Continue drilling with a Van der Horst or Edelman auger down to about 1.5 m below the groundwater level. The Van der Horst auger is less sturdy than the Edelman auger. Therefore, beware of encountering hard lumps of peat or non-decayed branches.
- If required, clean the borehole with the bailer until the slush has more or less gone.

- Slide the reservoir tube inside the external tube and install the combination in the borehole.
- Push both tubes into the borehole to the correct depth. The correct depth is reached when the top of the perforated section of the reservoir tube is just below groundwater level.
- Remove the external tube. Avoid smearing and clogging the slots in the perforated section of the reservoir tube by avoiding rotating or upward movements.
- Record the time and date of installation.
- Close the hole around the reservoir tube with e.g. the turf or some of the drilling material, in order to prevent the inflow of surface water.
- Measure (with sounding lead) and record (in cm) the distance between the top of the reservoir tube and the surface level.
- Close off the reservoir tube with the designated sealing cap.
    - After installation of the reservoir tubes or at the end of the day of installation, and prior to pumping the tube for flushing purposes, measure the water level in the reservoir tube using a sounding lead.
      If insufficient water has entered the reservoir, the sampling point may be moved, after consultation with the fieldwork supervisor (operational manager) or fieldwork coordinator (network manager).
    - Empty the reservoir tube by pumping, using the peristaltic pump and 2.5 m hose (PE 4/6 mm). Special attention should be given to removing the mud from the tube’s reservoir.
      If the inflow of water exceeds the pumping rate, pumping is to continue for 5 minutes at maximum capacity.
- Note the time of pumping.
- At least one day should elapse after installation before the reservoir tubes can be sampled.
- To prevent water contamination, first clean the sounding lead with demineralized water, and a clean (paper) towel.
- Measure the water level in the reservoir tube with a clean sounding lead.
- While extracting the sounding lead from the reservoir tube, clean the ribbon attached to the sounding lead with a clean towel.
- Reference is made to section D for the implementation of the water sampling.

D. Sampling of groundwater

- Couple the hose of the sampling nozzle to the suction side of the peristaltic pump.
- Remove by pumping (flush) a certain amount of groundwater (depending on the sampling method selected; see Table A5.2). If the water looks clean (void of silt particles), pumping can be stopped.

Table A5.2 Minimum amount of groundwater to be pumped for flushing for the different sampling methods.

Sampling method	Volume to be pumped
Sand and clay	≥1,000 ml
Peat	≥100 ml[1]

[1] The borehole tube or reservoir tube has already been flushed (after installation). Therefore, flushing can be limited to a smaller volume. Applying these minimum recommendations will ensure that the PE hose is flushed at least three times (the volume of the 6/4 PE hose is 13 ml per metre).

- If the pumped water is not clear of silt particles, the above flushing prescription is to be repeated (five times at most). Alternatively, the fieldwork supervisor or fieldwork coordinator is to be contacted.
- Note the total volume of water pumped.
  When using the flow cell, this means that the water used to fill the flow cell must be included in the total amount of flushing water.
- Filter the water in accordance with the relevant work plan, or, in the case of outsourced work, in accordance with the terms of reference.
- Fill the sampling bottles and seal them.
- Shut down the pump.
- Decouple the sampling nozzle hose from the peristaltic pump, and (for the sake of protection) insert the hose into the sampling nozzle.

E. Finishing of sampling

- When applying the sand or clay method, mark/indicate on the sampling nozzle (by hand) the soil surface level, and remove the nozzle from the borehole.
- Identify the end of the wet part of the nozzle, and measure, using the grade marks on the nozzle, the depth of the water table below the soil surface.
- Measure also the distance between the top of the perforated section and the top of the wet part of the nozzle.
- Record both measurements (cm). Round to the nearest multiple of 5 (cm).
- When applying the peat method, remove the reservoir tube from the borehole, for example using the steel lifting jack and lever with chain.
- After sampling, refill the borehole with the material drilled from the borehole at installation. Compact the material into the borehole using the auger. Spread any remaining material and replace the turf removed during installation.
- Clean all augers and nozzles used with a brush, and clean water if necessary, and dry the augers to prevent rusting. Clean the used reservoir tubes with a high-pressure water cleaner, paying special attention to the slots.

A5.3 Sampling of drain water (Instruction MIL-W-4013)

Material

- Android device with the latest version of the RIVM Field App installed;

- stopwatch or watch with second-hand;
- plastic measuring jug with 1 litre capacity;
- spade;
- pickets and felt-tip pen (inedible ink) to mark drain locations in the field;
- sampling bottles – type of bottles, labelling and pre-treatment in accordance with work plan or consignment.

If drains discharge below the ditch water level, other requisites are:

- electronic peristaltic pump, e.g. electronic 12 V peristaltic pump supplied by Eijkelkamp, with matching battery loader; or a hand-pump, type Probenahmepumpe 28 supplied by Carl Roth (supplier's code E514.1) (www.carlroth.nl) with accompanying 500 ml collection bottle;
- PE hose Ø 4/6 mm, 2–4 m long and a 1 m PVC tube into which the hose will fit.

Procedure/Work method
A. Selection of drains
The drains to be sampled (16 in total) are spread over the drained parcels of a farm, in accordance with Work Instruction MIL-W-4021. A suggestion for the spread of the drains is marked on a map, containing all parcels of the farm. Using this map, the sample taker looks for suitable drains, and marks those drains (if permission is granted) with a picket, numbered in accordance with the suggested drain positions on the map. To prevent the drain water from being contaminated, the drains have to be dug free from overgrowing plants and/or dirt.

Subsequently, prepare a 'step-by step map'. To this end, start from a recognisable, permanent point on the farm (e.g. a causeway, gate, corner of a parcel, or another selected drain) towards the selected drain. Count and note the number of steps and direction in the RIVM Field App.

If the suggested map cannot be followed (for example, because of no/low discharge drains, or because no drain can be found), the observation point should be relocated within the parcel, the new location identified on the plan, and the 'step-by-step map' adjusted. If there is no replacement available within the parcel to be sampled, contact the fieldwork supervisor.

For peat soils, only surface drains will be selected. Tile drains are not sampled in the Peat region.

After the first sampling, record the selection of locations on the map and subsequently within Simplemanager. This information will be the basis of any future sampling.

B. Pinpointing the time of sampling
Sampling can proceed if the three following conditions are met simultaneously:

1. the date is later than the date indicated on the raw data form under 'sampling AFTER'.
2. it is not a Friday, Saturday or Sunday.

