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Minerals Policy Monitoring Programme report 2019–2022

Methods and procedures

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A. Negash et al.

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Synopsis

Minerals Policy Monitoring Programme report 2019–2022

Methods and procedures

RIVM issues a report every four years, on the methods and procedures used in the Minerals Policy Monitoring programme (LMM). The results of the LMM provide the government with insight into the impact of the Minerals policy on farm management practices and water quality, amongst others. As such, the LMM is crucial for evaluating Dutch and European policies on the use of fertilisers (specifically nitrate and phosphate). This report describes the methods used between 2019 and 2022.

The LMM also monitors the effects of derogation on water quality, farm management practices and crop yields. Derogation entails that the Netherlands is allowed to apply more nitrogen from animal manure than is allowed by the European Nitrates Directive, under specific conditions. Countries with derogation are required to submit an annual report on the effects of applying an increased amount of nitrogen from animal manure. Since 2023, steps have been taken to gradually phase out derogation, with complete cessation scheduled for 2026.

In the period between 2019 and 2022, the LMM underwent some minor changes. The most notable change was the exclusion of farms recruited into the Derogation monitoring network from two research programmes. Additionally, since 2020, water samples have been analysed by a different laboratory.

Wageningen Economic Research and RIVM cooperate to collect information on farm management practices and water quality on Dutch farms. Wageningen Economic Research collects financial, economic and environmental data from more than 600 farms, while RIVM measures the quality of groundwater, soil moisture, ditch water and/or drainage water on approximately 450 of these farms. The participating farms are spread across the four Dutch soil regions (Sand, Clay, Peat, Loess) and four farm types (arable, dairy, intensive livestock and other). Together they represent roughly 85 per cent of the agricultural area of these regions.

Keywords: LMM, methods, WEcR, water quality monitoring, farm management monitoring, agriculture, fertilisers

Publiekssamenvatting

Landelijk Meetnet effecten Mestbeleid rapport 2019–2022

Methoden en procedures

Het RIVM beschrijft elke vier jaar de werkwijze van het Landelijk Meetnet effecten Mestbeleid (LMM). De metingen van het LMM geven de Nederlandse overheid onder andere inzicht in de effecten van het mestbeleid op de bedrijfsvoering en de kwaliteit van water onder en op landbouwbedrijven. Het meetnet is daarmee belangrijk voor de evaluatie van het Nederlandse en Europese beleid over meststoffen (nitraat en fosfaat). Dit rapport gaat over de werkwijze tussen 2019 en 2022.

Het LMM houdt ook bij wat de effecten van de zogeheten derogatie zijn op de waterkwaliteit, de bedrijfsvoering en de oogst. 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 om de effecten van een hogere hoeveelheid stikstof uit dierlijke mest elk jaar bij te houden. Het Derogatiemeetnet is een onderdeel van het LMM. De derogatieregeling wordt vanaf 2023 afgebouwd en stopt in 2026.

Tussen 2019 en 2022 is de opzet van het LMM iets veranderd. De grootste aanpassing is dat enkele bedrijven die mee deden aan twee onderzoeksprogramma’s, niet meer worden gebruikt voor het Derogatiemeetnet. Verder analyseert een ander laboratorium sinds 2020 de kwaliteit van het water.

Wageningen Economic Research en het RIVM verzamelen voor het meetnet informatie over de bedrijfsvoering en waterkwaliteit op landbouwbedrijven in Nederland. Wageningen Economic Research verzamelt financiële, economische en milieudata van ruim 600 landbouwbedrijven. Het RIVM meet de kwaliteit van het grondwater, bodemvocht, slootwater en/of drainagewater op ongeveer 450 van de bedrijven. Deze bedrijven zijn verdeeld over grondsoortregio’s (Zand, Klei, Veen en Löss) en bedrijfstypen (melkvee-, akkerbouw-, staldier- en overige bedrijven). Ze vertegenwoordigen ongeveer 85 procent van alle landbouwgrond in deze regio’s.

Kernwoorden: LMM, methoden, WEcR, waterkwaliteit monitoring, bedrijfsvoering monitoring, landbouw, meststoffen

Contents

Summary

The Dutch Minerals Policy Monitoring Programme (LMM) consists of two monitoring programmes: the evaluation monitoring programme (EM) and the derogation monitoring programme (DM). The role of the EM is to assess the effectiveness of the Dutch agricultural minerals policy and to report on water quality as stipulated in the European Nitrates Directive. The DM is required to obtain permission from the EU to deviate from the European Nitrates Directive. This derogation allows the Netherlands a higher maximum application of nitrogen from manure than stipulated in European Nitrates Directive. One of the conditions of the derogation is that the effects of the increased manure application on water quality 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 soil nutrient surplus and water quality. This report is a follow-up to the reports 'Minerals Policy Monitoring Programme report 2007–2010', 'Minerals Policy Monitoring Programme report 2011–2014' and 'Minerals Policy Monitoring Programme report 2015–2018'. It describes the methods and procedures used by the LMM during the period between 2019 and 2022. The presented methods form the basis of the reports and websites that present the results of the LMM research.

Approximately 340 out 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 them in the FADN. The FADN administration has specifically selected the circa 110 remaining farms for the LMM from the Agricultural Census and recorded them separately from the regular FADN sample. The agricultural practice of all these 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 and surplus deposits of nitrogen and phosphorus. RIVM organises the monitoring of groundwater, soil moisture, ditch water and/or drainage water. 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 livestock farms).

In order to optimise the monitoring network and to adapt to changing circumstances, a number of changes were made between 2019 and 2022. The main changes were the phasing out of any dairy farms from the derogation monitoring programme that also participated in two other research programmes. These dairy farms have been replaced by randomly selected farms. Additionally, a different laboratory was used to analyse samples. To prevent the transition from resulting in a break in trends, the so-called 'Dubbelmeten' (Dutch for Double analysis)

programme was initiated. In the programme laboratory, results of both the old and new laboratory were rigorously evaluated and compared.

The LMM data is 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/onderzoeksresultaten/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/onderzoeksresultaten.
The reports 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 en wordt gebruikt om te voldoen aan de rapportageverplichting van de Europese Nitraatrichtlijn. Het DM is nodig om met toestemming van de EU af te wijken van de Europese Nitraatrichtlijn. Derogatie houdt in dat Nederland, onder voorwaarden, meer stikstof met dierlijke mest op het land mag gebruiken dan volgens de Europese Nitraatrichtlijn is toegestaan. Aan de derogatie is de verplichting verbonden de effecten op de waterkwaliteit 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 stikstof en fosfaat bodemoverschot en de waterkwaliteit. Dit rapport is een vervolg op het ‘Minerals Policy Monitoring Programme Report 2007–2010’, het ‘Minerals Policy Monitoring Programme report 2011–2014’ en het ‘Minerals Policy Monitoring Programme report 2015–2018’. Het is een vastlegging van de gebruikte methoden en procedures van het LMM in de periode 2019–2022. De methoden die hierin worden gerapporteerd vormen 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-FADN). In het BIN verzamelt Wageningen Economic Research financiële, economische en milieudata van een steekproef van ongeveer 1.500 agrarische bedrijven. De andere circa 110 LMM-bedrijven zijn, voor het grootste deel, specifiek voor het LMM uit de Landbouwtelling geselecteerd en aanvullend op de reguliere FADN (Farm Accountancy Data Network)-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 het gebruik van meststoffen en het bodemoverschot van stikstof en fosfaat. Het RIVM organiseert de bemonstering van grondwater, bodemvocht, slootwater en/of drainagewater. Door gestratificeerde selectie wordt ervoor 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 2019–2022 is een aantal wijzigingen doorgevoerd met als doel het meetnet te optimaliseren en af te stemmen op de veranderende omstandigheden. De grootste veranderingen zijn dat een aantal

melkveebedrijven die onderdeel waren van twee andere onderzoeksprogramma's, en die ook gebruikt werden voor het Derogatiemeetnet, zijn uitgefaseerd. De melkveebedrijven zijn op een aselecte wijze vervangen om de steekproef op peil te houden. In deze periode heeft ook een laboratoriumtransitie plaatsgevonden. Om een trendbreuk als gevolg van de transitie te voorkomen is het zogenaamd "Dubbelmeten" programma uitgevoerd. Daarin zijn laboratorium resultaten uitgebreid vergeleken en onderzocht.

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/onderzoeksresultaten/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/onderzoeksresultaten.
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 at farms in the Netherlands.

The LMM currently has multiple objectives. Originally, the programme was set up to monitor the impacts of the government's agricultural policies on the water quality at farms in relation to farm management practices. The programme, however, also serves as an instrument to meet the monitoring requirements imposed by the European Nitrates Directive (91/676/EC) and derogation decisions (EC, 2005, 2010, 2014, 2018, 2020, 2022). Additionally, the LMM data is used to provide scientific support for fertiliser application standards, to study and evaluate the relationship between fertiliser 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 were mechanisation and the use of (artificial) fertilisers and pesticides in crop production and of feed concentrates in livestock farming.

Agricultural intensification has resulted in significant impacts on the quality of air, soil, groundwater, and surface water. In the mid-1980s, the Dutch government started formulating and implementing policies and measures to reduce emissions of nutrients from agriculture to 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. Therefore, the origins of the LMM predate both the Nitrates Directive and Water Framework Directive (WFD, 2000/60/EC).

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 influence agricultural practice, such as fertiliser use, and that they can thus influence emissions to groundwater and surface waters.

Changes in water quality due to policy interventions can only be detected by monitoring for an extended period. The monitoring of water quality aims to assess the impacts of fertilisation practices as directly as possible and with the shortest possible time delay. To this end, the programme samples on-site water leaching from the root zone, which corresponds to the precipitation surplus. The programme also monitors the quality of surface waters, which is a more indirect indicator.
For data reporting, the LMM currently distinguishes four principal soil type regions, hereafter referred to as 'regions'. Depending on the region, three

principal farm types are considered (Figure 1.1). 'Intensive livestock farming' is distinguished as a separate (fourth) type of farming in the Sand region only. With regard to water quality data, the farm types 'other livestock farms' and 'intensive livestock farms' are sometimes reported together.

Regions distinguished
- Sand region
- Clay region
- Peat region
- Loess region

Farm types distinguished
- Dairy farms
- Arable farms
- Other livestock farms*
- Intensive livestock farms*

* With regard to water quality data, these farm types are often reported together. Note that not all region–farm type combinations exist; see Chapter 2 for details.

Figure 1.1 Reporting units for data evaluation.

Within the LMM, classification units are a combination of a specific region with a specific farm type (for example dairy farms in the Sand region). In order to provide reliable conclusions at the level of the classification units, stratification is used in the selection of farms. Farms are the basic units for monitoring. 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 result in various strata. These aspects are explained in detail in Chapter 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 this 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 either sampling the upper metre of the groundwater, soil moisture or the water in subsurface drains. The type of water sampled depends on the presence of subsurface drains and the depth of the groundwater table. If present, surface drain water and ditch water are sampled on a selection of farms. Surface drain water, however, is only sampled in the Peat region. Figure 1.2 is a schematisation of the various sampling types.

Within the LMM various physicochemical parameters are tested to assess water quality. Principal among them are nitrogen and phosphorus compounds, which are used as indicators for nutrient leaching from agricultural soils.

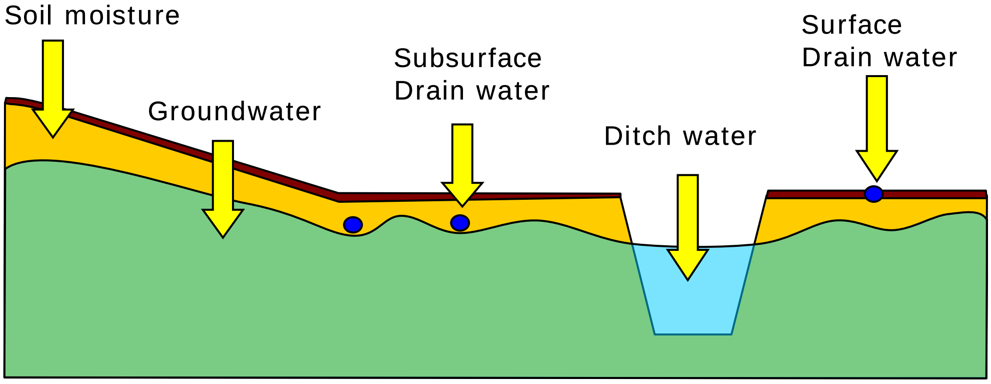


Figure 1.2 Schematisation of the various sampling types: soil moisture, groundwater, drain water and ditch water. The green area represents the water table, the blue dots (sub-)surface drains.

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

The LMM comprises two main activities. These are: 1) data collection, processing, and validation and 2) data analysis, evaluation, and reporting.

Data collected on agricultural practices in a given year is not directly related to the water quality measured in the same year. This is because there is a delay between the application of fertilisers and how they reflect in water quality. Therefore, it is assumed that farm management practices during year X will – at the earliest – affect water quality during year X + ½, + 1 or + 1½, depending on the region.

1.4 Organisations involved in the LMM

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

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

The LMM is implemented under the authority of, and funded 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 2019–2022 period. It intends to record and present information on the programme's principles, assumptions, methodology and procedures.

1.6 Reading guide

This report is structured as follows:

- Chapter 2: description of the LMM in terms of its design and composition.

- Chapter 3: description of the methodology and planning of data collection activities.
- Chapter 4: overview of methods used for data analysis and data presentation.

2 LMM design and composition

The LMM consists of two sub programmes: the Evaluation Monitoring Programme (EM) and the Derogation Monitoring Programme (DM). Farms that are eligible for participating in these programmes are recruited according to a range of criteria. This chapter describes the way farms are recruited and selected. Furthermore, this chapter elaborates on the two LMM sub-programmes mentioned above.

2.1 LMM organisation

2.1.1 Sub-programmes from 2019

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

In both previous reporting periods, 2011–2014 and 2015–2018, the LMM programme was divided into two sub-programmes:

- Evaluation Monitoring Programme (EM): monitoring long-term trends 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 is to assess the effectiveness of national agricultural policies.
- Derogation Monitoring Programme (DM): monitoring to meet the requirements of the EU Nitrates Directive with regard to derogation. DM has similar objectives to EM but is targeted at grassland farms allowed to derogate from limits specified in the EU Nitrates Directive. Such farms are permitted to exceed the 170 kg N ha^{-1} yr^{-1} limit for livestock manure stipulated within the Nitrates Directive, and to apply 230–250 kg N ha^{-1} yr^{-1}, depending on the region.

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

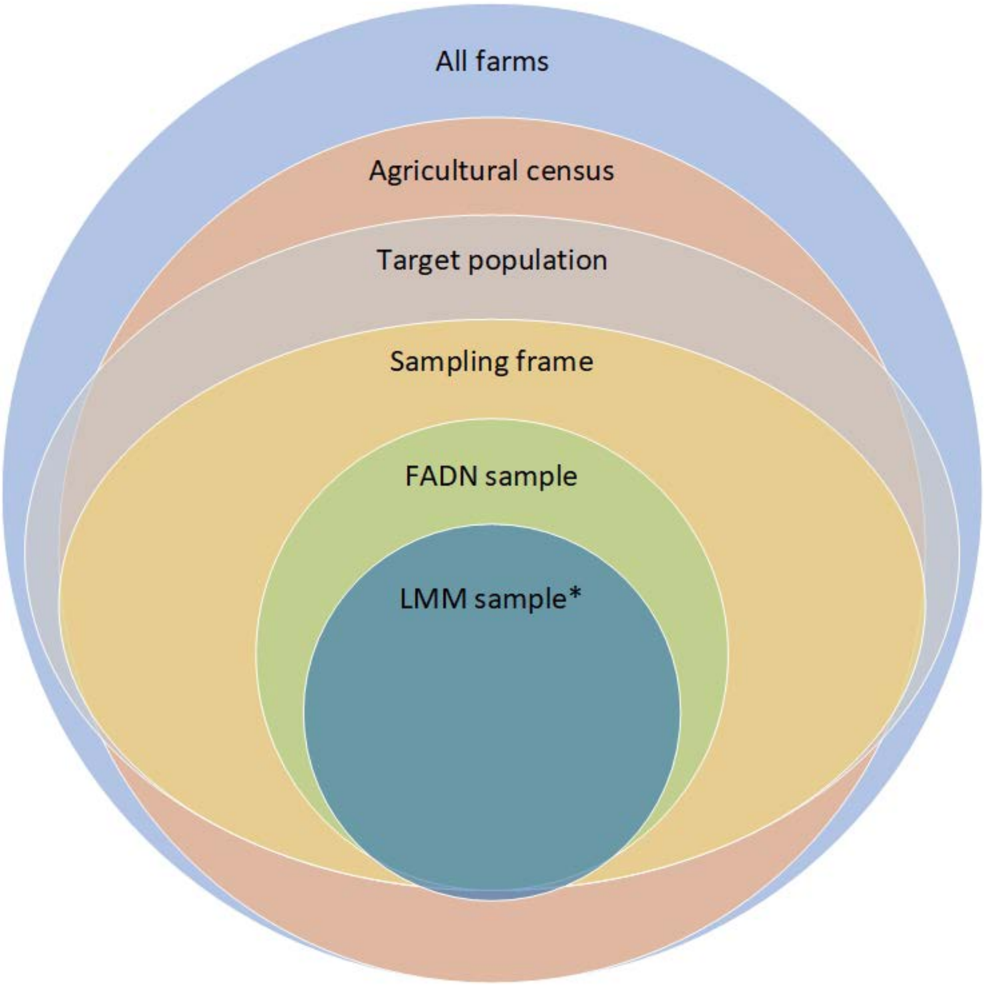
Besides the two main sub-programmes (Evaluation Monitoring and Derogation Monitoring), there are other programmes, often research projects, for which the LMM collects data. Examples include the ‘Koeien & Kansen’ (Cows and Opportunities) project and the ‘Bedrijfseigen stikstofbemesting’ pilot (Farm-Specific Nitrogen Application Standard for Animal Manure pilot). In some cases, participants of these programmes may also participate in a main programme (generally the DM) if they meet the selection requirements. However, this report does not focus on those programmes.

Changes in the sub-programmes
The structure of the sub-programmes has not changed significantly during the 2019–2022 period. However, from 2020 onwards, fifteen dairy farms participating in the ‘Koeien en Kansen’ (Cows and Opportunities) programme and 31 dairy farms participating in the ‘Noardlike Fryske Wâlden’ (North Frisian Woodlands) programme, which were also recruited for the DM, were phased out and replaced by other randomly selected dairy farms.

2.2 Selection and recruitment of farms

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

Preferably, farms participating in the LMM are recruited from the Farm Accountancy Data Network (FADN). The network, which is managed by Wageningen Economic Research, gathers detailed financial, economic, and environmental data from about 1,500 agricultural and horticultural farms with the aim of monitoring business activities and evaluating the impact of the Common Agricultural Policy (EC, 2024). 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., 2022a; Figure 2.1). Stratified random sampling entails dividing a population into strata (groups) on the basis of characteristics, and then randomly sampling from each stratum. 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 and history of the FADN in detail.