3. at least 80% of the selected drains (at least 13 drains) are producing sufficient discharge.

In frosty weather, drains may still be discharging while ditches are frozen. The thickness of the ice sheet permitting, a hole may be cut in the ice to allow the sampling of ditch water in combination with drain water. Note on the raw data form, under 'particulars', the thickness of the ice cover in centimetres. If the ice sheet on the ditches is too thick, only drain water can be sampled. The fact that the ditches were frozen should be registered on the raw data forms.

The sampling procedure for tile drains discharging above ditch water level is presented under C. For the sampling of tile drains discharging below ditch water level, reference is made to section D.

C. Sampling of tile drains discharging above ditch water level

- Proceed to the tile drain to be sampled, using the information described under A. Drains to be sampled are normally marked with a picket. These pickets may disappear in the course of time, for example during cleaning of the ditch. If necessary, a new picket should be installed.
- If required, clear the area surrounding the tile drain with the spade, and clean the bottom, to prevent contamination of the measuring jug.
- Check, using the measuring jug, whether the drain produces sufficient discharge (i.e. at least 0.2 l per minute). If the flow is adequate, use this water to rinse the jug, and subsequently empty the jug. If the tile drain does not produce enough water, or if the drain cannot be sampled for some other reason, while most of the other drains are discharging, an alternative tile drain should be identified on the same parcel.
  ** Note the number of steps and direction from the drain location originally selected.*
  ** If the relocation is permanent, the new location is to be indicated on the map of the farm, and the step-by-step map should be adjusted.*

The alternative drain should be situated in the same parcel. If no alternative drain is available on the same parcel, the fieldwork supervisor should be contacted.

- The following data must be filled in:
  - parcel number;
  - whether a replacement drain was selected;
  - if applicable, the location of the replacement drain;
  - the distance between bottom drain tube and the ditch water level (in cm);
  - any other information in accordance with the work order.
- Rinse the measuring jug once more, by filling it to at least 20%, shaking it and emptying it.
- Register the time required to collect 1 litre of drain water. This gives the discharge rate. Note this time (in minutes and seconds) under the heading 'discharge measurement'.
- Flush the sample bottles once with drain water from the measuring jug, by filling the bottles at least a quarter full, replacing the lids, and shaking vigorously.

- Empty the sample bottles, refill them completely with drain water from the measuring jug and cap them securely.
- Store the bottles in a cool box.

D. Sampling of tile drains discharging below ditch water level in clay and sand areas
When a drain discharges below the surface level of the ditch water, there is a risk of sampling the ditch water instead of the water from the drain. For this reason, as under B, the drain in question should be tested for sufficient discharge. The assumption is made that, if the drain discharges, the pressure is sufficiently high to prevent the mixing of ditch water and drain water within the tile drain.

Since there is no simple way of measuring the discharge, this aspect has to be judged visually. If there is discharge, this can be visible on the ditch water's surface (turbulence, disturbance), or silt loosened at the drain mouth may be transported by the drain's discharge into the ditch. If the water is sufficiently clear, discharge from a drain may be detected from the movement of aquatic weeds. An object may be inserted in the water in front of the drain to observe any movement. Sometimes the (unpleasant) odour of a sample indicates that drain water has been sampled. Nearby drains discharging above ditch water level may provide an indication of the likeliness of discharge by drains ending below ditch water level.

In the absence of any of these clues, the procedure for selecting an alternative drain should be followed (described in section C).

- If the flow of a drain is ascertained, the drain data are noted. A negative value should be used for the distance between the top of the drain and the ditch surface water level. The discharge should be noted as 'N.A.'.
- Insert a PVC pipe about 1 m long into the tile drain, and through this PVC pipe insert a hose as far as possible into the drain. Under certain circumstances the PVC pipe may not be convenient or required; for example, in the case of bends/curves in the drain, or if there is little manoeuvring space at the end of the drain. Leave the material for about 1 minute to allow unsettled silt to flush from the drain. Subsequently, switch on the peristaltic pump or use the hand-pump, and slowly flush about 1 litre of water. Use this water to flush the measuring jug or collector bottle.
- Fill the measuring jug or collector bottle with drain water and follow the procedure as described under C.

E. Sampling of tile drains discharging below ditch water level in peat areas
When drains connecting surface drains to a ditch discharge below ditch water level, water can be sampled from the surface drain. In that case, no discharge measurement is possible.

A5.5 Soil moisture sampling using a Edelman auger (Instruction MIL-W-4014)

Material

- spade;
- edelman auger: Ø 7 cm / Ø 10 cm – optionally provided with coloured tape to mark the depth at 10 cm intervals;
- knife or sturdy spatula;
- sealable plastic containers;
- sheet of plastic;
- weighing machine accurate to within 1 g, with a maximum load of at least 1,000 g;
- thermometer;
- cool box x 2;
- fieldwork vehicle;
- location map with all parcels and sampling locations (available through the Field App);
- field/hand-held computer with 2L-inputmodule;
- plastic cylinder (collar), length about 50 cm, Ø ±11 cm.

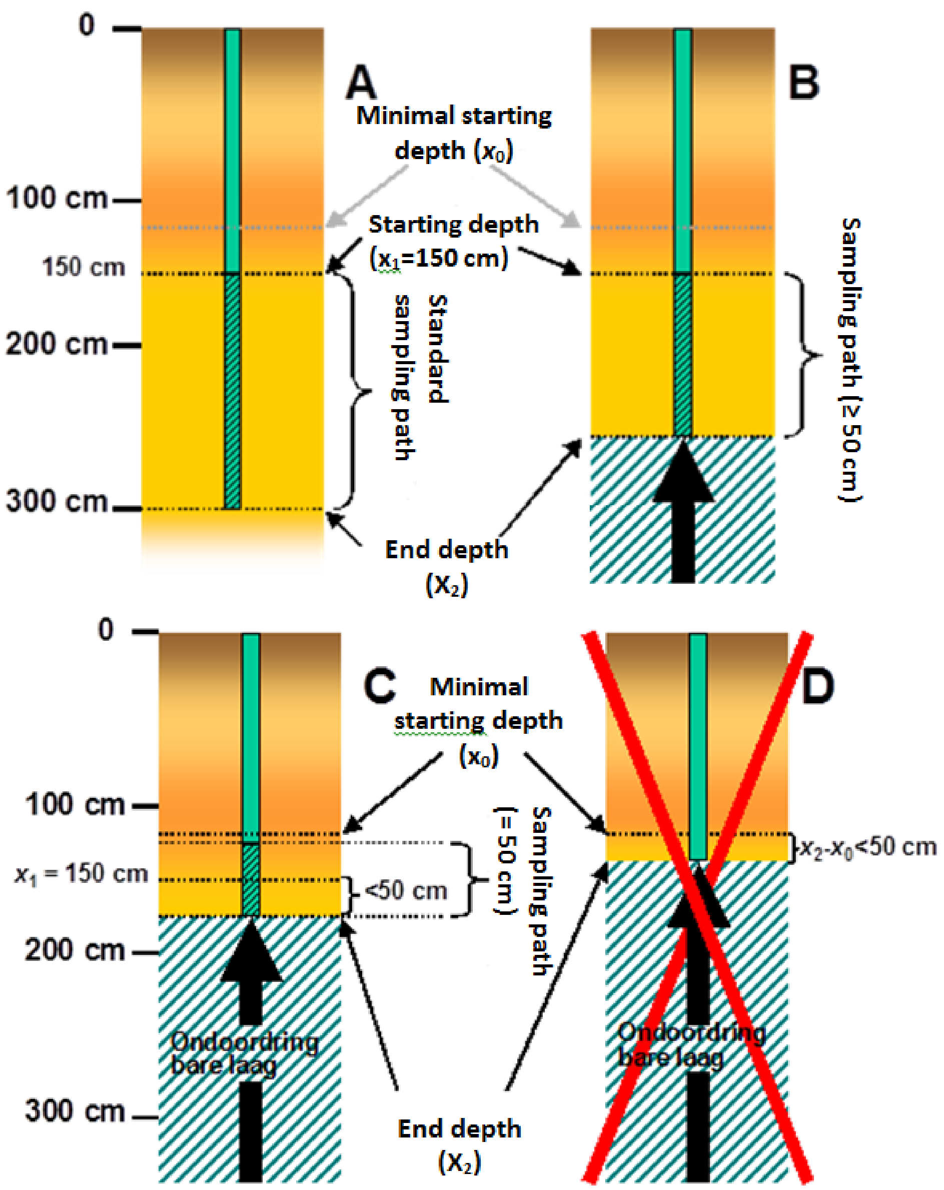
Procedure / Work method

A. Preparation

- Check that the materials are clean and in good condition.
- Number with a marker pen all the sample trays that are to be used to collect the sample material, as follows:
  - container number 1 = 120–130 cm deep (= X_0 = *minimum starting depth*);
  - container number 2 = 130–140 cm deep;
  - container number 3 = 140–150 cm deep;
  - container number 4 = 150–160 cm deep (= X_1 = *starting depth*);
  - container number 5 = 160–170 cm deep;
  - etc.

The last tray will be number 18 with sample material from 290 to 300 cm deep (= X_2 = *end depth*).
The *minimum starting depth* (X_0) is 120 cm to avoid plant roots.

B. Sampling



The minimum starting depth (X0) is 120 cm. The standard sample path is from 150 to 300 cm.

A. 'Deep' soil will be sampled over the standard sample path.

B. Impregnable layer above the end depth (300 cm), sampling depth ≥50 cm: the soil can be sampled over a path from ≥50 cm without adjusting the starting depth (X1).

C. Impregnable layer above the end depth (300 cm), resulting in sampling depth <50 cm: The soil will be sampled over a range from 50 cm by adjusting the starting depth (X1).

D. Insufficient depth. The soil cannot be sampled over a path of 50 cm without sampling above the minimum starting depth (X0). The sample point has to be shifted 10 to 20 metres horizontally.

Figure A7.1 Sample path, whether or not hampered by the presence of an impregnable layer.

For ‘deep’ soils (Figure A7.1-A) the ‘standard sampling path’ from 150 to 300 cm will apply. However, when an impregnable layer[4] is detected *before the end depth of the standard sampling path is reached*, the following procedure will apply.

a. The soil must be sampled uniformly over a trajectory of at least 50 cm.
b. The sampling must start below the minimum depth (*X_0 = 120).*

When the soil has insufficient depth, as in Figure A7.1-D, a new bore hole must be drilled 10 or 20 m further ahead. Since there may be an impermeable layer at the bottom of the drill hole, a multistage sampling method will be used. Initially, every 10 cm core starting from the minimum starting depth (*X_0)* will be put in a separate sealable container.

If it is practically impossible to find suitable sample points, a different minimum starting depth can be selected to avoid plant roots (*X_0* value) *after consultation with the fieldwork supervisor (operational manager) or fieldwork coordinator (network manager)*.

Collecting soil samples
Collect the samples according to Work Instruction MIL-W-4014, paragraphs 3.2.1–3.2.21.

Preparing individual samples
To determine how much soil is needed from each container to make an individual sample, follow Work Instruction MIL-W-4014, paragraphs 3.2.22–3.2.23.

Preparing composite samples
Two composite samples will always be used, regardless of the type of sampling; soil moisture/soil moisture, soil moisture/groundwater or groundwater/groundwater.

If fewer than 16 soil samples are taken, there is 1 mixed sample for analysing soil moisture and 1 mixed sample for groundwater.

Finishing of sampling and cleaning of material
Remove the collar and fill the hole by putting back the bored-out soil, if necessary using the Edelman auger to push it back. After filling the hole, replace the turf, if present.

Clean the Edelman auger, knife or spatula and plastic containers with a brush or paper towel and/or clean water. To prevent the augers from rusting, dry them thoroughly.

A. Conservation and transport of samples
Conserve the sampling jars with the soil moisture samples by cooling them to 4° C within 6 hours of sampling.
Transport the water samples, in accordance with Work Instruction MIL-W-4008, to their destination.

[4] An impregnable layer is a subsoil layer that is too hard to drill manually. A very dry layer, such as marl, is also considered to be an impregnable layer.

A5.6 Temporary storage and transport of samples (Instruction MIL-W-4008)

Material

- portable cool box;
- cool box or refrigerator, built into the fieldwork vehicle, with pre-set cooling temperature of +5(±3)° C;
- freezer;
- frozen cooling elements (<-15° C).

Procedure/Work method

The Soil and Water Operational Department uses two methods of storing and transporting samples under controlled conditions. The first method is the use of a portable cool box, if necessary in combination with cooling elements. The second is the use of a cool box or refrigerator built into the fieldwork vehicle.

A. Temporary storage under controlled temperature conditions

This instruction also applies to the storage of water samples during sampling itself.