*Note that not all farms included within the LMM are selected from the FADN.
Figure 2.1 Relationship between the farms included in the LMM, the FADN and agricultural businesses within the Netherlands (adjusted from Roskam et al. 2022a).

The LMM uses 'soil type area' as a third stratification variable. Furthermore, it sets 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 (i.e. farm type and economic size) are the same for 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 various soil types and districts, 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 2.2). The Loess region covers the southern part of the province of Limburg. The soil type districts used for stratified random sampling, presented in Figure 2.3, differ slightly from those used generally in the LMM (Figure 2.2). This difference is a result of soil type districts in the

Sand region being aggregated for the purposes of stratified random sampling.

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, for example specialised 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 account 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 2.2 Soil type regions with soil type districts distinguished in LMM

During the reporting period that covers 2019–2022, the following general guidelines were used for selecting and recruiting LMM farms:

1. *Overlap between sub-programmes*. Farms already participating in the EM sub-programme and registered for derogation are also included in the sub-programme DM to the extent possible in constituting and maintaining the research sample (such as for replacement of 'dropouts'). 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 2019–2022 monitoring period (FADN years 2018–2021) is to use a fixed group of participants. Prior to 2006, a 'revolving' sample was used with periodic replacement of participants after six–seven years (in accordance with the FADN practice). Since 2006, participants are no longer automatically replaced after six–seven years of participation. They are only replaced if they no longer meet the criteria in place, or if they choose to cease participation themselves. In practice, this means 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 to be potential LMM participants, as FADN farms are no longer automatically replaced after six–seven 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 from outside of 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 'Koeien en Kansen' (Cows and Opportunities). From 2020 onwards, they have been replaced by other dairy farms in the DM because of potential differences in fertiliser application by the farms in this project.
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 is uniformly collected.

2.3 The EM and DM sub-programmes

2.3.1 LMM planning for the 2019–2022 period

In 2010, RIVM and Wageningen Economic Research evaluated the organisation and functioning of the LMM (de Klijne et al., 2010). On the basis of this evaluation, three scenarios were formulated for the continuation of the LMM from 2011 onwards. 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 – to a limited extent – national policy needs, that was implemented.

This meant that the EM and DM sub-programmes were continued and that other sub-programmes, such as Exploratory Monitoring (VM), in which sixteen farms had been intensively monitored because of their participation in the 'Koeien en Kansen' (Cows and Opportunities) research project, were discontinued. The changes to the design of the LMM

included a decrease in the number of participating farms and a decrease in the monitoring frequency.
During the 2006–2010 period, the number of monitored intensive livestock farms in the Sand region increased from twelve to twenty farms per year. From 2011 onwards the sample was limited to twelve 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 twenty per year from 2018 onwards. In 2018, five extra intensive livestock farms were recruited, making a total of seventeen intensive livestock farms. Since 2019, a total of twenty intensive livestock farms have been monitored.

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

Table 2.1 Number of farms planned for the various sub-programmes for 2022 (FADN year 2021).

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 farm management that cause them to no longer meet the selection criteria for a sub-programme.

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

2.3.2 *Evaluation monitoring*

EM, the regular trend-monitoring network, is the LMM's longest-standing and most inclusive LMM sub-programme in terms of the categories reported on and the representativeness of Dutch agricultural practice. The main purpose of EM is to assess the effectiveness of agricultural fertilisation 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 the farm types listed in Table A3.4 of Annex 3.

Basically, farms are selected from the FADN, using stratified random selection, for which sixty strata, consisting of fifteen categories and four SO size classes, are applied. The categorisation and stratification used for the selection of farms for the EM sub-programme is presented in Figure 2.3.

<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 livestock 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 southwest</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 2.3 Strata with fixed numbers of farms used in LMM selection and farm types (numbered) for EM reporting. Strata where the number of farms depends on the area covered are not shown separately.

On a national scale, the sample of the EM sub-programme represents 86% of the area of cultivated land and 55% (28,000 farms) 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 86% to 91%. For ‘other cultivated land’, the coverage (16%) is relatively low (see Annex 2).

Table 2.2 shows the number of farms selected per region for the EM programme, the DM programme and the combination of both programmes, and the number of farms outside of both programmes.

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

2018

Region	Only EM	Only DM	Both EM and DM	Other	Total
Clay	44	10	50	1	105
Loess	31	1	19	12	63
Peat	5	14	46	0	65
Sand	76	22	137	1	236
Total	*156*	*47*	*252*	*14*	*469*

2019

Region	Only EM	Only DM	Both EM and DM	Other	Total
Clay	44	6	55	1	106
Loess	31	1	19	12	63
Peat	5	12	48	0	65
Sand	75	18	142	5	240
Total	*155*	*37*	*264*	*18*	*474*

2020

Region	Only EM	Only DM	Both EM and DM	Other	Total
Clay	41	3	57	18	119
Loess	29	0	20	1	50
Peat	6	9	51	4	70
Sand	72	11	149	27	259
Total	*148*	*23*	*277*	*50*	*498*

2021

Region	Only EM	Only DM	Both EM and DM	Other	Total
Clay	46	2	58	16	122
Loess	29	0	14	1	44
Peat	6	9	50	4	69
Sand	70	9	150	28	257
Total	*151*	*20*	*272*	*49*	*492*

*) Note that these numbers are based on participants registered in the water quality monitoring database.
**) The years displayed are those in which agricultural activities took place (FADN year).

Currently, a farm may fall into one of four categories on the basis of participation: it can participate in the EM, in the DM, in both the EM and the DM or in neither, in which case it falls into the 'other' category. The 'other' category consists of exceptions and of farms participating in other programmes than the DM or EM. Examples may include a supernumerary farm that was initially recruited for a stratum but did not meet the requirements, or a farm from another programme, such as 'Koeien & Kansen', which was recruited into the DM but at a later point no longer met the requirements for the DM and was not eligible as an EM farm either. The increase in the ‘other’ category over the last couple of years is due to the ‘Koeien & Kansen’ project and introduction of the ‘Bedrijfseigen stikstofbemesting’ project (BES pilot; Farm-Specific Nitrogen Application Standard for Animal Manure pilot).

2.3.3 *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 et al., 2007). In its derogation decision, the EC stipulates a minimum of 300 farms. Therefore, the size of the DM sample is fixed. Some of the farms already participating in EM were included in DM. Table 2.2 shows that the minimum number of farms is not reached in 2 out of 4 study years (a range of 292–301 farms per year). However, not all farms applying for derogation will actually use it, and farms might stop participating in the monitoring programme in the course of 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.

The derogation decision requires the monitoring network to be representative of all soil types, fertilising practices (manure application practices) and crop rotations. Therefore, all types of farming using derogation are included. This implies that farm types not represented in EM may (still) be eligible for the DM. An example of this would be the farm type-soil type combination pig farms in the Peat region, which is not a combination included in the EM.

One of the selection criteria for the inclusion of a farm in DM is that it is at least 60% grassland. Until 2013, the formal requirement for obtaining derogation was that at least 70% of the farm’s area consisted of grassland (Fraters et al., 2007). In 2014, the required grassland proportion was increased to 80% (Lukács et al., 2016). The difference in percentages between the selection criteria and formal requirement is related to a difference between the timing of recruitment for the monitoring programme and the moment of granting derogation, as well as to the different methods used to calculate farm size by the authorities (the Netherlands Enterprise Agency and Statistics Netherlands) and by the LMM. Only farms with derogation are eligible for DM. By definition, farms that operate 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.

According to the administration at the authorities, a limited number of LMM farms consist of multiple ‘census farms’. Some of these 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 cease.

At the start of the programme, the geographical stratification was based on the concept of groundwater bodies, which in the Netherlands is distinguished within the implementation of the Water Framework

Directive. This geographical stratification was used until FADN year 2012. From 2012 onwards, geographical stratification, like EM, has been based on the soil type districts.

Farms already participating in EM and applying for derogation form the foundation of DM. New farms from the FADN or, in the case of a lack of FADN candidates, from 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. However, some derogation farms participating in special programmes, such as 'Koeien & Kansen', 'Caring Dairy' and 'Noardlike Fryske Wâlden', have been incorporated into the DM as well. These have not been selected randomly. Most 'Caring Dairy' farms were phased out in 2013/2014, while farms originally participating in 'Noardlike Fryske Wâlden' and 'Koeien & Kansen' farms were phased out in 2020. Currently, a total of 112 strata are applied: 2 farm types, 4 size classes, and between 1 and 7 soil districts per region.

An overview of the number of farms in the various monitoring programmes since the start of the LMM is provided in Figure 2.4.

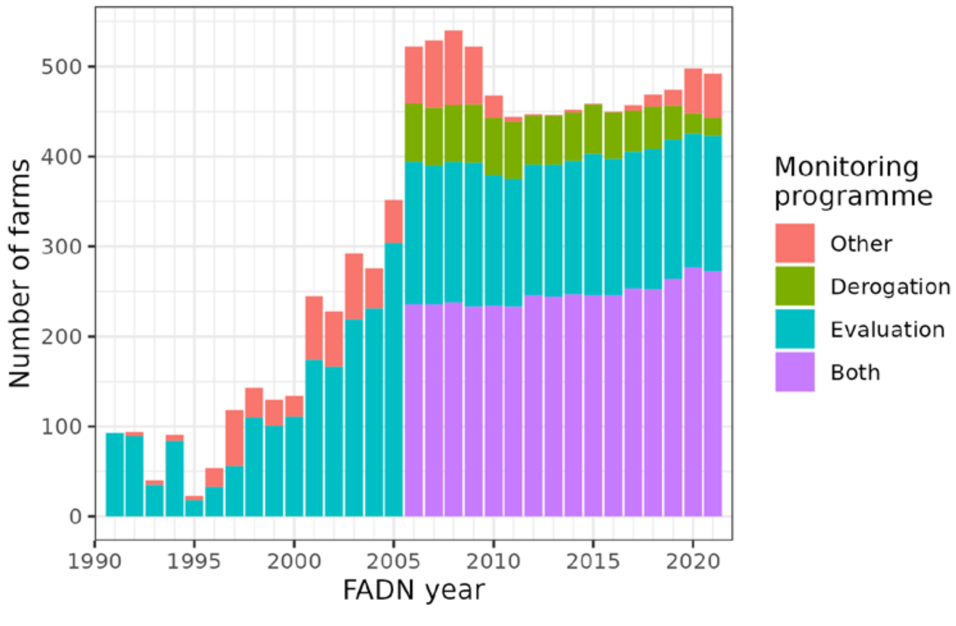


Figure 2.4 Historical overview of the number of farms selected for evaluation and derogation monitoring.

2.3.4 *Farm types for reporting purposes*

The original focus of the LMM 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 such as pigs and poultry, and other livestock farms, including livestock combination farms and crop-livestock combination farms but excluding specialised dairy farms (Table A3.4 of Annex 3), were incorporated into the LMM. Intensive livestock farms are monitored as a separate farm type only in the Sand region. 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 (i.e. combinations of region and farm type) are not identical to the strata used for the selection of farms. The strata used for selection generally consider soil type districts rather than regions (Figure 2.3). Results are reported 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 such as the LMM, limited heterogeneity within the farm type is important. A more homogeneous farm type allows for a smaller sample to be used. In all four regions, dairy farms represent a considerable proportion of the total land use. In the Peat region, the dominance of dairy farms is such that the EM exclusively focuses on dairy farms. Figure 2.5 shows the reporting categories in terms of region and farm type for both the EM and DM sub-programmes.

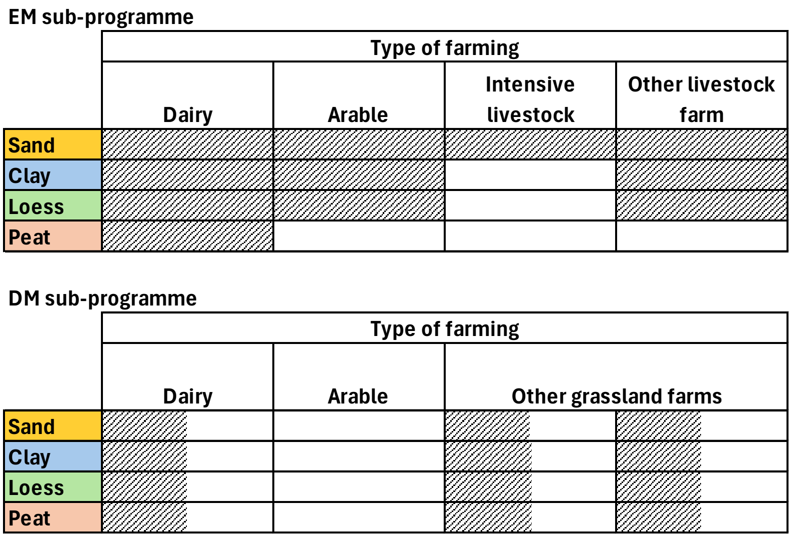


Figure 2.5 A simplified representation of the scope of sub-programmes with respect to farm types. The farm types monitored in the various sub-programmes are hatched. The EM farm types 'Dairy', 'Intensive Livestock' and 'Other livestock farm' are divided into two, to address the fact that some EM farms participate in the DM programme as well.

Figure 2.5 illustrates that EM includes four different farm types in the Sand region, three types in the Clay and Loess regions and only one farm type in the Peat region. In the DM, two farm types are distinguished: 'dairy farms', which are the focus of the DM, and 'other grassland farms', which include all other farm types 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 livestock farms'.

2.3.5 *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 various 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 Agricultural Census, except 15 farms participating in 'Koeien & Kansen'

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

3 Data collection and processing

Within the LMM, data on agricultural practice is collected by Wageningen Economic Research and data on water quality by RIVM. This chapter describes the way in which data is gathered and processed, as well as the changes that have taken place since the start of the programme. The chapter starts with a description of the collection of data on agricultural practices (Section 3.1), followed by a description of the data collection process regarding water quality (Section 3.2). The LMM also makes use of external data (secondary data) sources. These are described in Section 3.3.

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 2.2 and Annex 2). Data acquisition follows standard procedures and protocols.

An administrative staff of approximately 45 full-time employees at Wageningen Economic Research is responsible for collecting and registering farm data in the FADN. Generally, they have an agricultural as well as an administrative background and are thus well qualified to collect information on financial, technical, and economic issues. The administrative staff stays in regular contact with the participating farmers by email, phone, and during farm visits. Personal contact is of great importance for the staff to keep track 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 only be used anonymously for research purposes, will remain confidential and will not be disclosed or used for tax-collection purposes or by controlling authorities. To optimise the efficiency of the data acquisition process, Wageningen Economic Research utilises electronically recorded data, such as bank data on payments and expenditures, as far as possible.

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

Moreover, 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, the use of fertilisers, pesticides, energy and water, and the effect of surpluses or deficits of nutrients on the soil surface balance.

Most data in the FADN is 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 allows for calculations of usage, both per year and per growing season. The growing season covers the period from harvesting the previous crop up to and including the harvesting of the current crop.

On the basis of the data on agricultural practices, many derived indicators are calculated, such as indicators for the application and utilisation of fertilisers.

Annex 4 lists the number of farms per region that are used for data collection. The agricultural practices data in the EM is based on a larger number of farms than the water quality data is. All the farms in the FADN that meet the EM selection criteria 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 detailed (see van der Veen et al., 2006). The farms are grouped according to several 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 end of the year, input of self-contributed labour and capital).

From the collected data, an extensive body of farm statistics has been 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 4.2.1.

3.1.3 New/extra data collected during the 2019–2022 period

Within the last period (2019–2022), new data collected within the FADN was initiated within the LMM.

Catch crops: registration pre-crop
From 2019 onwards, the crop that was grown before the catch crop (i.e. the pre-crop) has been used to determine the fertiliser use standard for the catch crop. If the pre-crop was a leaching-sensitive crop, the application standard is lower than if it was not a leaching-sensitive crop. This tightening of nitrogen application standards only applies to sandy and loess soils. From 2019 onwards, the pre-crop grown before catch crops on sandy or loess soil has been added to the annual FADN data collection. From 2022 onwards, the registration of pre-crops has been extended to all soil types.

Tearing up grassland
At farms where grassland on sandy or loess soil has been torn up after May 31st, a lower nitrogen application standard (-50 kg N per ha) applies to the subsequent grassland crop. The date of tearing up grassland was added to the annual FADN data collection as of 2018.

Diluting manure with water
Diluting manure with water is an option to reduce nitrogen emissions. Since 2020, this measure, including the amount of water used for dilution, has been added to the annual data collected within the FADN.

Underwater drainage (passive and active water infiltration)
Passive water infiltration, which is also known as underwater drainage, entails the placement of perforated drains under peat meadows that spill into in ditches below ditch water level. In dry periods, water can flow from ditches into the peat, thereby maintaining water saturation and preventing peat decomposition. Since the start of 2018, the surface drainage, including underwater drainage, has been recorded for land plots with peat soil type and will be recorded at LMM farms.

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 an increase in crop yield 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 on the use of band application and precision agriculture techniques was conducted on FADN farms. As a result of this survey, the use of band application has been added to the annual FADN data collection.

From 2022 onwards, the use of the following techniques has been added to the annual FADN data collection. If a technique is implemented, the type of crop and the area on which it is applied are also recorded. Note that the list of techniques is not exhaustive and that other techniques have also been added to the FADN but are not mentioned below.

1. Variable application of solid fertiliser based on, for example, a biomass map (e.g. via satellite, drone, or sensor on tractor);
2. Variable application of liquid fertiliser or water from an air scrubber;
3. Variable application of liquid manure/digestate, based on, for example, an NIR sensor that allows for real-time measurement of the nutrient composition of liquid manure to be spread;
4. Variable application of solid manure or compost;
5. Band fertilisation without variable application;
6. Fertigation using drip hoses;
7. Application fixed driving paths, resulting in decreased areas of overlap or gaps during fertilisation, in less soil compaction and increased nutrient utilisation.
8. Non-inversion tillage;
9. Variable sowing;
10. Strip cropping.

Extension of recording of participation to equivalent measures
Farmers who have had higher than average crop yields for the past three years or use band application for maize cultivation on sand and loess soils are allowed to use extra fertilisers. This is permitted by ‘equivalent measures’, according to which an increased amount of fertiliser may be used under certain conditions (e.g. a higher-than-average yield, or a low soil nutrient status). 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 are recorded as such in the FADN.

In 2017, equivalent measures were extended to include other crops and soil types that qualified for nitrogen differentiation (i.e. higher nitrogen application standard). In addition, three 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 (i.e. nitrogen or phosphate) allowed 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, the level of farmers’ 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). Collecting this information enables Wageningen Economic Research to explain variations in nutrient management better.

3.2 Water quality data

3.2.1 Introduction

RIVM coordinates the collection of data on water quality. The generation of water quality data requires the following steps:

1. preparation for sampling;
2. sample collection;
3. sample treatment;
4. field analysis;
5. sample storage and transport;
6. laboratory analysis;
7. data recording and quality control;
8. data validation.

This process is applied to thousands of samples each year and is subject to strict quality control. RIVM optimises the process quality and minimises errors by formulating strict working procedures, facilitating optimal working conditions as much as possible, and computerising data recording.