- Put the samples in a portable cool box or built-in cool box/refrigerator immediately after they have been taken. *The built-in cool box or refrigerator should be switched on while travelling to the farm to be sampled, so that the required temperature is achieved in advance.*
- Make sure that the sampling bottles stand upright and are stable, to avoid toppling or breakage.
- If a portable cool box is used, it is recommended to use a number of frozen cooling elements – certainly if the outside temperature is above 15° C. The cooling elements should be placed on top of the sample bottles.
- Keep the (closed) portable cool box in a cool, dark location. *Refrain from putting the cool box in a sunny place. Preferably place it in the shade of a car or a building. Never leave the cool box unattended in the fieldwork vehicle, since the temperature may rise sharply if the vehicle is left in the sun.*
- Transport or dispatch (by courier) the samples as soon as possible after sampling to the laboratory responsible for testing, or to a storage space with a constant temperature of +5(±3)° C.
- Return any used cooling elements to the freezer.
- Clean and wipe dry the cool box after use.

B. Transport of samples

- The programme uses two methods of transporting samples to the designated laboratory.
  - The sample-taker himself/herself conveys the samples.
  - The samples are dispatched by courier at the end of the day of sampling, packed in a cool box.

ANNEX 6. Agencies involved in water sampling

Table A6.1 Sampling sub-projects and organisations carrying out water sampling over the period 2015–2018 (FADN years 2014–2017).

Period	**Programme**	**Sampling period**	**Organisation**
Winter 2014/15	Clay drains and ditches (CL dr/di)	Oct–Mar	CBD/VIN
	Clay groundwater (CL gw)	Nov–Dec Feb–Mar	LCSO/RIVM
	Clay ditches (CL di)	Nov–Mar	CBD/VIN
	Loess soil moisture (LO sm)	Sep–Feb	RIVM
	Peat groundwater (PE gw)	Nov–Mar	RIVM/TAUW
	Peat surface drain water and ditches (PE sdr/di)	Oct–Mar	CBD
	Peat ditches (PE di)	Nov–Mar	CBD
	Sand winter drains and ditches (SW dr/di)	Oct–Mar	CBD/VIN
	Sand winter groundwater (SW gw)	Nov–Mar	LCSO/RIVM
Summer 2015	Clay ditches (CL di)	June–Sep	CBD/VIN
	Peat ditches (PE di)	June–Sep	CBD
	Sand summer groundwater (SS gw)	Apr–Sep	LCSO/RIVM/ TAUW
	Sand summer ditches (SS di)	June–Sep	CBD/VIN
Winter 2015/16	Clay drains and ditches (CL dr/di)	Oct–Mar	CBD/VIN
	Clay groundwater (CL gw)	Nov–Dec Feb–Mar	LCSO/RIVM
	Clay ditches (CL di)	Nov–Mar	CBD/VIN
	Loess soil moisture (LO sm)	Sep–Feb	RIVM
	Peat groundwater (PE gw)	Nov–Mar	RIVM/TAUW
	Peat surface drain water and ditches (PE sdr/ di)	Oct–Mar	CBD
	Peat ditches (PE di)	Nov–Mar	CBD
	Sand winter drains and ditches (SW dr/di)	Oct–Mar	CBD/VIN
	Sand winter groundwater (SW gw)	Nov–Mar	LCSO/RIVM
Summer 2016	Clay ditches (CL di)	June–Sep	CBD/VIN
	Peat ditches (PE di)	June–Sep	CBD
	Sand summer groundwater (SS gw)	Apr–Sep	LCSO/RIVM/ TAUW
	Sand summer ditches (SS di)	June–Sep	CBD/VIN
Winter 2016/17	Clay drains and ditches (CL dr/di)	Oct–Mar	CBD/VIN
	Clay groundwater (CL gw)	Nov–Dec Feb–Mar	LCSO/RIVM
	Clay ditches (CL di)	Nov-Mar	CBD/VIN
	Loess soil moisture (LO sm)	Sep–Feb	RIVM
	Peat groundwater (PE gw)	Nov–Mar	RIVM/TAUW
	Peat surface drain water and ditches (PE sdr/ di)	Oct–Mar	CBD
	Peat ditches (PE di)	Nov–Mar	CBD
	Sand winter drains and ditches (SW dr/di)	Oct–Mar	CBD/VIN
	Sand winter groundwater (SW gw)	Nov–Mar	LCSO/RIVM

Period	Programme	Sampling period	Organisation
Summer 2017	Clay ditches (CL di)	June–Sep	KIWA/VIN
	Peat ditches (PE di)	June–Sep	KIWA
	Sand summer groundwater (SS gw)	Apr–Sep	LCSO/RIVM/ TAUW
	Sand summer ditches (SS di)	June–Sep	KIWA/VIN
Winter 2017/18	Clay drains and ditches (CL dr/di)	Oct–Mar	KIWA
	Clay groundwater (CL gw)	Nov–Dec Feb–Mar	LCSO/RIVM
	Clay ditches (CL di)	Nov-Mar	KIWA
	Loess soil moisture (LO sm)	Sep-Feb	RIVM
	Peat groundwater (PE gw)	Nov–Mar	RIVM/TAUW
	Peat surface drain water and ditches (PE sdr/di))	Oct–Mar	KIWA
	Peat ditches (PE di)	Nov–Mar	KIWA
	Sand winter drains and ditches (SW dr/di)	Oct–Mar	KIWA
	Sand winter groundwater (SW gw)	Oct–Mar	LCSO/RIVM
Summer 2018	Clay ditches (CL di)	June–Sep	KIWA
	Peat ditches (PE di)	June–Sep	KIWA
	Sand summer groundwater (SS gw)	Apr–Sep	LCSO/RIVM/ TAUW
	Sand summer ditches (SS di)	June–Sep	KIWA
Winter 2018/19	Loess soil moisture (LO sm)	Oct-Feb	LCSO/RIVM

ANNEX 7. Laboratory testing techniques and detection limits

Component/element	Symbol	LOD	Unit	Technique	SOP number	Conservation through/with
Dissolved organic carbon	DOC	0.3	mg/l	infrared (IR)	W-030	H_2SO_4 pH 2 /cooling
Chloride	Cl	0.21	mg/l	ionchromatography	W-060	Nothing
Nitrate	NO_3	0.31	mg/l	ionchromatography	W-060	Filtration and cooling (H_2SO_4 pH 2)
Nitrate	NO_3	0.31	mg/l	ionchromatography	W-060	cooling
Sulphate	SO_4	0.48	mg/l	ionchromatography	W-060	cooling
Nitrate + Nitrite (difference)	NO_3	3	mg/l	photometry/CFA	W-020	cooling
Nitrite	NO_2	0.4	mg/l	photometry/CFA	W-020	cooling
Electro-conductivity	EC(25)	0.5	mS/cm	potentiometry/CFA	W-020	cooling
Acidity	pH			potentiometry/CFA	W-020	cooling
Ortho-phosphate	PO_4	0.04	mg/l	photometry/CFA	W-023	H_2SO_4 pH 2[1] / cooling
Total nitrogen	N-total	0.2	mg/l	photometry/CFA	W-024	H_2SO_4 pH 2 / cooling
Ammonium	NH_4	0.064	mg/l	photometry/CFA	W-027	H_2SO_4 pH 2 / cooling
Aluminium	Al	0.01	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Arsenic	As	0.2	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Barium	Ba	1	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Cadmium	Cd	0.05	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Calcium	Ca	0.15	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Chromium	Cr	0.5	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Total phosphorous	P-total	0.05	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Iron	Fe	0.05	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Potassium	K	0.1	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Copper	Cu	0.5	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)

Component/element	Symbol	LOD	Unit	Technique	SOP number	Conservation through/with
Lead	Pb	0.2	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Magnesium	Mg	0.05	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Manganese	Mn	4	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Sodium	Na	0.2	mg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Nickel	Ni	0.5	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Strontium	Sr	1	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Zinc	Zn	4	µg/l	ICP-MS	W-036	pH 1–2 (HNO_3)
Electro-conductivity	EC(20)	3	µS/cm	potentiometry	W-067	cooling
Acidity	pH			potentiometry	W-067	cooling
Kjeldahl-N[2]	N-total unfiltered	0.06	mg/l	photometry/CFA	W-069	H_2SO_4 pH 2 / cooling
Total phosphorus[2]	P-total unfiltered	0.07	mg/l	photometry/CFA	W-069	H_2SO_4 pH 2 / cooling

[1] Conservation by acidification is not in accordance with NEN-EN-ISO 5667-3 (2012).
[2] Only measured for unfiltered ditch water samples. Samples are digested according to NEN-6645 (2005).

ANNEX 8. Monitoring of agricultural characteristics

This annex relates to the data on agricultural practices and nutrient management (see Section 4.2). Section A8.1 identifies the indicators for farm dimensions and nutrient management. The annex explains how data from the FADN network are used to calculate farm-specific use of livestock manure (Section A8.2), grass and silage maize yields (Section A8.3) and nutrient surpluses (Section A8.4).

A8.1 Data on agricultural practices and mineral management (FADN)

Farms differ in terms of management (individual choice of a farmer) and physical conditions (size, hydrology and soil conditions). This section describes the categories of farm dimensions and nutrient management (for a detailed description see Oudendag et al., 2017). Figure A8.1 shows the different processes and interactions that might take place on a farm, illustrating the kind of management choices a farmer has to make. The actual processes on a farm depend on the farm type (dairy, arable, intensive livestock or other), see section A8.1.1. This section describes the various indicators under two categories: 'characterisation of farms' (farm dimensions) (see section A8.1.2) and 'nutrient management' (see section A8.1.3).

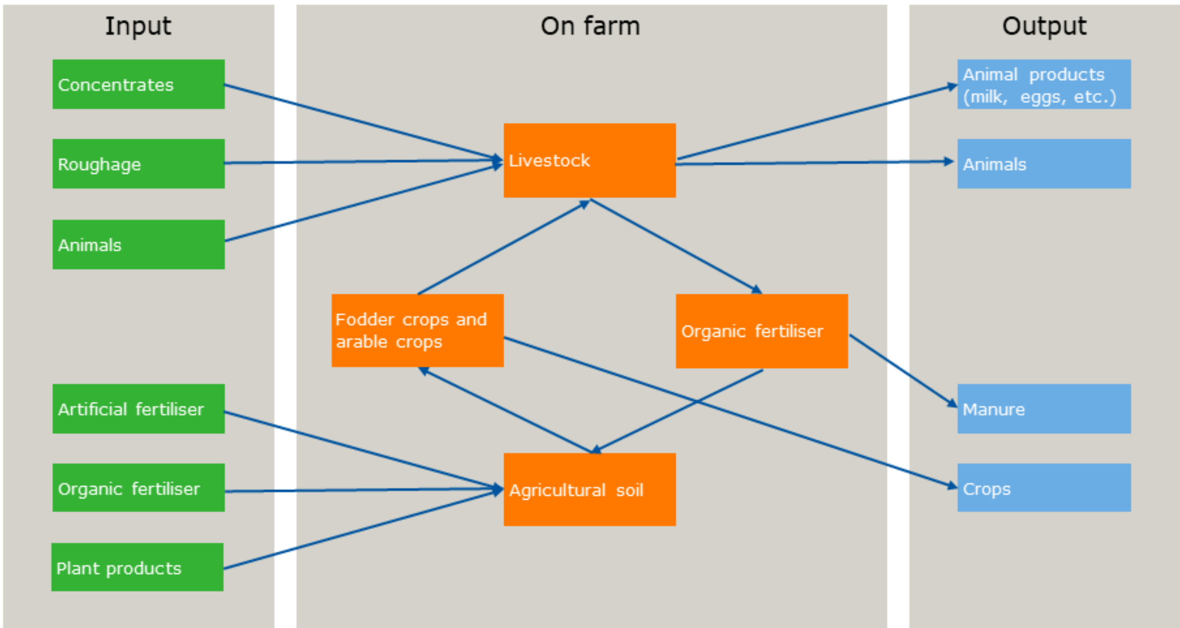


Figure A8.1 Farm processes and interactions.

A8.1.1 Farm processes as a function of farm type

Dairy farms

1. Livestock produces milk, meat and organic manure.
2. On-farm produced organic fertiliser is (partly) used on the farm's own agricultural land or removed from the farm.

3. In addition to on-farm-produced organic fertiliser, non-organic fertiliser and/or 'imported' organic fertiliser can be used on the farm's agricultural soil.
4. The agricultural soil is mainly used to grow fodder crops.
5. Fodder crops and inputs of concentrates and roughage are used as feed for the animals.

Arable farms

1. Imported organic fertiliser and non-organic fertiliser are used on the farm's own agricultural soil.
2. The agricultural soil is used for crops, most of which are removed from the farm for processing or consumption elsewhere (cash crops).