Changes in generation of water quality data in 2019–2022

Laboratory transition

The most significant development that took place within the LMM between 2019 and 2022 with regard to the generation of water quality data is the transition to a new laboratory for sample analysis. In 2020, Eurofins Scientific started analysing all LMM samples after winning a tender placed in 2019. Prior to 2020, samples were analysed by the Netherlands Organisation for Applied Scientific Research (TNO). The transition process was rigorous because changing laboratories can negatively influence the integrity of a monitoring network. Therefore, a lot of care was taken in selecting a laboratory and subsequently, when the analytical results of the two labs were compared meticulously and iteratively until satisfactory outcomes were achieved.

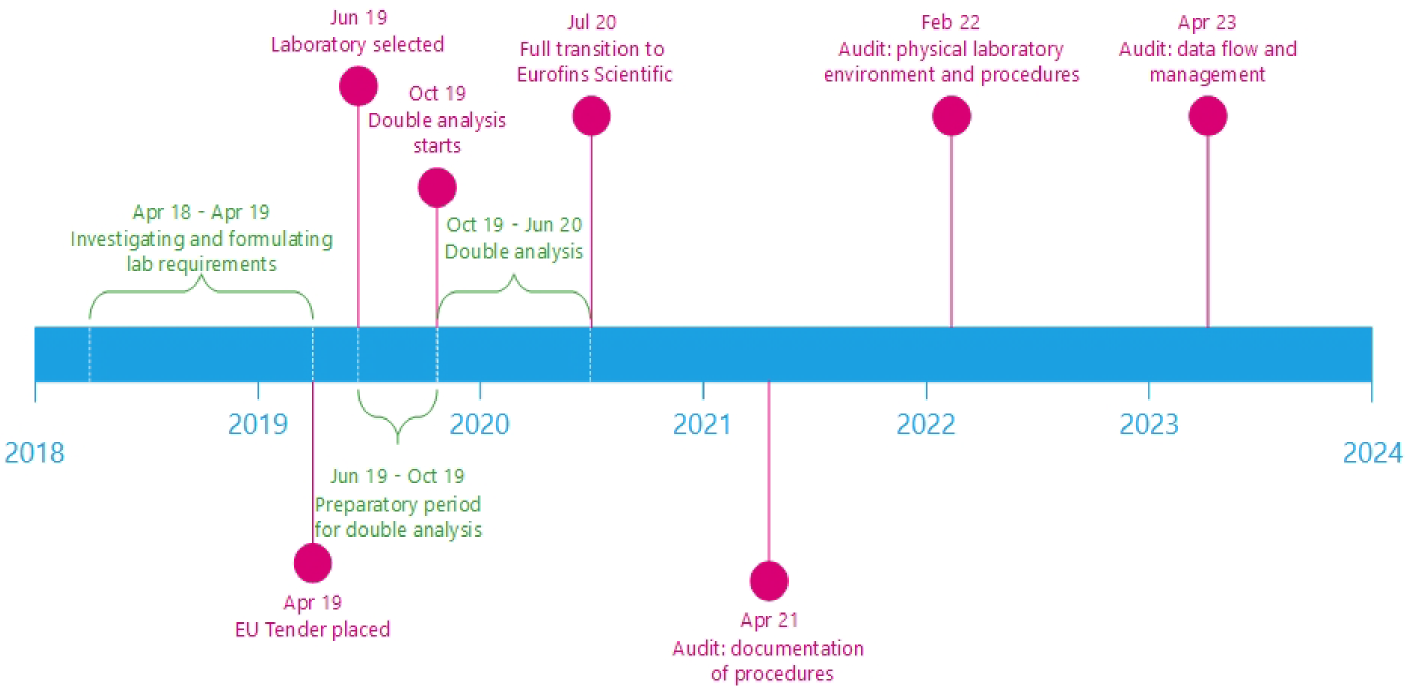


Figure 3.1 Timeline for the laboratory transition process.

The transition programme had the overarching goal of preventing a break in trends due to the laboratory transition by accurately quantifying and minimising deviations in analytical outcomes. To attain this, the transition programme included three steps, each serving a specific goal:

1. Determining the differences in performance features (e.g. limits of quantification, reproducibility of results, etc.) between laboratories that registered for the tender and TNO, and to subsequently select an appropriate laboratory;
2. Determining the differences in the outcomes of analytical procedures between the selected laboratory and TNO when the same samples are analysed. The samples selected to fulfil this goal would reflect the diversity in terms of matrix and origin, encountered in the LMM;
3. If differences in measured concentrations were detected, these needed to be quantified and the causes for their arising determined. This process also considered differences in samples representing a particular matrix or soil type region.

The steps and timeline of the transition process are presented in Figure 3.1 and described in more detail in Annex 10.

Field observations of crop type

An additional change that has taken place is that fieldworkers no longer record the kind of crop growing on the sampled agricultural plots. The exception to this is maize, the presence of which fieldworkers still document. This change was implemented in 2019. The reason for its implementation is that the data collected by fieldworkers was often incomplete and did not accurately reflect the types of crops grown. This is because the majority of the sampling for the LMM takes place during the winter period, outside the growing season. Therefore, it was decided to discontinue field observations and gather crop information from the Basisregistratie Gewaspercelen (BRP; Base Registration of Parcels) dataset. This dataset, maintained by the Netherlands Enterprise Agency (RVO), contains data on the crops grown on agricultural lots throughout the Netherlands.

3.2.2 *Preparation for sampling*

Prior to the start of water sampling, RIVM staff visit each new LMM farm recruited by Wageningen Economic Research. During this first visit, general information is collected through a standardised survey. From this survey, 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. The selection procedure used for the identification of sampling locations is protocolised (Work protocol MIL-W-4021).

At the start of a sampling year, farmers who already participate in the LMM receive a letter containing farm-related information from the previous sampling year, asking whether any relevant changes have taken place since the previous sampling campaign. Furthermore, at some farms the drains are flushed in preparation for the start of the new sampling campaign.

3.2.3 *Water sampling*

When fieldworkers arrive at the farms, they contact farmers if possible. This serves to record any other relevant changes in the field file.

Campaign structure

The method and timing (i.e. summer or winter) of water sampling is primarily determined by the soil type and the type of water being sampled. The types of water sampled are:

- groundwater (upper metre);
- soil moisture in the unsaturated zone below the root zone;
- tile drain water;
- ditch water;
- surface drain water.

The water sampled from the upper metre of groundwater, the soil moisture in the unsaturated soil below the root zone, and tile drains are used to quantify root zone leaching.

Water sampling is organised in various ‘sampling sub-projects’, independent from, and cross-cutting, the sub-programmes described in Chapter 2. A sampling sub-project is a combination of soil type region, season, and water type. The number of samples per farm, the sampling frequency, and the method of sampling may differ per sampling sub-project. The number of farms sampled within a sub-programme may also vary slightly between years, for example due to a farm dropping out of the programme before an adequate replacement has been identified.

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. During this period, ditch water was sampled exclusively in the Peat region. From 2004 onwards, the scope of the LMM was broadened to include the monitoring of surface water quality (i.e. ditch and drain water), resulting in an increase in the number of sampling sub-projects. This development was caused by the increased interest in the groundwater–surface water relationship following the recommendations of the Spiertz Committee (Velthof, 2000) and the monitoring obligations related to the Nitrates Directive and the derogation decision (Annex 1). The inclusion of surface water in the LMM has led to a better quantification of nutrient loss from agricultural land to the wider environment via terrestrial water systems.

Table 3.1 Sampling periods and frequency in the years 2019–2022 (FADN years 2018–2021).

Region	Season	Water type	winter 2018–2019	summer 2019	winter 2019–2020	summer 2020	winter 20210–2021	summer 2021	winter 2021–2022	summer 2022	Sampling frequency (times per season)
Sand	Winter	Drains and ditches (wet parts)									4 or 3†
		Ground-water									1
	Summer	Ditches (wet parts)									3
		Groundwater									1
Clay	Winter	Drains and ditches									4 or 3†
		Ground-water									2
		Ditches*									2 or 1†
	Summer	Ditches									3
Peat	Winter	Surface drains and ditches**									4
		Ditches***									3
		Ground-water									1
	Summer	Ditches									3
Loess	Winter	Soil moisture									1

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

In general, drains and ditches are sampled at the same time, wherever possible. During the winter campaign, drains and ditches are sampled in three-week intervals. During the summer period, ditches are sampled every five weeks and drains are not sampled. This is because drains are often dry and the water that is present is aged and therefore not directly representative of nutrient management practices. The locations sampled are kept constant from year to year as much possible. When this is not possible, an alternative sampling location is selected.

The upper meter of groundwater is sampled in all soil regions. In the dry Sand region, groundwater is the only type of water sampled. This is because there is no need for ditches or drains in well-drained soils. However, within the LMM, groundwater is only measured if the water table is within 5 meters of the ground surface. If the groundwater lies below this depth it is not sampled and soil moisture in the unsaturated zone is sampled instead.

The periods during which sampling is conducted, as well as the sampling frequencies during these periods for the various soil regions, are shown in Table 3.1 and Figure 3.2, respectively. The annual cycle covers about fifteen months: from October (year X) until December (year X + 1), depending on the soil region. An extension of the soil moisture sampling period to January or February (year X + 2) is possible in the event of extended frost or rainfall. The moment when the winter sampling sub-projects commence in the Peat, Clay and Sand regions depends on whether groundwater recharge is occurring. Groundwater recharge is assumed to have started when precipitation has been sufficient to cause discharge of sub-surface water via tile drains. However, the sampling of groundwater never starts later than December 1st and the sampling of soil moisture starts in October.

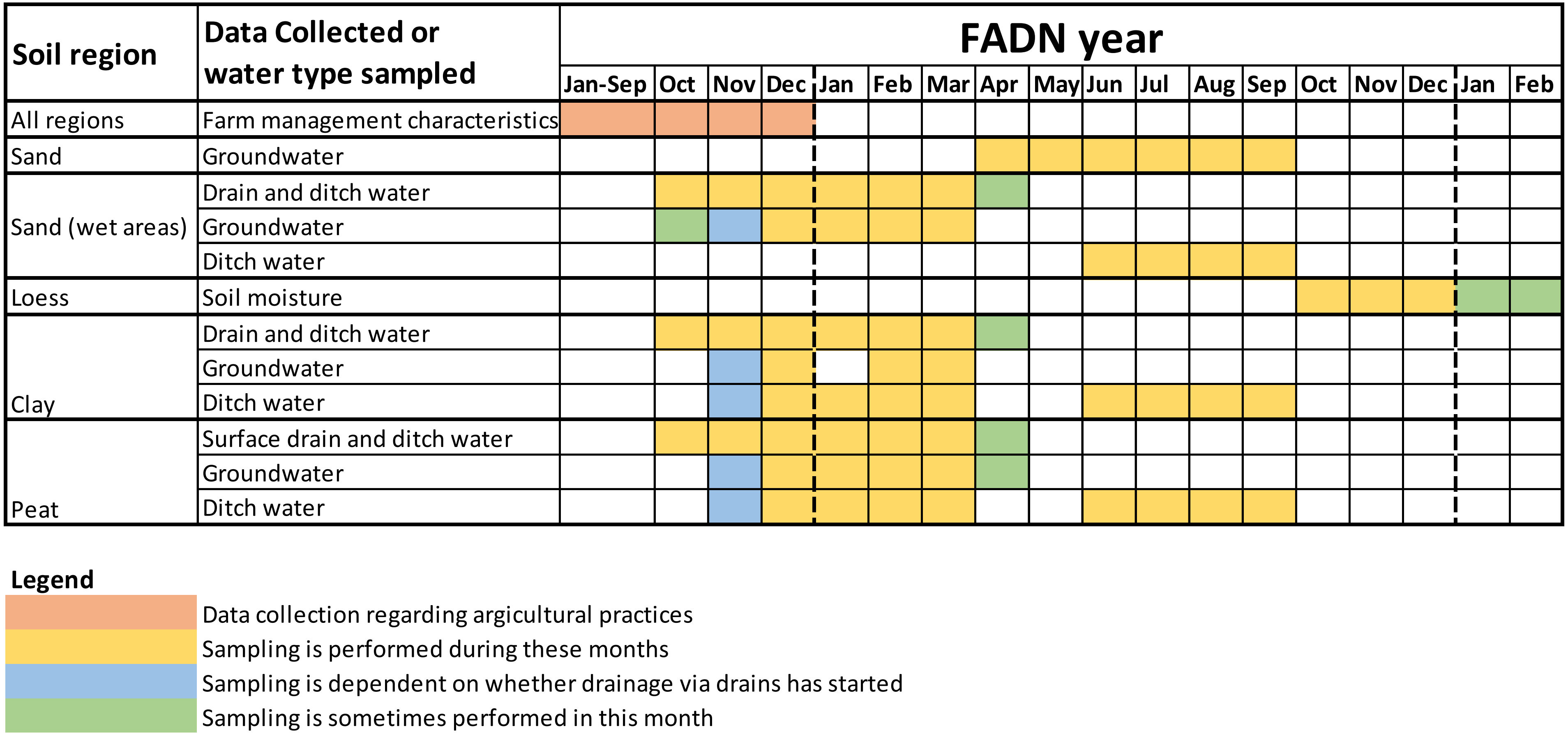


Figure 3.2 Overview of sampling periods, aggregated per region, performed for the winter 2018/2019–winter 2022/2023 period (FADN years 2018–2021).

Campaigns per soil region

Sand region

In the Sand region, soils are permeable and consequently, incident precipitation is expected to infiltrate vertically towards the groundwater. For this reason, samples on sandy soils are normally taken from the upper metre of the groundwater, or soil moisture when the water table lies 5 meters below the ground surface. Routine sampling of groundwater, or soil moisture, takes place once per year during the summer period. A subset of farms in the Sand region are identified as being located in the wet parts of the Sand region, and at these farms, additional winter sampling is conducted (Buis et al., 2015). Farms are identified to be located in the wet part of the Sand region if 25% of their area is drained by tile drains or if 50% of their area is drained by ditches. Drains and ditches are sampled at such farms because they may represent a pathway for the emission of nutrients to the environment. At these farms, groundwater, or occasionally soil moisture, is sampled once in winter in addition to drain and ditch water, which are sampled three times on arable farms or four times on other farm types (Table 3.1). In summer, ditch water is sampled three times at farms located in the wet parts of the Sand region.

Clay region

Clay soils are generally characterised by low permeability and associated low infiltration rates. Due to the low permeability, farms in the Clay region may have subsurface drains and ditches. Therefore, only a portion of the precipitation surplus results in groundwater recharge as 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 – where tile drains cover more than 25% of their area – and undrained farms – where less than 25% of the area is covered by tile drains. At drained farms, the LMM samples the drains and ditches three times on arable farms or four times on other farm types during the winter season (Table 3.1). At undrained farms, the LMM samples the upper metre of the groundwater twice, and ditches three or four times during the winter season. The ditch water at all farms is sampled three times during the summer period.

Peat region

In the Peat region, only a small portion of the excess rainfall is expected to result in groundwater recharge. Whilst the groundwater table is generally shallow (~0.5 m deep), farms in this region have a dense network of surface drains and ditches. As a consequence, excess precipitation is expected to enter ditches. For this reason, both groundwater and ditch water are sampled once and four times per winter season, respectively (Table 3.1). Ditch water is sampled three times during the summer period on all farms. The surface drains are also sampled on twenty farms, four times per year during the winter season.

Loess region

In the Loess region, where the groundwater table is usually below 5 metres, it is not possible to sample groundwater by hand boring, using the open auger method. Here, unsaturated soil is sampled at a depth of between 1.5 m and 3 m below the surface. This is conducted once per year during the winter season (Table 3.1).

Amendments
Over the course of its operation, certain additions or amendments have been made to the sampling campaign of the LMM. Since 2008, ditch water has 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 ditch and drain samples taken have, in some cases, been reduced from four to three. Samples collected for the LMM are generally filtered, but since 2017, additional unfiltered samples have been collected from ditches during the summer period.

3.2.4 *Sampling parties, methods, and procedures*

Responsibility for water sampling
Sampling is predominantly conducted by external contractors, although the extent to which this is the case varies per water type (Figure 3.3). RIVM remains the principal agent with respect to overall planning, first-time visits to new participants and quality control. Ditch and drain water is exclusively sampled by external parties (Annex 6). However, at 5% of the farms per region, RIVM staff carry out additional sampling for quality control purposes. Groundwater sampling, by contrast, is partly conducted by RIVM in a rotating sampling scheme, thus ensuring quality control. Approximately 25% of all groundwater sampling is conducted by RIVM staff, with the remainder being conducted by contractors. The sampling of soil moisture, which generally only takes place in the Loess region, is conducted by both RIVM staff and contractors. The workload is divided equally between the parties. Annex 6 provides a summary of the agents responsible for the various sampling sub-projects.

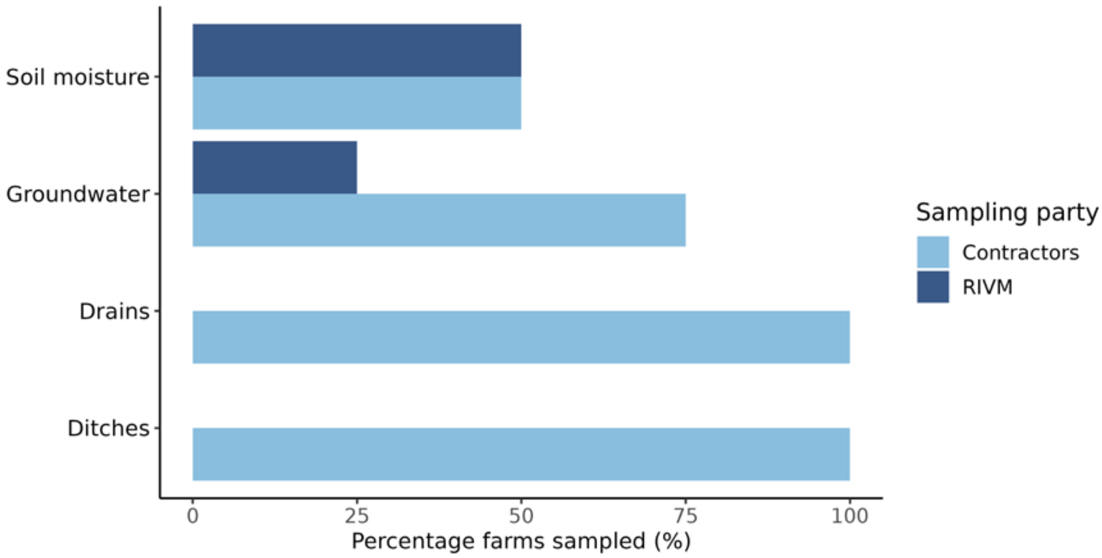


Figure 3.3 Distribution of sampling duties per water type.

Sampling methods

The sampling method depends on the water type being sampled, and in the case of groundwater, on the soil type. Normally, groundwater is sampled from temporary boreholes, using the open borehole method, also referred to as the 'sand method' (Figure 3.4. and Figure 3.5). In some cases, however, the method for peat soils is used (Figure 3.4.). In the method for peat soils, a bailer is used to prevent sediment and organic material getting into the water sample. Water from tile and surface drains is collected in simple jugs (Figure 3.6). The same method is used for water from ditches (Figure 3.7). Annex 5 provides detailed information on the various sampling methods.

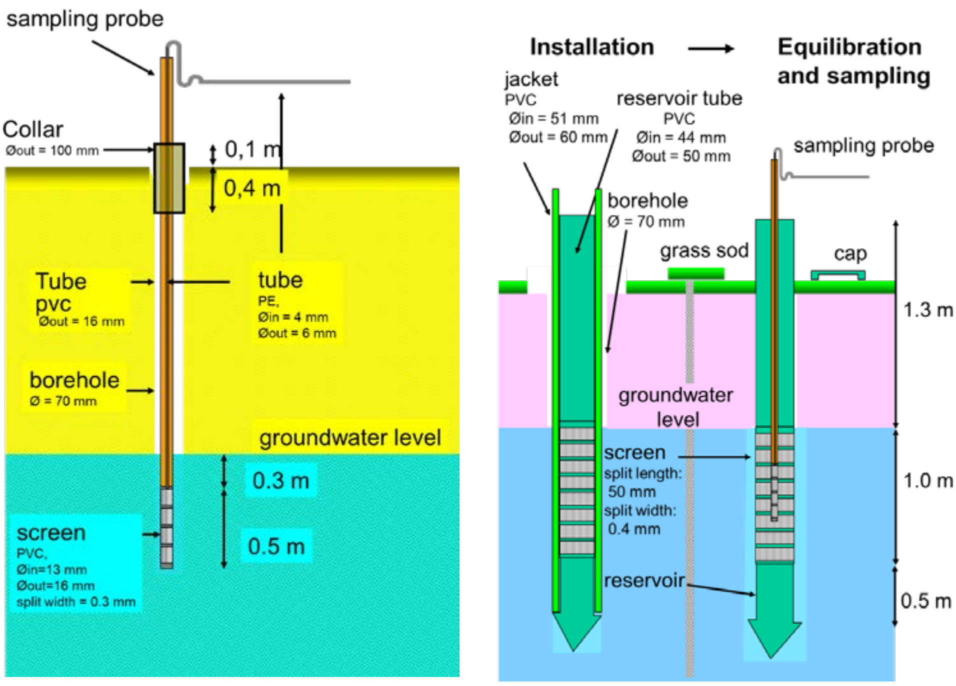


Figure 3.4 Sampling of groundwater using the 'open borehole' method (left) and the 'peat soil' method (right).

The water leaching from the root zone (i.e. groundwater, tile drains and soil moisture) and surface drain water is sampled at sixteen locations per farm. These sixteen samples are used to make two composite samples, each comprising eight samples. Water from ditches is sampled at a maximum of eight locations, and these samples are not mixed to make a composite sample. The number of ditch samples collected depends on the number of available ditches.

Figure 3.5 Sampling of groundwater in the Sand region using a temporary borehole.

Figure 3.6 Sampling of drain water.


Figure 3.7 Sampling of ditch water using a jug.

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

Groundwater samples are filtered in the field, whereas drain water and ditch water samples are filtered in the laboratory. Even though unfiltered ditch water samples are not filtered, large particles are removed by straining. The individual groundwater or soil moisture samples are combined to make two composite samples. Composite samples of soil moisture are combined in the laboratory. Figure 3.8 summarises the sample bottles used and their characteristics per medium sampled. Field and laboratory tests are described in more detail in Section 3.2.6.

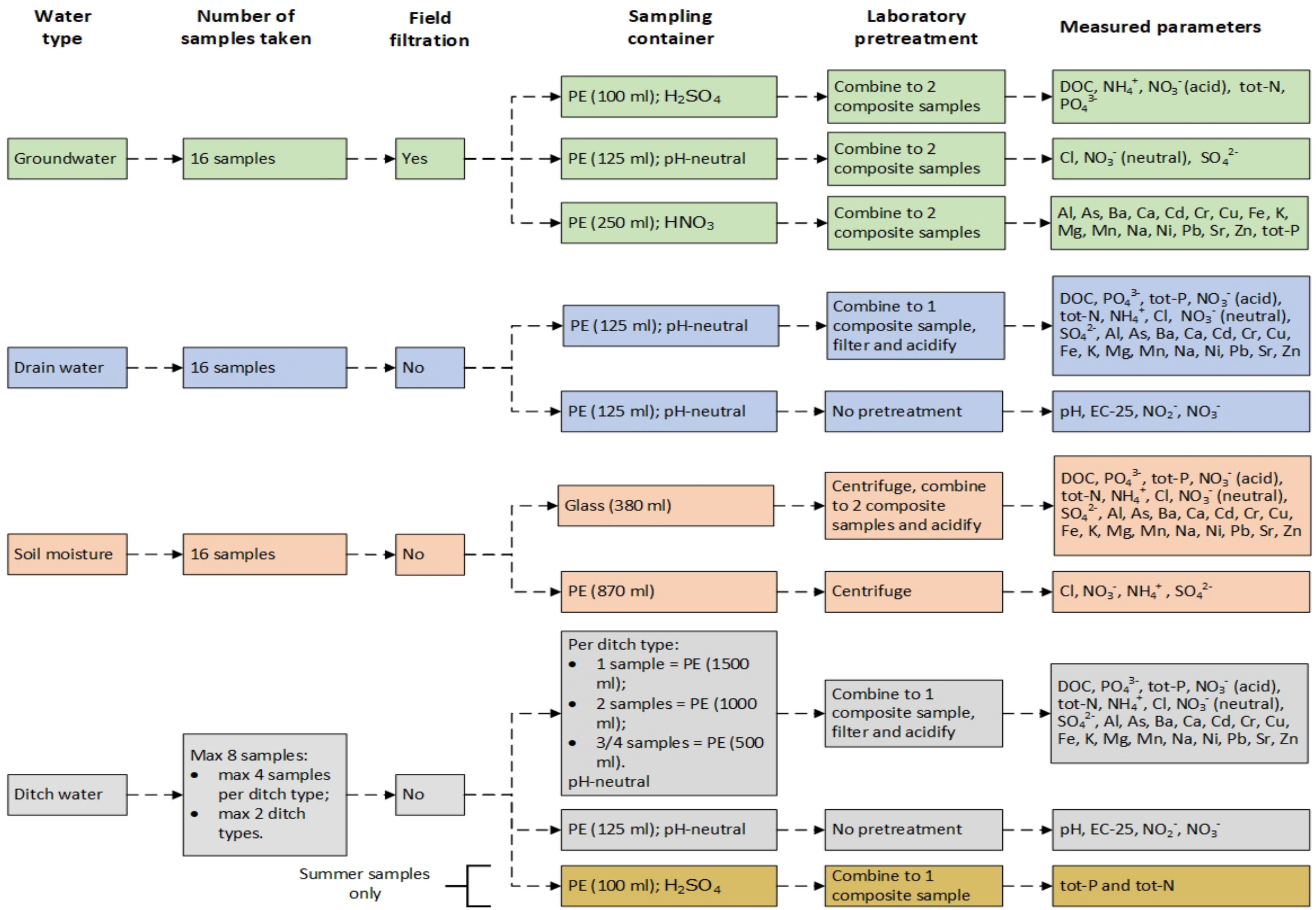


Figure 3.8 Characteristics of sample containers, sample treatment and laboratory analysis packages for different water types

3.2.5 *Storage and transport of water samples*

The storage and transport of water samples is conducted in accordance with standard Work Instructions (Annex 5). A portable cool box containing cooling elements is used for temporary storage of samples in the field and during transport between two or more sampling points. The samples are transferred to a fixed or mobile fridge in the fieldwork vehicle during the sampling day, or at the latest at the end of the day.

Normally, the samples are transported to the laboratory on the day of sampling. Either the fieldworker does this, or cool boxes are sent by courier. If same-day transport is not possible, the fieldworker is responsible for storing the samples in a refrigerator at a constant temperature of 4 °C. The refrigerator contains a warning system activated if the temperature drops below 1 °C or rises above 7 °C.

Number of samples taken

The effort involved in visiting participating farms for water quality sampling is substantial. The total number of farm visits (rounds) ranges from 1,900 to nearly 2,150 per year, and the total number of individual water samples collected from roughly 20,500 to 24,500 per year. Out of the individual samples, approximately 6,000 per year are measured in the field and approximately 16,000 in the laboratory. Individual samples are combined into composite samples, which results in between 3,250 and 4,600 composite samples per year for laboratory testing.

3.2.6 *Testing of water quality*

Field testing

Groundwater samples 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;
  - CellOx 325 for dissolved oxygen, salinity, and temperature;
  - TetraCon325 for EC.

In addition, the characteristics of the soil layers, the groundwater level and sampling point coordinates are recorded. At locations where soil moisture is sampled, the groundwater level is not recorded. Where water samples are taken from ditches, the width and depth of the ditch, in addition to visual clarity and the direction of the water flow are recorded. In water samples taken from tile and surface drains, the flow rate and distance to the ditch are recorded.

Laboratory testing

Individual samples

The chemical composition of individual soil moisture, ditch water and drain water samples are determined in the laboratory. The samples meant for individual testing are collected at the same times and locations as the samples used to make composite samples but are stored in separate containers and analysed separately (Figure 3.5).

Composite samples
Samples collected for the purpose of making composite samples are transported to the laboratory. A laboratory assistant combines samples to make the composite samples. Which samples are to be combined to create a composite depends on the water type, and this is determined by the laboratory assistant on the basis of field information. An equal amount of each sample is used to create the composite sample. Table 3.2 gives a list of possible numbers and types of composite samples per farm.

Table 3.2 Number and types of composite samples per farm.

Water type	**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 1–4 diw type 2	1 diw 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)

Extra samples from maize plots
Within the LMM, extra groundwater samples are taken from boreholes used for standard sampling if the borehole lies on a permanent maize plot. To be defined as a permanent maize plot three criteria have to be fulfilled:

1. The farm is in the Sand region;
2. The farm is a dairy farm or crop–livestock combination farm with dairy stock;
3. Maize has been grown on the plot for at least three consecutive years.

Permanent maize plots are recognised as a separate category in the LMM because, historically, more manure was applied relative to the amount absorbed by maize on these plots. Through the years however, regulations regarding manure application on permanent maize plots have become more stringent. These plots are however still monitored separately.

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 containing compounds: NO_3 , NH_4 and total nitrogen (N-total);
- phosphorus containing 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.

There are multiple reasons why macro and trace elements are measured within the LMM. These elements are used, amongst others, to explore ion balances for data validation purposes. Furthermore, metals in manure used to be an environmental problem and therefore, they were also included in the LMM.

The parameters analysed in unfiltered ditch water samples taken in summer are:
- Kjeldahl nitrogen;
- P-total.

Concentrations of N-organic are calculated as follows:

$$N_{organic}(mg\,N/l) = N_{total} - NO_3 - NH_4 \qquad \text{Eq. 1}$$

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 presents details of analytical techniques used and corresponding detection limits.

3.2.7 *Data recording and quality control*

Within the LMM, emphasis is placed on optimising dataflow because the monitoring network generates large quantities of data that is dependent on the input of multiple parties. Since 2017, this has been accomplished by using Simplemanager, a database and web application, and Field Application, an android application for recording data during field sampling.

Simplemanager provides one database for all information available, which is accessible using SQL. The database is accessible via an online interface that is tailored to each user (i.e. field worker, laboratory employee, sub-project coordinator, etc.). It contains, amongst others, information on the farms themselves, the location of drains, planning of field sampling and the results of laboratory analyses.

Field Application is an application used by fieldworkers instead of hand-held computers. It contains pre-formatted menus for recording field data. The recorded data is sent to Simplemanager via an internet connection, thus removing the need to physically transfer data. The data inputted by the fieldworker is automatically checked for impossible values (e.g. minimum/maximum permitted values) or is simply a redefined list of possible options. GPS coordinates are automatically recorded for drain and ditch water sampling points.

All the steps taken pertaining to the recording of data during the entire process, from the planning of sampling campaigns up to the construction of the final database for reporting purposes, are described below:
1. Information about new LMM participants is gathered. This information includes, amongst others, the locations and areas of the lots the farmer owns, the location of ditches and drains, and other practical information. During this step, changes in already registered participants are updated, if necessary.
2. The sampling round is planned. This entails that the collection of samples from the farms participating in the sampling round is

delegated to the various external contractors that assist RIVM in conducting fieldwork. Fieldwork coordinators from RIVM and the external contractors that conduct the fieldwork plan sampling excursions together. RIVM remains in contact with the fieldworkers throughout the sampling campaign. Part of the planning process includes the timely preparation and dispatchment of the cool boxes containing prelabelled sample collection beakers and tubes to fieldworkers. In preparation of the laboratory analysis, Eurofins is informed about the sampling and the required analyses for the various samples. Simplemanager is used to facilitate the entire planning process.

3. During the fieldwork, field data and samples are collected. The collected data pertains to, for example, groundwater table depth, weather conditions and physicochemical data collected using probes (e.g. pH and EC). The data is collected with the help of the Field Application, which contains the relevant data fields for the type of sampling excursion. During sample collection, the barcodes present on the prelabelled sampling beakers are scanned, thus registering the sample in the Field Application.
4. The collected samples are sent to and analysed by the laboratory. The laboratory uses its own software and data formats when managing data pertaining to the samples. During this step, the laboratory documents the expiration dates for the various types of analyses that need to be conducted. The outcome of the laboratory analysis, including whether analysis was conducted after expiration, is reported in interim reports on a monthly basis. The reports are used for interim data validation.
5. The field data collected by the Field Application (step 3) and the results of sample analysis by the laboratory (step 4) are both stored in the so-called APEX database. The fieldworkers upload data to the APEX database using the Field Application and receive a notification as to whether the upload has been successful.
   The laboratory also uploads the results of the analyses to the APEX database via the Simplemanager application at the end of a sub-project. The uploaded results always share the same format and are automatically reorganised in the APEX database in such a way that it conforms with the structure and units used in the database.
6. The diverse data uploaded to the APEX database is all verified. The collected field data is controlled and validated within Simplemanager by the fieldworkers. They check each other’s input by reviewing inputs flagged as unlikely by the application. In addition to this, for quality control purposes, the field data of approximately 10% of locations is randomly selected to be reviewed even if it has not been flagged.
   The results of the laboratory analysis are reviewed by RIVM researchers. Any noted irregularities or dubious results are communicated to the laboratory. For more details on the validation process see Section 3.2.8.
7. Upon validation, field and laboratory data is uploaded onto a second database, called BASE. This database exclusively contains validated data and functions as an archive for all the LMM field and laboratory results related to water quality. The BASE database also contains other types of data, such as geographical data pertaining

to soil type and groundwater depths, and farm (management) information pertaining to, for example, acreage.
8. The validated field and laboratory data is communicated to LMM participants (i.e. farmers) directly. This is done annually by sending an automatically generated report in which the participants can see how the quality of the water on their farms compares to the average for their farm type in their soil region. A sample of these automatically generated reports is manually reviewed for inconsistencies. The averages presented in the reports are those for the specific subset (i.e. farm type and soil region) to which the participant belongs, so that participants see how they compare to other farms on the same soils with similar farm types. For privacy reasons, comparison to other farms is presented only if more than ten farms are in a subset (i.e. same soil type and farm type). This information is private and shared exclusively with the farmers themselves. Additionally, the farmers can only assess their performance against the average and not against other individual farms.
9. The data used for the various LMM reports are derived from a dataset produced from the data contained within the BASE database. The various data in the BASE database is coupled to each other and transformed into table form to allow for easy manipulation during data analysis. This dataset is the basis for all LMM reports and products relating to water quality.

Error prevention
Fieldwork can be a repetitive, and therefore 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 in Field Application;
- strict quality control of recorded information. Before storage in the central database, data is automatically checked for completeness and consistency by a validation module in Simplemanager. Data that is suspected of errors is flagged and checked by an RIVM employee. Any issues are then checked with the relevant fieldworker.

Quality control system
The sampling of water and subsequent treatment and transport of samples are subject to 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 to this, several evaluation meetings are held during the year. Also, fieldworkers discuss progress and programmes during their weekly visit to the head office when they collect new fieldwork supplies;
- Auditing of fieldwork by RIVM staff (i.e. 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 RIVM fieldworkers once a year. The principal objectives of these field audits are to:

- o verify working methods and ensure that Work Instructions are adhered to;
- o identify and report on deviations from the Work Instructions, and register the wishes and suggestions of fieldworkers;
- o identify and communicate to fieldworker's actions to correct deviations;
- o improve the efficiency of fieldwork by evaluating practice and procedures, and by adjusting procedures if required.

The laboratory analyses are also embedded in a strict quality control system with Work Instructions and audits. During the 2019–2022 period, the laboratory analyses were conducted by Eurofins Scientific, which is certified by the Dutch Accreditation Council (registration number L 086) according to EN ISO/IEC 17025:2005. The raw laboratory results are checked for global inconsistencies with computer scripts in R (R Core Team, 2023), while the sampling is still ongoing. This allows for the early discovery of any inconsistencies. 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 tests: (a) tests on samples' internal chemical consistency; and (b) tests on spatiotemporal consistency. 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. This is conducted using NO_3 concentration and EC values.

While many major ions are measured in the LMM, bicarbonate is not. Despite the lack of data on bicarbonate concentrations, the EC can still be calculated using the concentrations of other major ions and knowledge of Dutch surface and groundwater. For the data validation, the EC values of composite samples are calculated from the major ions in ground and surface water. The EC values of individual and composite samples are compared to ensure that they are of the same order of magnitude. Spatiotemporal consistency is tested by performing an outlier analysis. For this validation step, the data is compared to historic data to check whether the new data fits 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 (i.e. NO_3, and NH_4);
- The value of P-total, which should equal or exceed the amount of orthophosphate;
- In the case of unfiltered ditch water samples collected in summer, 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 must be equal to or exceed the equivalent sum of anions, as bicarbonate is not measured;

- 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.

Data validation is carried out by two experts in parallel. If outliers are identified, there are communicated to the laboratory and, if relevant, to the fieldworkers. If the laboratory confirms that the results of the analyses were incorrect, the data is replaced by the corrected data or marked as 'not available'. If the laboratory cannot confirm that the data is wrong and there are no reasons to assume that something went wrong in the field, then the data remains in the database. In the case of inexplicable extreme outliers or impossible data, data is labelled as such in the database. This labelled data can be excluded during data analysis, and is excluded from the data used in reports.

3.3 Use of secondary data

3.3.1 Information sources related to water quality

Map material

To locate and describe the farms participating in the LMM, 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:

- A soil map of the Netherlands (1:50,000), aggregated into 7 main soil types, with grid cells of 50 x 50 m resolution (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 (van Duijnen et al., 2023) and the Nitrates Directive report (Fraters et al., 2020);
- A groundwater regime map (1:50,000) derived from the above soil maps;
- A 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 achieved using auxiliary software (QGIS) 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 conditions (e.g. ownership or use). 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. This data is incorporated into the programme's database.