Intensive livestock farms

1. Livestock produces meat and/or eggs and manure.
2. On-farm-produced organic fertiliser is (partly) used on the farm's own agricultural land or removed from the farm.
3. In addition to on-farm-produced organic fertiliser, non-organic fertiliser may be used on the farm's agricultural soil.
4. The agricultural soil is used to grow fodder crops and/or arable crops, depending on whether the farmer chooses to produce feed for her/his own livestock.
5. Self-produced crops and concentrates and roughage from outside are used as feed for the animals.

On farms of the farm type 'other animal farms', combinations of the different processes take place.

A8.1.2 Characterisation of farms

The LMM uses data on agricultural practices to establish a general characterisation of farms. Farms are characterised on the basis of the following parameters:

- surface of cultivated land;
- livestock density;
- milk production;
- classification of cultivated land.

Surface of cultivated land

Fertiliser application, crop production and nutrient surplus are expressed per surface unit. For these parameters, the total area of cultivated land is used. This total area is the land used by the farmer for crop production and on which fertiliser is applied. Parcels leased out or outside the Netherlands, stretches of natural land, ditches, and built-up or paved surfaces are not included in the definition of cultivated land in the LMM.

Livestock density

Livestock density is expressed in Phosphate Livestock Units (LSUs) per hectare of cultivated land. The LSU is a unit used to compare numbers of animals based on their average phosphate production. One adult dairy cow produces 41 kg of phosphate on average per year, which is equivalent to 1 LSU. A dairy cow aged 1–2 years produces 18 kg of phosphate (0.44 LSUs); a dairy cow aged 0–1 years produces 9 kg of phosphate (0.22 LSUs) (Ministry of Agriculture, Nature & Food Quality, 2000).

Milk production
At dairy farms, milk production is reported both per dairy cow and per ha. To this end, the ‘fat and protein corrected milk’ (FPCM) parameter is applied. This measure relates to milk production with a correction for fat content and protein content, according to the following formula (CVB, 2016):

*FPCM = kg milk * (0.337 + 0.116 * fat content + 0.06 * protein content)*

This correction enables a better correlation of production with nutrient and fodder consumption.

Classification of cultivated land
Since nutrient requirements and nutrient uptake differ per crop, the quality of percolating water may be a function of the crop grown. On dairy farms, the production of fodder crops is the main objective of land use. In its analysis of crop production on dairy farms, the LMM distinguishes between grass, silage maize, other fodder crops and marketable crops. The category ‘other fodder crops’ includes crops such as mangold (mangel-wurzel), alfalfa and cereals used as fodder. Crops not produced for fodder are considered to be sold on the market (cash crops).

On arable farms, the production of crops is the primary production objective. For each farm, the areas and surface percentages of different cash crops (such as potatoes, sugar beets, cereals and pulses) are reported, as well as those of fodder crops (grass and silage maize).

On intensive livestock farms and farms grouped under ‘other farms’, the production objective is often a combination of crops. For these farms, both the fodder crops and the cash crops are taken into consideration.

A8.1.3 Nutrient management
In the LMM, the nutrient management of farms is characterised by fertiliser use (consumption) and nutrient surpluses.
Fertilisers are divided into inorganic fertilisers, livestock manure and other organic fertilisers. Other organic fertilisers include compost. The production and use of other organic fertilisers has increased in recent years, so greater attention is paid to registration and calculation.

Fertiliser use at farm level is reported, and a distinction is made between the use of fertilisers on arable land and on grassland. Fertiliser use on natural grassland and use abroad are not taken into account because the Dutch mineral policy is about Dutch agricultural land. Pasture manure and fertiliser use is corrected for pasture manure produced abroad and fertiliser used abroad. This calculation method was introduced in 2015 and covers the whole period for which data are available.
Approximately since 2008, the FADN has recorded whether grazing of livestock on land belonging to the farm takes place abroad and, if so, during what period. It has also recorded whether there were fertiliser uses in the area abroad belonging to the farm and, if so, the amount of fertiliser used.

On dairy farms, information pertaining to the use of grassland (degree of grazing and mowing) and the storage capacity of organic manure are also taken into account.

A8.1.3.1 Calculation of fertiliser usage

On-farm use of livestock manure

In order to calculate the use of nutrients in livestock manure, the on-farm production of manure must first be calculated. In the case of nitrogen, this means the net production after deducting the 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 excretion standards (Netherlands Enterprise Agency, 2020a: tables 4 and 6). This method does not apply to farms that use the guidance document issued for this purpose (see the section below entitled 'Farm-specific use of livestock manure'). The nitrogen and phosphate production of livestock is calculated using standardized methods, which are annually updated by the Working Group on Uniform Mineral and Manure Excretions (Statistics Netherlands, 2020a).
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, 2020a: table 5). If no sampling results are available, the output of on-farm-produced manure is calculated on the basis of the farm-specific mineral content per cubic metre of manure, provided the relevant farm uses the Farm-Specific Excretion (BEX) method or the stable balance method. Standard quantities are used for other farms. The total quantity of fertiliser used at farm level is then calculated using the following formula:

Quantity of fertiliser used on farm per year = production + opening stock level – closing stock level + input – output

On farms with intensive livestock production, the allocation method for fertilising with livestock manure is used. When it appears that fertiliser use on livestock farms is outside the probability limits, the established manure allocations (in metric tonnes) are used. Nitrogen and phosphate quantities in manure produced by the livestock are based on certain standards (Netherlands Enterprise Agency, 2020a: table 5). If the fertilization based on the allocation method is outside the probability limits, then the farm is not suitable for research. The effect of this adjustment is that there are fewer farms inside the fertilization probability limits and hence fewer farms available for research. The allocation method influences fertiliser use but has little influence on the calculations of the soil surplus.

Farm-specific use of livestock manure

Since 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 (latest version: Netherlands Enterprise Agency, 2020b). Manure production on these farms is not calculated on the basis of standard quantities, but separately for each farm (see Section A8.2).

Use of fertilisers on arable land and grassland
The quantities of fertilisers used on arable land are registered directly in the FADN. The type of fertiliser, the quantities applied, and the time of application are all collected. 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 nitrogen and phosphorus contents derived from sampling results (if available), or;
- the farm-specific mineral content if manure production is calculated separately for each farm (see below), or, if this is not the case;
- the applicable standard nitrogen and phosphorus contents (Netherlands Enterprise Agency, 2020a: table 5).