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). This data has been available for each coordinate from 1970 onwards, and it is based on interpolation of all weather station data and – from around the year 2000 onwards – also on radar precipitation data. RIVM uses this meteorological information to apply net precipitation standardisation of the nitrate concentration data. More detail is given in Boumans and Fraters (2017).

3.3.2 *Information sources related to farm management*

Annual Agricultural Census in the Netherlands

The annual Agricultural Census, which covers most agricultural firms in the Netherlands, describes the structure of the agricultural sector (data on farms, crops grown, and animals held/reared). The Agricultural Census is 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). It can be considered to be a complete enumeration.

Data from the Agricultural Census is frequently used within the LMM. First of all, this data is 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, if insufficient farms of a particular type are available 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. RVO plays a key role in providing policy information (e.g. rules, regulations and financial schemes) to agricultural firms in the Netherlands, as well as in gathering information from those firms.

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

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.

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, RVO provides data about parcels. The FADN incorporates the information from the BRP recorded by RVO. This system records annual data for each farm on their cropped plots (reference date May 15), and for each cropped plot data are recorded on crop type, area, user type (e.g. property, non-recurrent lease, etc.), secondary crop (e.g. yes/no and if “yes”, which crop) and use as pasture (e.g. yes/no and if “yes”, with or without grazing).

RVO provides specific data per farm about the supply and removal of livestock manure, the participation in schemes with an expansion of the application standards, such as the use of straw-rich manure and equivalent measures for an extra amount of nitrogen fertiliser to higher fielding crops.

Finally, the LMM uses 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., 2023b). The WUM consists of 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 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 livestock 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 excretions calculated by WUM have been the basis for the various standards.

For intensive livestock farms, keeping 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)
Every year, the NEMA working group calculates emissions to the air from agricultural activities in the Netherlands on a national scale (van Bruggen et al., 2023b). 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 van der Zee et al. (2023). NEMA comprises representatives from the CBS, PBL, WUR and RIVM. In calculations of emissions to the air at farms within the FADN, the LMM uses NEMA emission and TAN factors, as far as possible.

Feed suppliers, research laboratories and ANCA
Most of the analyses of soil and silage performed in the Netherlands are carried out by laboratories such as Eurofins Scientific. The LMM uses the

data from such laboratories in various 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.

The LMM sometimes also uses data published by the laboratories themselves to calculate the farm-specific composition of grass/corn silage. Where silage is not (fully) analysed, the LMM uses average composition data from laboratories such as Eurofins Scientific. 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 ten-year dataset (2008–2017) of soil analyses per parcel of FADN farms was obtained from Eurofins Scientific. This information was then linked to the BRP data, the FADN data (i.e. farm structure and fertiliser management) and the water quality data of RIVM. The data was used to investigate relationships between soil quality and nitrate concentration (van der Wal et al., 2019)

Finally, dairy farmers provide the Wageningen Economic Research Staff with data obtained from the calculation tool, Annual Nutrient Cycling Assessment (*Kringloopwijzer;* ANCA). This calculation tool is used by Dutch dairy farms to estimate the efficiency of dietary phosphorus and nitrogen utilisation at farm level. 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

Information and data derived from the LMM is disseminated via newsletters (both a paper newsletter for LMM participants and a digital newsletter for the professional community), reports, scientific papers, data selection tools and websites.

LMM data is 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/metingen-wat-en-hoe/hoe-worden-resultaten-gebruikt).

The following section describes the data analysis. The presentation of the data and the reports are discussed in Section 4.2.

4.1 Data analysis

4.1.1 Data on agricultural practices and mineral management (FADN)

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

LMM publications present and discuss the agricultural practices at participating farms in different ways. The annual DM publication summarises the most recent results using weighted data from 2019 onwards. DM publications before 2019 are based on 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 used for the EM. Weighting procedures for DM are based on the DM-stratification and are described in van Duijnen et al (2021b; Annex 6).

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

The results for dairy farms in all soil regions, and for arable farms in the Clay, Sand and Loess regions are published on an annual 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 livestock farms’ have been published from 2022.

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

Target population and research sample

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 (Figure 2.1).

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 on fertiliser 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. In this case, 'disproportional' means 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 but also considers all FADN farms that have been part of the LMM target population since 1991. 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. The higher the specificity (i.e. the lower the aggregation level), the smaller the number of available sample farms. 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 weigh the available farm data, the research sample data is 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; Vrolijk et al., 2005, appendix 1). The input for this tool is a file comprising available FADN data (i.e. results of agricultural practices and characteristics of individual farms) and corresponding characteristics of the farms in the target population, which are provided by the Agricultural Census. The corresponding farm characteristics, which are 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 the 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.

4.1.2 Data on water quality

Aggregating analysis results to calculate averages for reporting purposes

Water quality data is 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 in the season when samples were collected.

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

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

Further aggregations depend on the specific analysis and report. Usually, data presented in reports and websites is further aggregated by farm type and soil region. As of 2020, farm type-related and regional averages of EM data presented on LMM website (https://lmm.rivm.nl/) and in the Nitrates Directives report (Fraters 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 ten farms is required. If fewer farms are used, both reliability and confidentiality are compromised. If there are fewer than ten farms of a particular farm type, data of this group is not presented specifically. However, these farms are included when determining the average of the region.

Handling of detection limits

The limit of detection (LOD) is the lowest concentration of a substance that can be reliably detected with the laboratory equipment in use. Below this value, it cannot reliably be concluded that the substance is present.

Up to 2017, the following formula was used when dealing with concentrations below the LOD:

$$Corrected\ Concentration = factor \cdot LOD \qquad \text{Eq. 2}$$

where the factor is a value between 0 and 1, and generally one of: 0, 0.5 or 1. In the LMM, both in EM and DM, a factor equating to 0 (zero) is generally used. So, if the concentration was below the LOD, the concentration was considered to be zero.

Since 2017, the actual output of the analyser has been used when reporting concentrations below the LOD in both EM and DM. The concentration is therefore not considered to be zero. However, because analysers work with a calibration curve, it is possible to obtain negative values when using analyser output. Furthermore, 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. The output of the analysers has been recorded from 2006 onwards, and therefore, this method has been used on this data in reports published since 2017. This means that values reported in reports published prior 2017 may show slight differences when compared with reports published after 2017. For data obtained before 2006 it is only known whether the measured value is below the detection limit and the actual analyser output is not known. Therefore, when data from before 2006 is reported, the value is generally set to zero.

Presentation of detection limit in charts and graphs
In tables, where averages or percentile values are reported, those values below the LOD are reported as '< dg' or '< dt'. In graphs, the applicable detection limit is generally visually represented as, for example, a horizontal line. Generally, the numerical value of the LOD is reported in tables or graphs as well.

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 – calculated as the weighted or unweighted average (depending on the report) of the annual farm averages. For the presentation of trends in nitrate concentrations the data is standardised for variations in net precipitation, sample size and sample composition (Boumans and Fraters, 2017). 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 concentration, from the impacts of extraneous variables such as climate or 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 (Boumans and Fraters, 2017).

The method takes into account variables that may affect the measured nitrate concentrations. The variables considered are precipitation surplus, groundwater level, date of sampling, soil type and drainage class. Three classes are distinguished on the basis of groundwater regime and farming characteristics. In addition, the model takes into account the prevalence of each farm type in a region.

4.2 Presentation of data

Currently, a large part of the LMM data is reported online rather than in reports:

- The results regarding water quality can be found on the RIVM-LMM website (https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten). The results on agricultural practice (1991–2021 period) can be found on the WUR websites (www.wur.nl/lmm and www.agrimatie.nl).
- The main results on agricultural practice from DM for the years 2006–2018, along with the annual DM reports, can be found on the WUR website (www.wur.nl/lmm).
- 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 sections describe the data selection tools (section 4.2.1), reports publishes using the results of the LMM (section 4.2.2) and supplementary research conducted, and reports published (section 4.2.3).

4.2.1 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 is presented:

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

Selections can be made by:

- year;
- farm category;
- soil region type;
- water type;
- period (summer or winter);
- chemical parameter.

It is also possible to export data in CSV formatted files. Results are presented per group (i.e. region, farm category, water type and period). Only the results of groups of at least ten farms are provided.

Data on www.wur.nl/lmm

The WUR-LMM website (www.wur.nl/lmm) uses the publication tool Agrimatie.nl (www.agrimatie.nl). This tool gives insight into the profit performance, impact on societally relevant topics and the 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), societally relevant topics (e.g. animal welfare, sustainable agriculture) 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 easily navigate using interactive charts and clear search and filter functions. The charts can also be downloaded for personal use, as shown by the example in Figure 4.1.

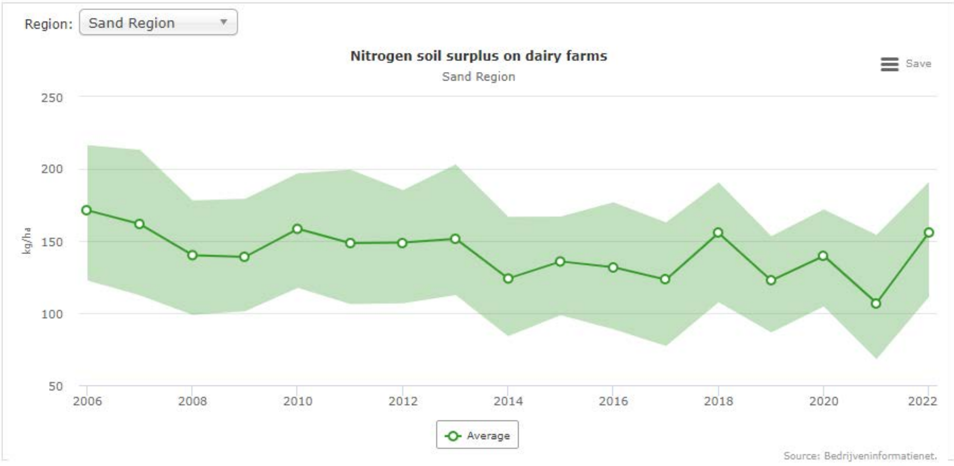


Figure 4.1 Nitrogen soil balance surplus for dairy farms in the Sand region for the 2006–2022 period. Please note that the 2022 results are preliminary.

In the last period, data on new topics has been included on the LMM-page of agrimatie.nl ('Mestbeleid LMM' in Dutch). This data relates to nitrogen and phosphate use efficiency at soil level, the share of farms with irrigation and the amount of water used for irrigation purposes.

Additionally, an indicator for dairy farms on homemade protein has been developed and is regularly published in 'LMM e-nieuws', the LMM digital newsletter.

4.2.2 *Reports on monitoring results*

The LMM results and other reports pertaining to the LMM are published 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 they do include the identification of differences between years and/or reporting categories, and extreme values.

The reports often present information for different periods. Often, the most recent year of the previous report is referenced, which allows a quick comparison of the results between the various years.

In terms of agricultural practices, the reports place an emphasis on the area of agricultural land, classification of farmland, stocking density, milk production, use of manure and artificial fertilisers, mineral surpluses and crops yields for grassland and silage maize.

The reports pertaining to water quality generally focus on concentrations and trends in nitrogen and phosphorus containing compounds.

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

- Every year, EM water quality results are published on the RIVM website as web reports (https://www.rivm.nl/landelijk-meetnet-effecten-mestbeleid/resultaten/basismeetnet). The results for 2019–2021 are currently presented on the website. Before 2011, these results were published in regular results reports (for example de Goffau et al., 2013). The data per soil region and farm type are also accessible via the selection tool (https://lmm.rivm.nl/).
- Every year, EM and DM results of agricultural practices are published on the WUR website (http://www.wur.nl/lmm and http://www.agrimatie.nl). The DM results are posted once the report on DM (for example van Duijnen et al. 2023) has been published. The EM results are published once a year.
- Every year, a report on 'Agricultural practices and water quality on farms registered for derogation' (for example van Duijnen et al. 2023) 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 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 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).
- Every year, results of the EM pertaining to the water quality under farms are delivered to the Environmental Data Compendium (CLO) and published on their website (https://www.clo.nl/en).

4.2.3 *Specific research*

During 2019–2022, specific research was carried out and published. The results of this research are not described in this report. Here we merely provide a summary of each and a reference to the report in which details can be found:

RIVM (Tenner et al., 2021) conducted a pilot study to investigate the use of different nitrate sensors in the monitoring of water quality. The goal was to determine whether sensors can produce better measurements of the quantities of fertilisers that leach from agricultural land into groundwater and surface water. In the pilot, eight different sensors were tested and compared over a two-month period. The project was part of the Water Sensors Nutrients Innovation Programme (WaterSNIP).

RIVM (Fraters et al., 2022) compared the results of measured nitrate concentrations to the outcome of model results in Loess soils. Within the Smart Fertilisation ('Slim Bemesten') pilot project conducted by farmers in South Limburg, a model was created and used to predict nitrate concentration in the water leaching into the groundwater table from the root zone. The goal of the model was to show which measures could be taken to reduce the groundwater nitrate concentrations in loess soils, whilst still applying enough fertiliser to ensure healthy crops. RIVM conducted measurements and compared the results to those calculated by the model.

RIVM conducted a study (Wuijts et al., 2022), commissioned by the European Parliament, in which an overview is provided of the legal and environmental context in which nitrogen emissions to water are measured in the EU. The study describes how the European Commission ensures that monitoring systems and their results are comparable throughout the EU. Furthermore, the development of nitrate concentrations in the EU in view of the European Green Deal is explored and (policy) recommendations are provided for EU institutions and Member States.

Deltares, RIVM and KNMI (Rozemeijer et al., 2021) investigated the effect of climate variability on the eutrophication of groundwater, streams, rivers, lakes, estuaries, and marine waters in the Netherlands. The results indicate that water quality of all Dutch water systems is affected by climate variability.

RIVM (Spijker et al., 2021) developed a predictive modelling framework, using a Random Forest algorithm, to create annual maps with full national coverage of nitrate concentrations leaching from the root zone of Dutch agricultural soils, and to test this model for the year 2017. For the study, nitrate data from a national monitoring programme was combined with a large set of auxiliary spatial data, such as soil types, groundwater levels and crop types.

RIVM (van Beelen and van der Wal, 2021) investigated long-term trends in phosphate concentrations in groundwater using data from 165 farms sampled since 2006. Additionally, the concentrations were compared to groundwater quality criteria.

Wageningen Economic Research (Roskam et al., 2022b; internal report) evaluated the allocation method of manure. The report describes the effects of the allocation method and the new probability limits on fertiliser calculations. The goal of this analysis was to determine the effects of the allocation method on livestock farming. The effects of this new fertiliser calculation method, and consequently its effects on soil surplus, were analysed for livestock farms, arable farms and dairy farms for the years 2011, 2014 and 2017. The results show that the allocation method and the adjusted fertilisation limits (application standard times 2.5) significantly reduced the number of livestock farms set at an unknown value (N.B.).

Wageningen Economic Research (Roskam and Eweg, 2022; internal report) examines the extent to which data from the Annual Nutrient Cycling Assessment (ANCA) can be used in recording data in the FADN. The results show that there are similarities between the data from the ANCA and the FADN. At the same time, however, there are also major differences; both between data sources and per variable. In this report, four suggestions are made for possible follow-up steps for the use of the ANCA for the FADN

An overview of all LMM reports from its inception until 2023 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 and 2015-2018 in the reports by van Vliet et al. (2017) and van Duijnen et al. (2021a). The present report describes only the important changes in the period 2019–2022.

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.

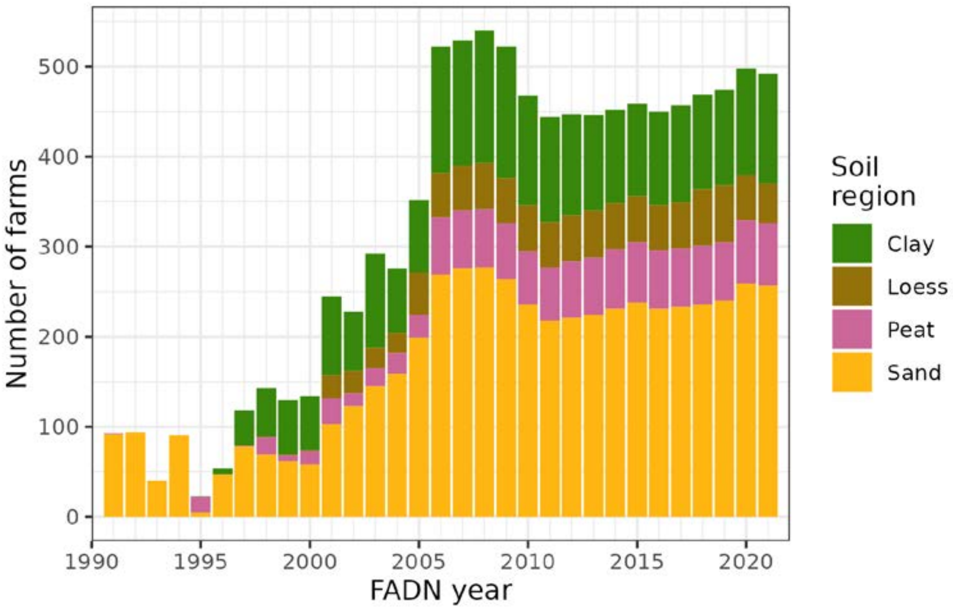


Figure A1.1 Number of farms per soil region monitored in the LMM.

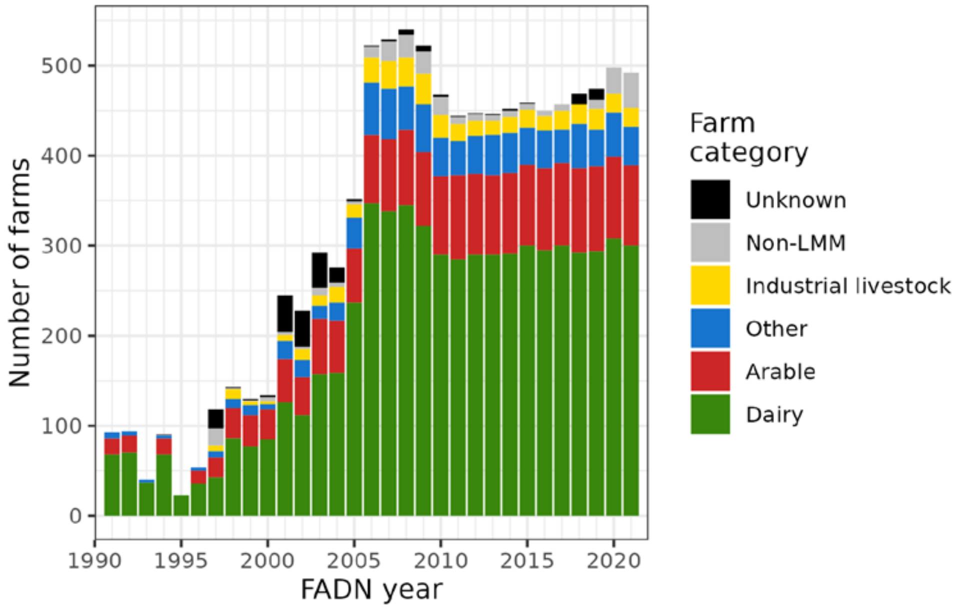


Figure A1.2 Number of farms per farm category monitored in the LMM.

A1.1 Major changes 2019–2022

No major change has occurred to the LMM set-up between 2019-2022. However, a notable change that has occurred to the LMM set-up is that participants of the 'Koeien en Kansen' programme and the 'Noardlike Fryske Wâlden' programme were phased out from the DM in 2020. The dairy farms have been replaced via random sampling to maintain the DM sample size.

There have also been other changes pertaining to the collection and analysis of samples, namely:

- fieldworkers no longer record the kind of crop growing on the sampled agricultural plots. The exception to this is maize. This change was implemented in 2019 and the reason for its implementation is that the data collected by fieldworkers was often incomplete and did not accurately reflect the types of crops grown. This is because the majority of the sampling occurs in the winter period, outside the growing season;
- samples analysis is conducted by Eurofins Scientific since 2020.

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 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
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

Year	Changes	Policy impetus	Substantiation	Remarks
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 farms 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
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

Year	Changes	Policy impetus	Substantiation	Remarks
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
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

Year	Changes	Policy impetus	Substantiation	Remarks
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	
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

Year	Changes	Policy impetus	Substantiation	Remarks
2011	General: discontinuation of exploratory programmes such as ‘Koeien & Kansen’ and ‘Telen met Toekomst’	Cutback in expenditure		Some ‘Koeien & Kansen’ farms continued in derogation network, and are 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
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

Year	Changes	Policy impetus	Substantiation	Remarks
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
2019	Fieldworkers stopped recording the crops present		The decision was made to use a single source of crop type information as fieldworkers only collected crop type at locations where groundwater was sampled.	

Year	Changes	Policy impetus	Substantiation	Remarks
2020	Dairy farms participating in the ‘Koeien en Kansen’ (KeK) and ‘Noardlike Fryske Wâlden’ (NFW) and recruited for the DM were replaced.		The NFW research programme ended and the participants from KeK started participating in the BES pilot and therefore (potentially) no longer met the DM requirements	

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., 2022a).

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 2020 as an example year, the total number of farms in the Annual Census was 52,695. The FADN target population (meeting the size criterion) in 2020 was 43,554 farms. This number accounted for 99,5% of the total agricultural production capacity expressed in SO (Roskam et al., 2022a).

The recruitment of farms for participation in the FADN takes place each year, according to the annual selection plan. The legal obligation is to annually send data relating to a sample of 1,500 farms to the European Commission.

[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 livestock 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 inception 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 (such as 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 districts.

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 to its postcode, is in the Sand region, while the specific farm may, for example, be dominated by peat-rich soils. This variability 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 at farms with soils different from those of the region as a whole.

b. Types of farming
According to the Agricultural Census, circa 52,107 farms were active in agriculture and horticulture in the Netherlands in 2021 (Annex 3, Table A3.2). They cultivated a total area of 1.8 million ha. Grassland dominated the total cultivated area (nearly 54%). About 30% of the cultivated land was in use for arable agriculture and 11% for other fodder crops. The remaining 4% was identified as ‘other land’ (75,000 ha of outdoor horticultural crops). Almost 46% of the 1.8 million hectares of cultivated land was in use by dairy farms, 26% by arable farms and 11% by other grazing livestock 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.

Allocation of farms to SO size classes

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 2020 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)	40.000	40.000	40.000	40.000
Number of farms in Agricultural Census	1.400	800	500	200
Average area per farm (ha)	29	50	80	200
Number of farms in LMM	10	10	10	10
Selection chance	10 in 1,400	10 in 800	10 in 500	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 livestock 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 livestock 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 livestock 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 livestock 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 2021.

From Table A2.3 it can be concluded that:

- over 89% of all farms and all cultivated land are situated in the Sand and Clay regions. With an area of 27,000 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 55% of all farms. The individual ‘coverage’ is slightly higher for grassland, arable farming and other fodder crops (86–91%); for ‘other cultivated land’ the coverage (16%) is relatively low;
- among the regions, the coverage of total cultivated land varies between 80% in the Peat region and 86% in the Clay and Sand regions. 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.

Region	Number farms	Grassland (ha x 1000)	Other fodder crops (ha x 1000)	Arable farmland (ha x 1000)	Horticultural land (ha x 1000)	Total cultivated land* (ha x 1000)	Share in total extent (%)
LMM Sand region	28,383	462	139	197	41	839	47%
LMM Clay region	18,129	343	50	322	33	748	42%
LMM Peat region	4,726	167	14	5	1	187	10%
LMM Loess region	869	11	3	13	0	27	1,5%
Total agri- & horticulture in NL	52,107	984	206	537	75	1,802	100%
Research population Sand region							
- Dairy farms	7,146	316	64	10	0	391	22%
- Arable farms	3,033	16	22	125	2	165	9%
- Intensive livestock farms	1,735	19	16	20	1	56	3%
- Other farms	3,241	76	18	20	2	116	6%
Total	15,155	427	119	175	5	727	40%
Total % of Sand region	53%	92%	86%	89%	13%	86%	
Research population Clay region							
- Arable farms	4,538	21	12	255	5	293	16%
- Specialised dairy farms	4,226	245	27	7	0	280	16%
- Other farms	1,760	55	6	15	1	77	4%
Total	10,524	322	44	277	6	650	36%
Total % of Clay region	58%	94%	89%	86%	19%	86%	
Research population Peat region							
- Specialised dairy farms – North	1,212	73	8	0	0	81	4%
- Specialised dairy farms – West	1,223	65	3	0	0	69	4%
Total	2,435	138	11	1	0	150	8%

Region	Number farms	Grassland (ha x 1000)	Other fodder crops (ha x 1000)	Arable farmland (ha x 1000)	Horticultural land (ha x 1000)	Total cultivated land* (ha x 1000)	Share in total extent (%)
Total % of Peat region	52%	82%	81%	15%	3%	80%	
Research population Loess region							
- Dairy farms	258	1	1	9	0	11	0,6%
- Arable farms	124	5	1	1	0	7	0,4%
- Other farms	146	3	1	1	0	5	0,3%
Total	528	10	3	11	0	24	1,3%
Total % of Loess region	61%	91%	88%	86%	25%	88%	
Total LMM research population	28,642	897	178	464	12	1550	86%
% of agri- & horticulture in NL	55%	91%	86%	86%	16%	86%	

Source: Agricultural Census 2021
* horticultural glass acreages not included

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. On the basis of their activities (production of crops and/or livestock), farms are classified in 'farm types'. All cropped areas and numbers of head per species are converted into a so-called standard output (SO) (*standaardopbrengst* in Dutch). The SO of a crop or livestock refers to its yield (in euros), achievable on an annual basis under normal circumstances. The proportion of the production from specific livestock 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 livestock, 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 livestock.

In addition, minor modifications occur in the list of products and livestock used. These modifications relate to livestock 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 livestock			
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 livestock, mainly feed crops
4810	Specialising in sheep		
		4843	Other grazing livestock
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 2021 (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 livestock) is divided further into ‘dairy farms’ (type 4a) and ‘other grazing livestock 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 (2021).

Farm category	**Number of farms**	**Grassland (ha x 1,000)**	**Other fodder crops (ha x 1,000)**	**Arable farmland (ha x 1,000)**	**Horticultural land (ha x 1,000)***	**Total cultivated land (ha x 1,000)***	**Share in total extent (%)**
1) Arable	11,189	48	43	371	3	464	26%
2) Horticulture	6,995	6	4	20	58	88	5%
3) Permanent cul-tures	1,512	1	1	19	1	21	1%
4a) Dairy	14,119	706	104	19	1	830	46%
4b) Other grazing	11,500	167	25	9	0	201	11%
5) Intensive livestock	3,799	16	12	24	1	52	3%
6) Mixed cropping	1,220	6	4	42	9	62	3%
7) Mixed livestock	375	11	3	2	0	16	1%
8) Mixed crop–livestock	1,398	23	10	32	3	68	4%
Total (ha x 1,000)	52,107	984	206	537	75	1801	100%
Share of land use (%)		54%	11%	30%	4%		

Source: Agricultural Census 2021
* horticultural glass acreages not included

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

Main farm type	2018		2019		2020		2021	
	acreage (x 100 ha)	(%)	acreage (x 100 ha)	(%)	acreage (x 100 ha)	(%)	acreage (x 100 ha)	(%)
1) Arable	158	19%	164	19%	170	20%	171	20%
2) Horticulture	54	7%	54	6%	54	6%	56	7%
3) Permanent cultures	3	0%	3	0%	3	0%	3	0%
4a) Dairy	394	48%	398	47%	397	47%	392	47%
4b) Other grazing	102	12%	113	13%	111	13%	113	13%
5) Intensive livestock	48	6%	47	5%	44	5%	41	5%
6) Mixed cropping	16	2%	16	2%	16	2%	19	2%
7) Mixed livestock	15	2%	14	2%	12	1%	12	1%
8) Mixed crop–livestock	37	4%	39	5%	38	4%	35	4%
Total SAND region	**827**	**100%**	**849**	**100%**	**846**	**100%**	**844**	**100%**
1) Arable	277	38%	277	37%	280	37%	276	37%
2) Horticulture	38	5%	39	5%	41	5%	42	6%
3) Permanent cultures	18	2%	18	2%	17	2%	17	2%
4a) Dairy	277	38%	283	37%	281	37%	280	37%
4b) Other grazing	50	7%	57	8%	58	8%	59	8%
5) Intensive livestock	11	2%	11	1%	11	1%	10	1%
6) Mixed cropping	38	5%	38	5%	38	5%	41	5%
7) Mixed livestock	3	0%	3	0%	3	0%	2	0%
8) Mixed crop–livestock	27	4%	30	4%	29	4%	28	4%
Total CLAY region	**737**	**100%**	**753**	**100%**	**755**	**100%**	**754**	**100%**
1) Arable	5	3%	5	2%	5	3%	6	3%
2) Horticulture	2	1%	2	1%	2	1%	2	1%
3) Permanent cultures	0	0%	0	0%	0	0%	0	0%
4a) Dairy	144	81%	151	80%	150	80%	150	80%
4b) Other grazing	23	13%	26	14%	25	14%	26	14%
5) Intensive livestock	1	0%	1	0%	1	0%	1	0%
6) Mixed cropping	0	0%	1	0%	0	0%	1	0%
7) Mixed livestock	1	1%	1	0%	1	0%	1	0%

Main farm type	**2018**		**2019**		**2020**		**2021**	
	acreage (x 100 ha)	(%)	acreage (x 100 ha)	(%)	acreage (x 100 ha)	(%)	acreage (x 100 ha)	(%)
8) Mixed crop–livestock	1	1%	2	1%	2	1%	2	1%
Total PEAT region	**178**	**100%**	**187**	**100%**	**187**	**100%**	**187**	**100%**
1) Arable	10	38%	10	38%	10	38%	11	40%
2) Horticulture	0	1%	0	1%	0	0%	0	0%
3) Permanent cultures	2	6%	2	6%	1	5%	1	5%
4a) Dairy	8	28%	8	29%	8	29%	7	27%
4b) Other grazing	2	9%	3	9%	3	10%	3	11%
5) Intensive livestock	0	1%	0	1%	0	1%	0	1%
6) Mixed cropping	1	5%	1	4%	1	5%	1	4%
7) Mixed livestock	0	0%	0	0%	0	0%	0	0%
8) Mixed crop–livestock	3	12%	3	12%	3	11%	3	11%
Total LOESS region	**27**	**100%**	**27**	**100%**	**27**	**100%**	**27**	**100%**
1) Arable	450	25%	456	25%	466	26%	464	26%
2) Horticulture	94	5%	95	5%	96	5%	99	5%
3) Permanent cultures	22	1%	22	1%	21	1%	21	1%
4a) Dairy	823	47%	839	46%	835	46%	830	46%
4b) Other grazing	177	10%	198	11%	197	11%	201	11%
5) Intensive livestock	60	3%	59	3%	56	3%	52	3%
6) Mixed cropping	55	3%	56	3%	56	3%	62	3%
7) Mixed livestock	19	1%	18	1%	15	1%	16	1%
8) Mixed crop–livestock	68	4%	73	4%	72	4%	68	4%
Total Netherlands	**1768**	**100%**	**1816**	**100%**	**1815**	**100%**	**1812**	**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 2018–2021. The specification is based on the eight NSO main types of farm, in which NSO type 4 (grazing livestock) 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 livestock (designated as type 4b). Between 2018 and 2021, the number of agriculture and horticulture farms dropped by more than 20% (from 65,507 in 2017 to 52,107 in 2021). 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 farm type**	**NSO (main) farm types used in LMM selection**
Sand	Arable farms	NSO main type 1: arable farms
		NSO type 6100: other mixed cropping on condition that 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 livestock (excluding NSO types 4500 and 4611)
		NSO type 7300: livestock combinations, mainly grazing livestock
		NSO main type 8: crops/livestock combinations
Clay and Loess	Arable farms	NSO main type 1: arable farms
		NSO type 6100: other mixed cropping on condition that 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 livestock (excluding NSO types 4500 and 4611)
		NSO type 7300: livestock combinations, mainly grazing livestock
		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 and A4.2 show 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 RIVM's water quality monitoring programme (see also Table A4.3).

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

Agricultural practices – EM

Clay region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	137		83	18	238
2019	137		83	18	238
2020	139		86	15	240
2021	133		79	17	229

Peat region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018			48		48
2019			48		48
2020			48		48
2021			44		44

Loess region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	21		22	8	51
2019	21		22	8	51
2020	20		23	8	51
2021	18		18	9	45

Sand region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	69	74	175	34	352
2019	72	69	176	28	345
2020	67	69	178	28	342
2021	65	70	171	31	337

All regions combined

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	227	74	328	60	689
2019	230	69	329	54	682
2020	226	69	335	51	681
2021	216	70	312	57	655

Table A4.2 Farms included for data collection on agricultural practice for DM

AGRICULTURAL PRACTICE – DM

Year	***Clay region***	***Loess region***	***Peat region***	***Sand region***	***All regions***
2018	*60*	*20*	*59*	*156*	*295*
2019	*60*	*20*	*60*	*160*	*300*
2020	*59*	*20*	*60*	*159*	*298*
2021	*57*	*17*	*59*	*154*	*287*

Tables A4.3 and A4.4 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 A4.3 Number of eligible farms included for data collection on water quality for EM.

Water Quality – EM

Clay region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	33		48	13	94
2019	32		54	13	99
2020	31		56	11	98
2021	31		59	12	102

Peat region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018			51		51
2019			53		53
2020			57		57
2021			56		56

Loess region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	21		21	8	50
2019	21		21	8	50
2020	20		21	8	49
2021	19		20	9	48

Sand region

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	40	20	141	12	213
2019	41	20	144	12	217
2020	39	19	149	14	221
2021	36	15	147	20	218

All regions combined

Year	Arable	Intensive livestock	Dairy	Other livestock	Total
2018	94	20	261	33	408
2019	94	20	272	33	419
2020	90	19	283	33	425
2021	86	15	282	41	424

Table A4.4 Number of farms included for data collection on water quality for DM.

Water Quality – DM

Year	Clay	Loess	Peat	Sand	All regions combined
2018	60	20	60	156	299
2019	61	20	60	160	301
2020	60	20	60	160	300
2021	60	17	59	158	294

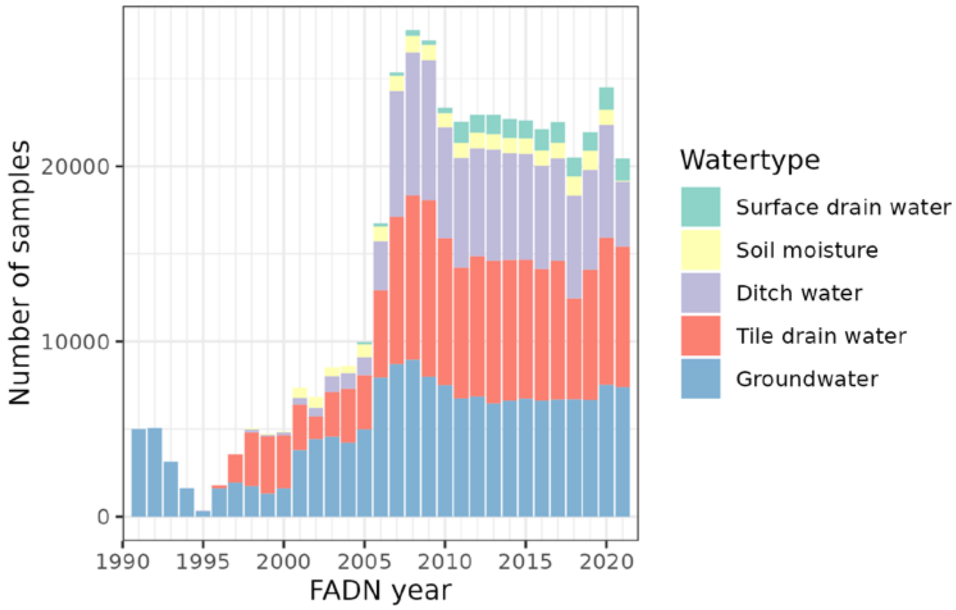


Figure A4.1 Historic overview of the number of individual samples taken from different water types.

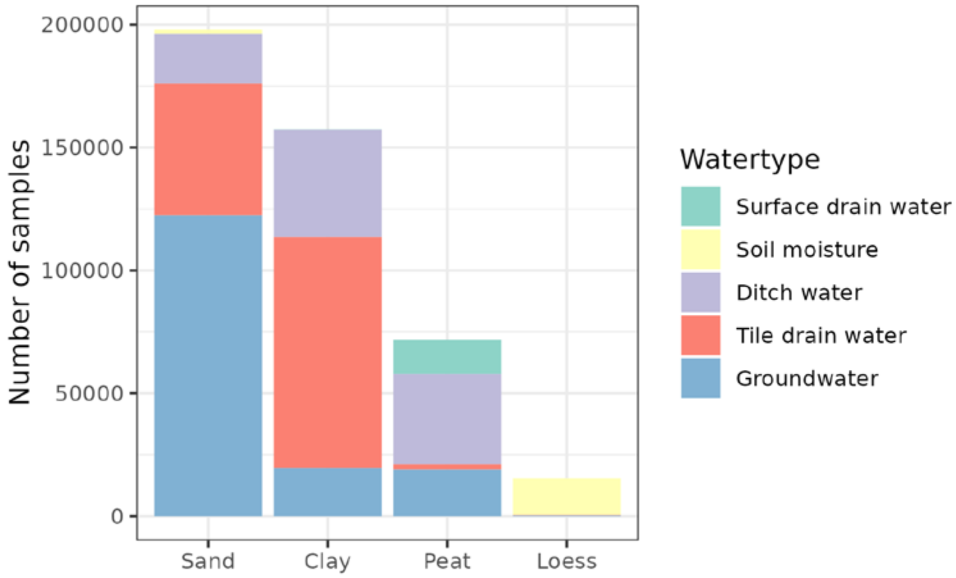


Figure A4.2 Number of individual samples taken from the various water types in the four soil regions during the whole history of the LMM (1992–2021).