The quantity of fertiliser applied on grassland is calculated as follows:

Fertiliser use on grassland = fertiliser use at farm level -/- fertiliser use on arable land

In the case of farms where grassland accounts for less than 25% of the total cultivated area, fertiliser use on grassland is estimated and the fertiliser use on arable land is calculated as follows:

Fertiliser use on arable land = fertiliser use at farm level -/- fertiliser use on grassland.

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

Use of plant-available nitrogen
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 Netherlands Enterprise Agency (2020a: 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% since 2008) for all grazing livestock manure produced and applied on the farm. A lower statutory availability coefficient (30%) 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 taking the available surface area per crop in the FADN and subsequently calculating the weighted average using the application standards as supplied by the RVO (Netherlands Enterprise Agency, 2020a, table 2). Since 2010, application standards for phosphate have been differentiated (depending on the phosphate status of the soil). In order to determine the soil phosphate status, results of soil tests are recorded in the FADN. If the soil phosphate status is unknown, it is recorded as 'high'.

Lower and upper limits
On LMM farms, fertilisation with inorganic fertilisers, livestock manure and other organic fertilisers must be within the LMM confidence intervals in order to eliminate any data registration errors. This applies to the separate nitrogen and phosphate quantities, as well as to the total quantities of fertiliser applied (i.e. inorganic fertilisers, livestock manure and other organic fertilisers). Table A8.1 lists the confidence intervals for non-organic dairy farms.

Table A8.1 Lower and upper limits for applied quantities of inorganic fertilisers, livestock manure and other organic fertilisers on non-organic dairy farms, and total quantities of fertilisers applied (inorganic fertilisers, livestock manure and other organic fertilisers), expressed in kilogrammes of nitrogen and phosphate per hectare.

Nutrient and type	Lower or upper limit	Kg per hectare
Nitrogen		
Inorganic fertilisers	Lower limit	0
	Upper limit	400
Livestock manure	Lower limit	0
	Upper limit	500
Other organic fertilisers	Lower limit	0
	Upper limit	400
Total fertiliser use	Lower limit	50
	Upper limit	700
Phosphate		
Inorganic fertilisers	Lower limit	0
	Upper limit	160
Livestock manure	Lower limit	0
	Upper limit	250
Other organic fertilisers	Lower limit	0
	Upper limit	200
Total fertiliser use	Lower limit	25
	Upper limit	350

A8.1.3.2 Calculation of surplus nutrients

Nutrient 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 the 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. In other words, it is assumed that, in the long term, the input of organic nitrogen and phosphate in the form of crop residues and organic manure is equal to the annual decomposition. An exception to this rule is made for peat soils and reclaimed peat subsoils (*dalgronden* in Dutch). 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 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.

The calculation method used to determine the nitrogen surplus on the soil surface balance starts with the calculation of the surplus on the farm gate balance. The surplus on the farm gate balance is 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 on the farm gate balance is then corrected to account for input and output items on the soil surface balance. The phosphate surplus on the soil surface balance is equal to the surplus on the farm gate balance. Table A8.2 lists the confidence intervals for surpluses on the farm gate balance. A more detailed explanation of the calculation methods can be found in the following sections of this Annex.

Table A8.2 Lower and upper limits for the surplus on the farm gate balance, expressed in kilogrammes of nitrogen and phosphate per hectare.

Nutrient	Lower or upper limit	Kg per hectare
Nitrogen		
	Lower limit	-250
	Upper limit	800
Phosphate		
	Lower limit	-100
	Upper limit	250

A8.1.3.3 Livestock manure storage rate

The 'livestock manure storage rate' relates the storage capacity for livestock manure to its production. A rate of 6 months means that half of the annual production of manure can be stored. When the manure storage rate is above 7 months, farmers may store manure longer than legally obliged (namely 7 months, as of 2012), enabling them to use it when crops need it most.

The animal manure storage rate capacity is calculated as:

manure storage capacity / (annual livestock manure production/12)

A8.1.3.4 Rate of grazing

The indicator 'rate of grazing' provides information on the time dairy cows spend grazing (in the field) during the period May–October. A

100% grazing rate would mean that the cows were feeding in the field for 24 hours a day for the full period. In reality, this value is not attainable, as cows are generally milked twice a day. A score of more than 80% is high, indicating that, outside milking hours, the cows are permanently in the field. The rate of grazing is calculated as:

*(number of grazing hours of dairy cows in the period May–October / (184 days * 24 hours / day)) * 100%.*

A8.1.3.5 Rate of mowing

The rate of mowing indicates how often the grassland is mowed in a year. A mowing rate of 300% means that it is mowed three times per year on average. The mowing rate is calculated as:

*(area of grassland mowed annually / pasture area) * 100%.*

The combination of the indicators 'rate of grazing' and 'rate of mowing' provides information on the overall use of grassland.

A8.2 Farm-specific use of livestock manure

Since 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, the so called BEX-method (latest version: Netherlands Enterprise Agency, 2020b). Manure production on these farms is not calculated on the basis of standard quantities, but separately for each farm, provided the following criteria are met:

- The farm itself has reported that it uses the BEX method.
- Recorded maize yield is greater than zero.
- Calculated energy uptake from grassland products is not negative.

The deviations of the calculated specific excretions from the standard excretions for phosphate and nitrogen are within the range of -40% and +20%. These limits are based on expert judgement. If the excretion falls outside the boundaries, the excretion is calculated on a standard basis.

Since 1 May 2015, the guidance document on farm-specific excretion by dairy cattle has been 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:

- 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 (according to the method explained in Aarts et al., 2008). In the guidance document, the uptake is calculated using a correction method for feed uptake.
- The allocation of VEMs to fresh and conserved grass is calculated on the basis of the net number of grazing hours reported by the farmer, whereas the guidance document (Ministry of Economic Affairs, 2015) and Aarts et al. (2008) define three classes based on reported grazing hours. The latest guidance document (Netherlands Enterprise Agency, 2020b) determines fresh grass uptake by the number of grazing days and hours per day of grazing.

A8.3 Calculation of grass and silage maize yields

A8.3.1 Calculation procedure

The calculation procedure for determining grass and silage maize yields in the FADN is largely identical to the procedure described in Aarts et al. (2005, 2008). First, the energy requirement of the dairy herd is determined on the basis of the milk production and growth achieved. All transactions and stock changes of feed products are registered in the 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 then determined from measurements and content data for silage supplies, as far 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 then assumed that the remaining energy requirement is covered by grass produced on the farm. The number of grazing days registered in the 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 VEMs) obtained by the animals from farm-produced feed. The nitrogen and phosphate uptake are then calculated by multiplying the uptake in VEMs by the nitrogen:VEM and phosphate:VEM ratios. Finally, the nitrogen, phosphate, kVEM and dry-matter yields (in kilogrammes) for grassland are calculated by adding to the uptake the average quantities of nitrogen, phosphate, kVEMs and dry matter lost during feed production and conservation.