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 7, May 2022]
MIL-W-4002	Use of control sheets for equipment calibration [version 7, October 2022]
MIL-W-4006	Measuring pH, specific conductivity and oxygen content in an aqueous solution using the WTW Multi 350i [version 8 July 2022]
MIL-W-4008	Temporary storage and transportation of samples [version 7, January 2024 2019]
MIL-W-4010	Concise description of the soil profile [version 7, May 2022]
MIL-W-4012	Sampling of surface water/ditch water using a measuring jug [version 8, November 2022]
MIL-W-4013	Sampling of drain water [version 8, September 2023]
MIL-W-4014	Soil sampling for soil moisture testing using an Edelman auger [version 9, August 2023]
MIL-W-4015	Sampling of groundwater in sand, clay and peat using a sampling nozzle and a peristaltic pump [version 8, May 2022]
MIL-W-4016	Preparation of RIVM sampling nozzle for sampling groundwater and ditch water [version 7, January 2023]
MIL-W-4017	Field visits and work site inspections within the Environmental Quality Monitoring (MMK) Department [version 6, April 2023]
MIL-W-4018	Safety during fieldwork [version 8, February 2022]
MIL-W-4020	Compiling and archiving of the business information of agricultural firms [version 7, June 2023]
MIL-W-4021	Identifying the position of sampling points [version 9, February 2022]
MIL-W-4022	Recording the temperature in refrigerators [version 6, October 2022]
MIL-W-4023	Data validation and drafting (written) reports for individual LMM participants [version 7, April 2022]

SOP / Doc. No.	Title
MIL-W-4025	Drafting a working plan for measurements within the LMM programme [Version 4, October 2023]
MIL-W-4104	Collection of ground, ditch, and drain water or soil samples [version 5, October 2023]

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)

Materials

- sealing caps for reservoir tubes (HDPE, 50 mm);
- sampling nozzles, in various lengths, of PVC material with a 50 cm perforated section (slot size 0.3 mm) and external graduation (RIVM design, according to Work Instruction MIL-W-4016);
- external tube: length 300 cm; $Ø_{int}$ 5.2 cm, $Ø_{ext}$ 6.0 cm (PVC, impact-resistant, yellow);
- manual drilling equipment of various sizes:
  - Edelman auger: Ø 7 cm / Ø 10 cm;
  - sand pump or 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 loose clay): Ø 7 cm / Ø 10 cm;
- lifting jack, lever and chain;
- filter gravel: bag with 25 kg content;
- clay plug material: type Mikolit 00: 25 kg bag;
- ball valve and tube;
- bailer with a length of 73 cm Ø 63 mm;
- sampling vehicle (for example quad bike);
- PE hose/tube: $Ø_{int}$ 4 mm, $Ø_{ext}$ 6 mm;
- plastic cylinder (collar): length ~50 cm, Ø ±11 cm;
- plastic sheet;
- map with all plots and locations where groundwater samples are to be taken (available through the Field App);
- reservoir tube with a 100 cm perforated section (slot size 0.4 mm), 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;
- peristaltic pump;
- spade;
- (paper) towel
- sounding lead;
- high-pressure water cleaner;
- 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 the sampling point using the map with marking locations available in the Field App. If the position of the sampling point has not yet been established, determine a 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.
- Record the xy-coordinates and other field observations in the Field App.
- Remove the turf using a spade. Keep the turf separate so that it can be replaced after sampling. On arable land, drilling can be conducted immediately.
- Place the plastic sheet next to the borehole to collect and 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; installing a sampling nozzle according to open borehole method
This method can be used if the soil material in the groundwater-saturated zone is sufficiently loose to cause spontaneous slumping of the borehole. The method also requires a swift and abundant influx of groundwater. The above conditions apply primarily to sandy soils, but the open borehole method can also be 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 to facilitate 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 which may cause the influx of groundwater to be slower and lead to an underestimation of the groundwater.
- At a peat location, use the bailer 1 or several times if necessary, until the slush is more or less removed.
- Install the sampling nozzle in the borehole and push it, if necessary with jerking movements, as far as possible into the hole. Push up to a depth that the upper meter of groundwater can be sampled.
- Often, sampling can start within half an hour of the installation of the sampling nozzle. For the sampling methodology refer to section E of this Instruction. In the case of slow influx the borehole may be left overnight granted it is capped to prevent contamination.

C. Sampling in clay; installing sampling nozzle according to closed borehole method

This method can be used if the soil material in the groundwater-saturated zone is so compact that the slumping of the borehole does not occur. Generally the “open borehole method” is used for clay soils but in some cases this method is necessary.

- Drill a hole 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. Note that as the fraction of clay or silt increases, the influx of groundwater slows which can lead to an underestimation of groundwater level. An indication of groundwater level can be gained by looking at the ditchwater level or at the depth at which tile drains have been placed.
- Install the sampling nozzle in the borehole and push it, if necessary, to a depth such that the upper meter of groundwater can be sampled.
- Deposit the filter gravel around the sampling nozzle until approximately 50 cm above the top of perforated section of the sampling nozzle is covered.
- Deposit approximately 20-30 cm clay plug material around the sampling nozzle on top of the filter gravel.
- Deposit the clay material extracted during the drilling process around the sampling nozzle on top of the clay plug material to prevent the inflow of surface water.
- If cattle are present, the sampling nozzle may be shortened using a saw so that it does not protrude from the soil surface. Make sure that the tube within the nozzle is not damaged during the process. Cover the nozzle with a tile and make sure the tile doesn’t protrude above the soil surface.
- When all the necessary sampling nozzles have been placed, or at the end of the day, use the pump to flush the sampling nozzles.
- Due to the slow influx of groundwater, return in 1 to 7 days to sample the groundwater. For the sampling methodology refer to section E of this Instruction.

D. 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 partly due to the use of larger filters with a bigger surface area, which are less easily clogged by organic material, and due to the use of a bailer to remove sediment and particulate organic matter. 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 preserved branches.
- If required, clean the borehole with the bailer until the present slush has more or less been removed.
- Slide the reservoir tube inside of the external tube if there is a chance that the perforations of the reservoir tube will be clogged

shut when placing it. This will likely only be necessary if a narrow hole has been drilled (7 cm diameter) and is generally not required if an auger with a diameter of 10 cm has been used.

- Push both tubes into the borehole to the correct depth. If the external tube has not been used, then only push the reservoir tube 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 if this has been used.
  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, for example, the turf or some of the drilling material, in order to prevent the inflow of surface water.
- Use the sounding lead to measure the distance between the top of the reservoir tube and the surface level and record the distance (in cm).
- Close the reservoir tube with the designated sealing cap.
- After installation of the reservoir tubes, or at the end of the day, 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 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.
- Record the time at which the reservoir was pumped clean.
- At least one day should elapse after installation before the reservoir tubes can be sampled.
- To prevent sample contamination, first clean the sounding lead with demineralised water and a clean (paper) towel.
- Measure the water level in the reservoir tube with the clean sounding lead.
- While extracting the sounding lead from the reservoir tube, clean the ribbon attached to the sounding lead with a clean towel.
- Refer to section E for the implementation of the water sampling.

E. Sampling of groundwater

- Couple the hose of the sampling nozzle to the suction side of the peristaltic pump.
- Flush a certain volume of groundwater depending on the implemented sampling method (Table A5.2). If the flushed water is clear (i.e. free of sediment), flushing can be stopped.

Table A5.2 Minimum amount of groundwater to be pumped for flushing for the various 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 sediment, repeat the above described flushing procedure up to a maximum of five times.
- Record the total volume of water pumped just prior to sample collection.
  When using the flow cell, the water used to fill the flow cell must be included in the recorded total volume of water flushed.
- Filter the water and fill and seal the sample containers in accordance with work instructions (MIL-W-4104). In the case of outsourced work do so in accordance with the terms of reference.
- Shut down the pump.
- Decouple the sampling nozzle hose from the peristaltic pump, and insert the hose into the sampling nozzle to protect it.

F. Transport

- Temporarily store and transport the samples according to work instructions (MIL-W-4008; see Annex A5.6)

G. Completion of sampling and aftercare

- When applying the sand or clay method, manually mark the soil surface level on sampling nozzle, and remove the nozzle from the borehole.
- Identify the end of the wet part of the nozzle, and measure the depth of the water table below the soil surface using the grade marks on the nozzle. Record the measured depth (cm) to the nearest multiple of 5 cm.
- Measure the distance between the top of the perforated section and the top of the wet part of the nozzle. Record the measured distance (cm) to the nearest multiple of 5 cm.
- When applying the peat method, remove the reservoir tube from the borehole. If necessary, use the steel lifting jack and lever with chain.
- Refill the borehole with the soil material extracted from the borehole during drilling. Compact the soil material used to refill the borehole intermittently 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 perforations.

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

Materials

- Android device with the latest version of the RIVM Field App installed;
- stopwatch or watch with second-hand;
- 1 litre plastic measuring jug;
- spade;
- pickets and felt-tip pen with 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;
- folding ruler;
- grabber tool;
- shoulder length waterproof gloves;
- wading suit;
- sample storage box.

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 through 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 distribution of drain locations to be sampled is marked on a map. Using this map, the sample taker looks for suitable drains at the identified locations, and marks those drains with a picket, numbered in accordance with the suggested drain positions on the map. When searching for drains it may be useful to use the grabber tool to aid in combing through the sides of ditches into which the drains drain. This can be especially useful when there is not of discharge and the drains are hard to identify visually. When a drain is identified, the drain has to be dug free from overgrowing plants and/or soil to prevent the drain water from being contaminated.
Subsequently the GPS-coordinates are recorded in the Field App. If a drain can't be found or not enough water is flowing out of it, another drain is selected on the same parcel by the fieldworker. Mark the location of the new drain on the map and record the GPS-coordinates. In the case that there is no other drain on the parcel, contact the fieldwork supervisor.

For locations in the Peat region, only surface drains are selected to be sampled. Tile drains are not sampled like in the Sand or Clay 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. Establishing the time of sampling
Sampling can proceed if the three following conditions are met simultaneously:

1. the date falls within the period in which sampling is planned;
2. it is not a Friday, Saturday or Sunday;
3. at least 80% of the selected drains (n = 13 drains) are producing sufficient discharge.

The sampling procedure for tile drains discharging above ditch water level is presented in section C. The sampling of tile drains discharging below ditch water level is presented in section D. The sampling of surface drains discharge under the ditch water level in the Peat region is presented in section F.

C. Sampling of tile drains discharging above ditch water level

- Proceed to the tile drain to be sampled the map containing drain locations and the GPS-coordinates. Drains to be sampled are normally marked with a picket. These pickets may disappear in the course of time, for example during dredging 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 of the drain, 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 discharge is adequate, use this water to rinse the jug, and subsequently empty the jug. If the tile drain does not produce enough discharge, 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:
    - *Record the GPS-coordinates of the new drain.*
    - *If the relocation is permanent, the new location is to be indicated on the map of the farm in the Field App. A relocation is considered permanent if it is not expected that the original drain will produce adequate discharge in the future.*

  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 recorded in the Field App:
    - parcel number;
    - whether a replacement drain was selected;
    - GPS-coordinates;
    - the distance between bottom drain tube and the ditch water level (in m);
    - any other information in accordance with the work assignment.
- Rinse the measuring jug once more, by filling it to at least 20%, swirling it and emptying it. Make sure not to come into contact with the water when holding the measuring jug.
- 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’ in the Field App.

- Rinse the sample bottles once with drain water from the measuring jug, by filling the bottles to 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 seal them securely.
- Store the bottles in a cool box.
- Check whether all data recorded in the Field App have been validated.

D. Sampling of tile drains discharging below ditch water level in clay and sand areas

- Proceed to the tile drain to be sampled using the map marking drain locations and the GPS-coordinates. Drains to be sampled are normally marked with a picket. These pickets may disappear in the course of time, for example during dredging of the ditch. If necessary, a new picket should be installed.
- 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 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 as turbulence and as sediment present at drain mouth being 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. If necessary, an object may be inserted into 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 discharge by drains discharging below ditch water level. In the absence of any of these clues, the procedure for selecting an alternative drain should be followed as described in section C.
- If the flow of a drain is ascertained, the drain data are noted using the same method discussed in section C. When recording the distance between the top of the drain and the ditch surface water level a negative distance should be recorded. Additionally, 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 approximately 2 m into 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 with drain water and follow the procedure as described in section C.

If the drain discharges at a depth greater than 40 cm below the ditch water surface level it is not necessary to take a sample so as to comply with occupational health standards. If a drain cannot be sampled, then an alternative drain may be sampled as described in section 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 this case, record that sample was taken from a surface drain and the discharge should be noted as 'N.A.'..

F. Transport
- Temporarily store and transport the samples according to work instructions (MIL-W-4008; see Annex A5.6)

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

Materials
- sealable plastic sample containers;
- sample jar (870 ml PE);
- sample jar (380 ml glass);
- 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;
- thermometer;
- fieldwork vehicle; sheet of plastic;
- plastic cylinder (collar), length about 50 cm, Ø ±11 cm;
- location map with all parcels and sampling locations (available through the Field App);
- spade;
- two cool box's;
- field App;
- scale accurate to within 1 g, with a maximum load of at least 1,000 g;
- cleaning brush;
- (paper) towel;
- Y-piece;
- umbrella;
- marker pen.

Procedure / Work method
A. Preparation
- Check that the materials are clean and in good condition.
- Number with a marker pen all the sample containers 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*).

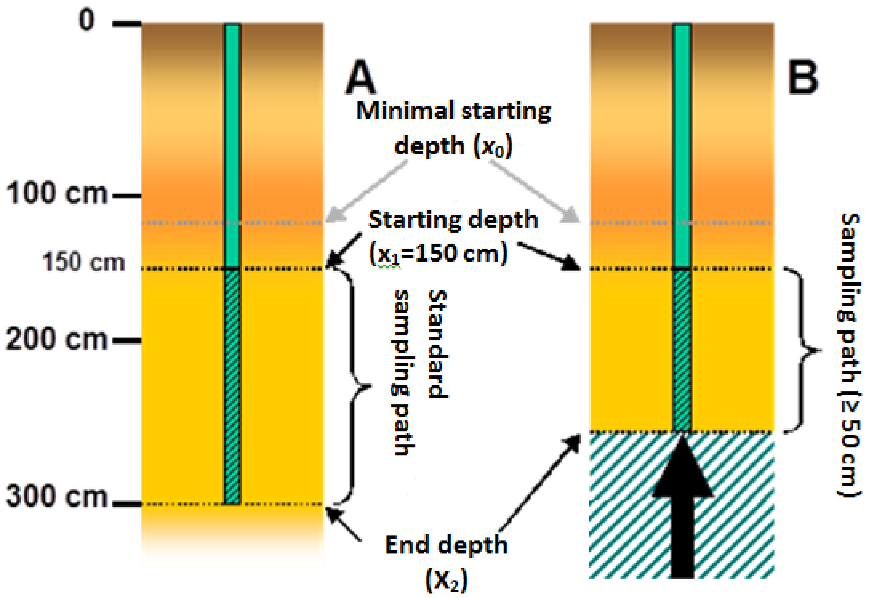
The *minimum starting depth* (X_0) is 120 cm to avoid plant roots.

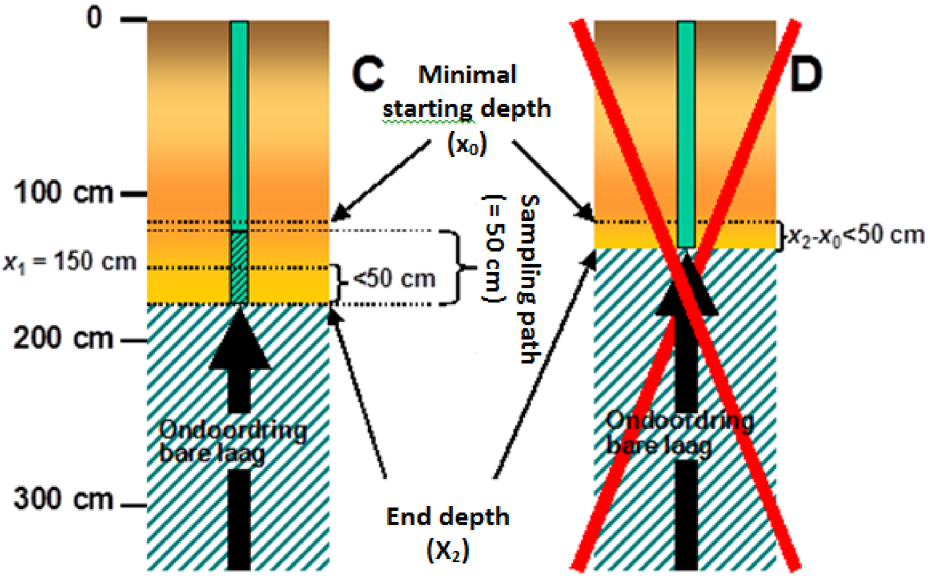
B. Sampling

The weather can exert a large influence on the sampling of soil moisture. Sampling of soil moisture should not be carried out in the case of precipitation, not matter how light, because the soil samples may become wet.

Sampling of soil moisture should also not be conducted if there are strong winds or if ambient temperatures exceed 20°C in the Loess region and 23°C in the Sand region. Under these conditions soil moisture can evaporate.

Sampling should be aborted immediately if these conditions arise during sample collection. It is possible to pre drill boreholes to at most 50 cm above the planned starting depth. The borehole does however have to be sealed by placing a lid on the opening.





a. ‘Deep’ soil will be sampled over the standard sampling vertical transect.
b. Impregnable layer above the end depth (300 cm) but a total sampling vertical transect ≥50 cm: the soil can be sampled over a transect from ≥50 cm without adjusting the starting depth (X_1).
c. Impregnable layer above the end depth (300 cm) and a total sampling vertical transect <50 cm: The soil will be sampled over a range from 50 cm by adjusting the starting depth (X_1).
d. Impregnable layer leads to an insufficient total sampling vertical transect. The soil cannot be sampled over a vertical transect of 50 cm without sampling above the minimum starting depth (X_0). The sampling location has to be shifted by 10 to 20 metres.

Figure A7.1 Examples of possible sampling profiles that can be encountered. The hatched portions represent impregnable soil layers. The minimal starting depth (X_0) is 120 cm. However, the standard vertical transect to be sampled 150-300 cm.

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

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

When the sampling transect has insufficient depth, as in Figure A7.1-D, a new borehole must be drilled 10 to 20 m away from the current borehole. 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 collected after the minimum starting depth (*X_0)* will be stored in a separate sealable sample container. The amount sample material needed from each sample container to attain the target weight required for analysis is determined after all samples have been collected from the borehole.
The minimum depth (X_0) is 120 cm because root activity is minimal below this depth. If it is practically impossible to find suitable sample

[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.

points, a different minimum starting depth can be selected (*X_0* value) *after consultation with the fieldwork supervisor (operational manager) or fieldwork coordinator (network manager)*. At farms where during previous sampling campaigns it was not possible to start sampling at 120 cm, it is possible to pre-emptively start the sampling transect at a depth between 60 – 120 cm. At the very least the transect must be from 60 – 110 cm, but if possible, it is preferable that a deeper transect is sampled.