A8.3.2 Selection criteria

The calculation procedure described above is applied to all farms despite the fact that on mixed farms it can be difficult to clearly separate the product flows between different production units. The criteria about specialised dairy farms and the existence of other animals are not adopted.

The following selection criteria used in Aarts et al. (2008) to describe the population of 'typical' dairy farms were not used in our calculations:

- At least 15 ha are used for the cultivation of fodder crops.
- There are at least 30 dairy cows.
- Annual milk production is at least 4,500 kg of FPCM per cow.

In line with Aarts et al. (2008), however, the following additional confidence intervals for yields were applied with respect to the outcomes:

- silage maize yield of 5,000 to 25,000 kg of dry matter per hectare;
- grassland yield of 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 an accounting error. In that case, the grass and silage maize yields of the farms concerned are excluded from the report.

A8.3.3 *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 applies to the following data:

1. composition of silage grass and silage maize pits;
2. supplement 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. Since 2006, the composition of silage grass and silage maize pits per farm has also been registered in the FADN. The FADN calculation procedure uses these farm-specific composition data if at least 80% of all silage pits have been 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 (e.g. dry-matter yields, VEM uptake, nitrogen or phosphate content). Data on average silage grass and silage maize pit composition are obtained annually from Eurofins (previously BLGG).

Re. 2

A so-called mobility factor is taken into account when calculating the energy requirement. This factor depends on, among other things, the number of grazing days. Aarts et al. (2008) distinguish three grazing categories: no grazing (0 grazing days), fewer than 138 grazing days, and more than 138 grazing days. The number of grazing days has been registered in the 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

The ratio of energy uptake from fresh grass to uptake from silage grass was calculated on the basis of the number of grazing days registered in the 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 of Aarts et al. (2008) is not complete with respect to the percentages adopted for conservation losses. To avoid any misunderstandings, the percentages used in the FADN to calculate conservation and feed production losses are stated in Table A8.3.

Table A8.3 Percentages used to calculate conservation losses and feeding losses.

Conservation losses					**Feeding losses**
Category	**Dry matter**	**VEM**	**Nitrogen**	**Phos-phate**	**Dry matter, VEM, nitrogen and phosphate**
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

A8.4 Detailed explanation of methods to determine the nitrogen surplus on the soil surface balance

The nitrogen surplus at farm level is first calculated as described in Section A8.2 and then 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 A8.4.

For calculation of the part of green manure and catch crops in the nitrogen surplus on the soil surface balance, it is also assumed that the yearly input equals the output. At crop level a normative value for delayed nitrogen supply, depending on the type of green manure and the time of incorporation into the soil (before or after winter), is allotted to the subsequent crop, ranging between 10 and 30 kg/ha. If fertilising of the green manure or catch crop exceeds the normative value for the delayed nitrogen supply, the normative value is raised by the difference.

Table A8.4 Calculation methods used to determine the nitrogen surplus on the soil surface balance (kg of nitrogen per hectare per year).

		Calculation method	
Description of items		**Quantity**	**Inputs**
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, 2020a: table 5). If farm-specific manure production is known, the output of on-farm-produced manure is corrected accordingly.
	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 are based on data compiled by Statistics Netherlands (2010, 2011). Since 2010, all compound feed data have been calculated for each farm. Standards for silage grass and silage maize 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 (2020a: 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	Animals	Balance of outputs and stock changes of animals and meat	Netherlands Enterprise Agency (2020a: tables 7 and 8).
	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, 2020a: table 5). If farm-specific manure production is known, the output of on-farm-produced manure is corrected accordingly.
	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 Centraal Veevoederbureau (2012).
	Other	Balance of all inputs, outputs and stock changes of all other products in the case of net production (output)	
	Animal products (e.g. milk, wool and eggs)	Balance of all inputs, outputs and stock changes of all animal products	Netherlands Enterprise Agency (2020a: tables 7 and 8).
Nitrogen surplus at farm level		**Farm input -/- Farm output**	
Input on soil surface balance	+ Mineralisation	For grassland on peat soils: 160 kg of nitrogen per ha per year (Van Kekem, 2004). Other crops on peat soils and reclaimed peat subsoils (irrespective of the crop): 20 kg of nitrogen per ha per year. All other soil types: 0 kg. In 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 loess). Mineralisation in reclaimed peat subsoils was estimated on the basis of the overall soil classifications of each farm (based on postcode), in accordance with the Alterra soil map, 2006 version.	

	+ Atmospheric deposition	The basic data are derived from the RIVM (2020).
	+ Nitrogen fixation by leguminous plants	Clover on grassland (Kringloopwijzer, 2020): the quantity of nitrogen fixation depends on the proportion of clover 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). The calculation takes into account a correction for the ratio of clover to clover density (0.82). Other crops (Schröder, 2007): - Lucerne: 160 kg of nitrogen per ha - Peas, broad beans, kidney beans and French beans: 40 kg of nitrogen per ha
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 emissions resulting from stabling and storage: the stable code under the Regulations on the Use of Ammonia in Livestock Farming (*Regeling Ammoniak en Veehouderij*, RAV) is used as the starting point. The total nitrogen emissions are calculated as a percentage of the emitted ammonia nitrogen (based on the RAV emission factor). The emitted ammonia nitrogen is determined on the basis of the TAN percentages in the manure (Van Bruggen et al., 2017). Mineralisation and immobilisation of nitrogen in slurry and solid manure are taken into account (Van Bruggen et al., 2017) - Ammonia emissions resulting from grazing are calculated as a percentage of the total quantity of ammonia nitrogen excreted on grassland (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: - The gross standard-based excretion is calculated by adding the standard-based emission factor to the net standard-based excretion (Oenema et al., 2000; Groenestein et al., 2005, 2015; Tamminga et al., 2004). This factor depends on the type of animal. - The emissions resulting from grazing are then calculated by multiplying the quantity of nitrogen excreted by grassland manure (net standard-based

		excretion x grassland fraction) by the emission percentage of the total quantity of ammonia nitrogen 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 Velthof et al. (2009: appendix 14). 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

ANNEX 9. Overview of LMM reports from its start till 2020

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R. van Duijnen | T.C. van Leeuwen | M.W. Hoogeveen

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