Collecting soil samples

- Proceed to the sampling site using the map provided in the Field App.
  If there no sampling location has been identified then identify one using the procedure described in Working Instruction MIL-W-4021
- In the case that the sampling location deviates from the location marked in the Field App note that a deviation has occurred and record the new GPS-coordinates and other relevant information in the Field App.
- Record the weather conditions.
- Record the ambient temperature in °C.
- Remove the turf using a spade and place this on the plastic sheet. Keep the turf so that it can be replaced when sampling is completed. On arable land, drilling can be conducted immediately.
- Drill to a depth of approximately 30 cm with the Edelman auger (Ø 10 cm).
- Install the collar in the hole, fully protecting the hole from intrusion of loose soil. Ensure that the collar protrudes from the surface to facilitate removal after sampling. The collar also prevents soil material from entering the borehole and contaminating the sample material.
- Continue drilling to a depth of 120 cm (X_0) using an Edelman auger (Ø 7 cm).
- Store the drilled material on the plastic sheet.
- Record if an impregnable layer (e.g. clay or marl) or perched water table is encountered when drilling. If either are encountered choose a new sampling location within a radius of 10 to 20 m on the same parcel that is at least 10 m away from the border of the parcel. If no suitable sampling location has been found after three attempts contact the fieldwork coordinator to identify an alternative sampling site (parcel) according to Work Instructions (MIL-W-4021).
  The Field App contains information on the end depths of boreholes drilled at sampling locations in previous years. This information can be used to estimate the starting and end depths.
- Once the starting depth had been reached, drill and remove material every 10 cm. To ensure that the auger doesn't become overfull don't exceed two or three rotations.
- "Clean" the soil core by removing the top ~5 cm of soil and the protruding material on the sides of the soil core using a knife or spatula.
- Place the soil core in a sample container. Start by filling the sample container with a number label 1 first. When placing the

sample in the container use a knife or spatula to prevent hand contact with sample.

- Seal the sample container properly to prevent moisture loss from the sample. Store the sample in a dry location (e.g. on the plastic sheet or in a box in the fieldwork vehicle).
- In the scenario that less than 10 cm soil material is recovered with the auger, complete the drilling and clean the borehole by slowly rotating clockwise when pulling the auger out.
- Complete the previous 4 steps until the end depth of 300 cm or an impregnable layer is reached. Store every 10 cm in a sample container.
  In the event sampling is being conducted alone and not in a team, it is advised to mount the Y-piece onto the tail end (handhold) of the spade and subsequently store the auger on the Y-piece. This is done to prevent contamination of the auger.
- In the scenario that groundwater is encountered at a sampling location where the intention was to sample soil moisture it is necessary to sample the groundwater and not the soil moisture. Alternatively, another sampling location may be identified on the same parcel. The procedure to be followed to decide to sample another location is as follows:
  1. Groundwater is not to be sampled if it’s presence is incidental (e.g. if it is due to a perched water table).
  2. Assess what the situation was in previous years and whether groundwater was encountered then as well.
  3. If soil moisture was sampled in previous years and the fieldworker expects that changing the sampling location will make soil moisture sampling possible, then it is permissible to sample elsewhere on the same parcel. When in doubt consult the fieldwork coordinator.
  4. In wet years the occurrence of a perched water table is more likely. Since a perched water table is related to the presence of an impenetrable layer the previously described steps can be followed. Stop with collecting soil samples when water starts to drip of the auger. In the case that a perched water table was not encountered at the sampling location in previous years then it is necessary to sample soil moisture at the location. If the perched water table is shallow (< 120 cm), then the sampling may relocated to a location within a radius of 20 m. This is a one-time relocation. If it is not possible to relocate the sampling location within this radius then contact the fieldwork coordinator. Under exceptional circumstances the sampling location may then be relocated to another parcel in accordance with Work Instructions (MIL-W-4021).
  5. If a perched water is encountered multiple times on a new farm or new parcel that has previously never been sampled, and it is not possible to start sampling at the minimum sampling depth, it is maybe necessary to sample the perched water table. This needs to be discussed with the fieldwork coordinator. If possible it desirable to sample the perched water table in future years as well.

- If instead of soil moisture, groundwater is to be sampled the follow the Work Instructions applicable to sampling groundwater (MIL-W-4015; see A5.2).
- Record the starting depth from which soil samples have been collected.
- Record the final depth (X_2) from which soil samples have been collected. If the final depth sampling is less than 300 cm note why the final depth could not be sampled.
- In the event that less than 5 sample containers have been filled (i.e. less than 50 cm of soil has been sampled), choose a new sampling location within a radius of 10 to 20 m on the same parcel that is at least 10 m away from the border of the parcel. If no suitable sampling location has been found after three attempts contact the fieldwork coordinator to identify an alternative sampling site (parcel) according to Work Instructions (MIL-W-4021).
- It is possible that when even when 50 cm of soil has been sampled and 5 sample containers have been filled that not enough sample material has been collected. In this case drill a borehole directly next to the existing borehole and sample the same vertical transect and fill five sample containers (i.e. 10 cm soil core per container). In total there will then be 10 sample containers, two per 10 cm of the soil transect. The samples collected at the same depth in the two boreholes are then combined evenly, by weight, to ensure equal representation.

Preparing individual samples

- The amount of sample material needed from each sampling container to produce and fill a sample jar (870 ml PE) for an individual sample can be determined as follows:
  - If the entire soil transect has been sampled (i.e. X_2 = 300 cm) then 33 grams of sample material needs to be collected from each of the last 15 containers (i.e. containers representing the vertical transect: 150 – 300 cm; sample containers 4 – 18) so that the target sample weight (T) of 500 g is collected.
  - In the case that 5 or more sample containers have been filled with sample material from a depth greater than the starting depth (i.e. X_1 = 150 cm; X_2-X_1 > 50 cm) then an equal amount of soil must be collected from each container such that the target weight of 500 g is collected.
  - In the case that less than 5 sample containers have been filled with sample material from a depth greater than the starting depth (i.e. X_1 = 150 cm; X_2-X_1 < 50 cm) then 100 g of soil material needs to be collected from the last 5 containers (i.e. representing the deepest soil) so that the target sample weight is collected.
- Place the sample jar (870 ml PE) onto the weight scale and scoop the determined amount of sample material from relevant containers into the sample jar.

Try to avoid including any stones or pebbles in the sample jar.

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
Per sampling site, two composite samples will be made, regardless of the water type. The possible composite samples are therefore soil moisture-soil moisture, soil moisture-groundwater or groundwater-groundwater. If fewer than 16 soil samples have been collected, and both groundwater and soil moisture have been sampled, then one composite sample is made for soil moisture and the other for groundwater.

Fill the glass pots (380 ml) with sample material. The number of pots to be filled depends on the number of soil moisture samples taken. See the Work Instruction MIL-W-4104 for the instructions pertaining to the preparation of groundwater composite samples. Use multiple pots per sample if necessary, so that the target mass of 1500 g is obtained. Every pot can contain approximately 400 g sample material.

Number of soil samples	Required mass sample material (g)
1	1500
2	750
3	500
4	375
5	300
6	250
7	214
≥8	188

Once collected store the glass pots in a cooler box out of the sun.

C. Conservation and transport of samples
- Conserve the sampling jars with the soil moisture samples by cooling them to 4º C within 6 hours of sampling.
- Temporarily store and transport the samples according to work instructions (MIL-W-4008; see Annex A5.6)

D. Completion of sampling and aftercare
- Remove the collar and refill the borehole with the soil material extracted from the borehole during drilling. Compact the soil material used to refill the borehole intermittently using the auger. Spread any remaining material and replace the turf removed during installation.
- 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.

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±3º C;
- freezer.

Procedure / Work method

The Soil and Water Operational Department uses two methods of storing and transporting samples under controlled conditions. The first method uses a portable cool box. 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.

- Store 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 attained at the time of arrival.
- Make sure that the sampling bottles stand upright and are in a stable position, to avoid toppling or breakage. Store the closed portable cool box in a cool dark location.
  Keep the portable cool box out of the sun and store it in the shadow of a car or building, as possible. Never store the portable cool box unattended in the fieldwork vehicle as 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 5ºC and the capability to signal if temperatures drop below 2ºC or exceed 8ºC.
- 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 transports the samples.
  - The samples are transported by courier at the end of the day or week 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 2018/19	Clay drainwater and ditches (CL dr/di)	Oct-Mar	KIWA
	Clay Groundwater (CL gw)	Nov-Dec Feb-Mar	Lievense Lievense/RIVM
	Clay ditches (CL di)	Nov-Mar	KIWA
	Loess soil moisture (LO sm)	Oct-Feb	Lievense/RIVM
	Peat groundwater (PE gw)	Nov-Mar	Lievense/RIVM
	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
Summer 2019	clay ditches (CL di)	June-Sep	KIWA
	Peat ditches (PE di)	June-Sep	KIWA
	Sand summer groundwater (SS gw)	Apr-Sep	Lievense/RIVM
	Sand summer ditches (SS di)	June-Sep	KIWA
Winter 2019/20	Clay drainwater and ditches (CL dr/di)	Oct-Mar	KIWA
	Clay Groundwater (CL gw)	Nov-Dec Feb-Mar	Lievense Lievense/RIVM
	Clay ditches (CL di)	Nov-Mar	KIWA
	Loess soil moisture (LO sm)	Oct-feb	Lievense/RIVM
	Peat groundwater (PE gw)	Nov-Mar	Lievense/RIVM
	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)	Nov-Mar	Lievense/RIVM
Summer 2020	clay ditches (CL di)	June-Sep	KIWA
	Peat ditches (PE di)	June-Sep	KIWA
	Sand summer groundwater (SS gw)	Apr-Sep	Lievense/RIVM
	Sand summer ditches (SS di)	June-Sep	KIWA
Winter 2020/21	Clay drainwater and ditches (CL dr/di)	Oct-Mar	KIWA VERIN
	Clay groundwater (CL gw)	Nov–Dec Feb–Mar	Lievense/RIVM Lievense/RIVM
	Clay ditches (CL di)	Nov-Mar	KIWA VERIN
	Loess soil moisture (LO sm)	Oct-feb	Lievense/RIVM
	Peat groundwater (PE gw)	Nov-Mar	Lievense/RIVM
	Peat surface drain water and ditches (PE sdr/di)	Oct-Mar	KIWA VERIN
	Peat ditches (PE di)	Nov-Mar	KIWA VERIN
	Sand winter drains and ditches (SW dr/di)	Oct-Mar	KIWA VERIN
	Sand winter groundwater (SW gw)	Nov-Mar	Lievense/RIVM

Period	**Programme**	**Sampling period**	**Organisation**
Summer 2021	clay ditches (CL di)	June-Sep	KIWA VERIN
	Peat ditches (PE di)	June-Sep	KIWA VERIN
	Sand summer groundwater (SS gw)	Apr-Sep	Lievense/RIVM
	Sand summer ditches (SS di)	June-Sep	KIWA VERIN
Winter 2021/22	Clay drainwater and ditches (CL dr/di)	Oct-Mar	KIWA VERIN
	Clay groundwater (CL gw)	Nov–Dec Feb–Mar	Lievense/RIVM Lievense/RIVM
	Clay ditches (CL di)	Nov-Mar	KIWA VERIN
	Loess soil moisture (LO sm)	Oct-feb	Lievense/RIVM
	Peat groundwater (PE gw)	Nov-Mar	Lievense/RIVM
	Peat surface drain water and ditches (PE sdr/di)	Oct-Mar	KIWA VERIN
	Peat ditches (PE di)	Nov-Mar	KIWA VERIN
	Sand winter drains and ditches (SW dr/di)	Oct-Mar	KIWA VERIN
	Sand winter groundwater (SW gw)	Nov-Mar	Lievense/RIVM
Summer 2022	clay ditches (CL di)	June-Sep	KIWA VERIN
	Peat ditches (PE di)	June-Sep	KIWA VERIN
	Sand summer groundwater (SS gw)	Apr-Sep	Lievense/RIVM
	Sand summer ditches (SS di)	June-Sep	KIWA VERIN
Winter 2022/23	Clay drainwater and ditches (CL dr/di)	Oct-Mar	KIWA VERIN
	Clay Groundwater (CL gw)	Nov-Dec Feb-Mar	WSP WSP/RIVM
	Clay ditches (CL di)	Nov-Mar	KIWA VERIN
	Loess soil moisture (LO sm)	Oct-feb	WSP/RIVM
	Peat groundwater (PE gw)	Nov-Mar	WSP/RIVM
	Peat surface drain water and ditches (PE sdr/di)	Oct-Mar	KIWA VERIN
	Peat ditches (PE di)	Nov-Mar	KIWA VERIN
	Sand winter drains and ditches (SW dr/di)	Oct-Mar	KIWA VERIN
	Sand winter groundwater (SW gw)	Nov-Mar	WSP/RIVM

ANNEX 7 Laboratory testing techniques and detection limits

Component / element	**Symbol**	**LOD**	**Unit**	**Technique**	**SOP number**	**Conservation through / with**
Dissolved organic carbon	DOC	3.2	mg/l	infrared (IR)	TC12W	H_2SO_4 pH 2 /cooling
Chloride	Cl	3.2	mg/l	ionchromatography	IC20W	Nothing
Nitrate	NO_3	0.13	mg/l	ionchromatography	IC20W	Filtration and cooling (H_2SO_4 pH 2)
Nitrate	NO_3	0.13	mg/l	ionchromatography	IC20W	cooling
Sulphate	SO_4	1	mg/l	ionchromatography	IC20W	cooling
Nitrate + Nitrite (difference)	NO_3	0.22	mg/l	photometry/CFA	skalar	cooling
Nitrite	NO_2	0.04	mg/l	photometry/CFA	skalar	cooling
Electro-conductivity	EC(25)	0.5	mS/cm	potentiometry/CFA	skalar	cooling
Acidity	pH			potentiometry/CFA	skalar	cooling
Ortho-phosphate	PO_4	0.04	mg/l	photometry/CFA	AA13W	H_2SO_4 pH 2[1] / cooling
Total nitrogen	N-total	0.42	mg/l	photometry/CFA	AA17W	H_2SO_4 pH 2 / cooling
Ammonium	NH_4	0.06	mg/l	photometry/CFA	AA11W	H_2SO_4 pH 2 / cooling
Aluminium	Al	0.01	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Arsenic	As	0.2	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Barium	Ba	2	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Cadmium	Cd	0.05	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Calcium	Ca	6.7	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Chromium	Cr	0.5	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Total phosphorous	P-total	0.05	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Iron	Fe	0.05	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Potassium	K	0.53	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)

Component / element	Symbol	LOD	Unit	Technique	SOP number	Conservation through / with
Copper	Cu	0.5	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Lead	Pb	0.2	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Magnesium	Mg	0.75	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Manganese	Mn	4	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Sodium	Na	4.3	mg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Nickel	Ni	0.5	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Strontium	Sr	43	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Zinc	Zn	4	µg/l	ICP-MS	ICPMS1S	pH 1–2 (HNO_3)
Electro-conductivity	EC(20)	3	µS/cm	potentiometry	skalar	cooling
Acidity	pH			potentiometry	skalar	cooling
Kjeldahl-N[2]	N-total unfiltered	0.06	mg/l	photometry/CFA	AA17W	H_2SO_4 pH 2 / cooling
Total phosphorus[2]	P-total unfiltered	0.07	mg/l	photometry/CFA	AA18W	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 various 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).

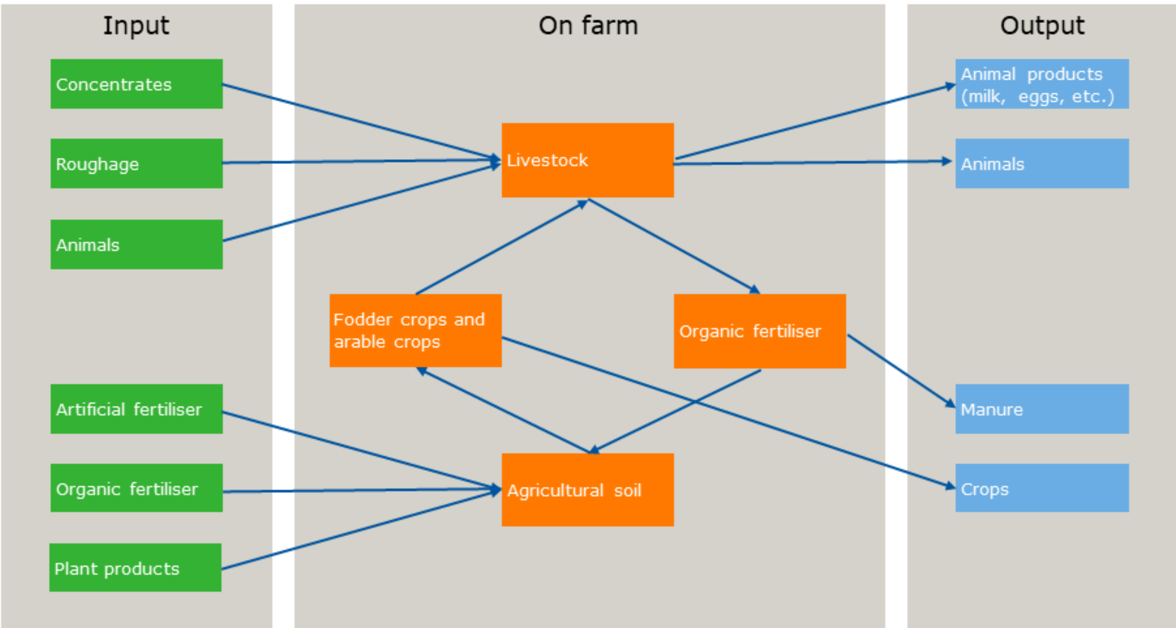


Figure A8.1 Farm processes and interactions.

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 (mainly livestock manure) is (partly) used on the farm’s own agricultural land or removed from the farm.

3. In addition to on-farm-produced organic fertiliser, artificial 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 livestock.

Arable farms

1. Imported organic fertiliser and artificial 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 livestock.

At farms of the farm type ‘other livestock farms’, combinations of the various 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 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 artificial 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 non-agricultural 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, 2024: 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 standardised methods, which are annually updated by the Working Group on Uniform Mineral and Manure Excretions (Statistics Netherlands, 2020).
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, 2024: table 11). 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

At 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, 2024: table 11). If the fertilisation 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 fertilisation 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, 2024). 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, 2024: table 11).

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 livestock on grassland (pasture manure). The quantity of nutrients in pasture manure is calculated for each livestock category by multiplying the calculated excretion by the percentage of the year that the livestock spent 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 (2024: table 9). The quantity of nitrogen from artificial 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 (i.e. artificial 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 RVO (Netherlands Enterprise Agency, 2024, table 1). 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 artificial 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 (e.g. artificial fertilisers, livestock manure and other organic fertilisers). The lower limits for the various types of fertiliser are static. The upper limits are dynamic and depend on the application standards for nitrogen, animal manure, or phosphate. The farm-specific application standard is multiplied by a factor of 2.5. Table A8.1 lists the confidence intervals for non-organic dairy farms.

Table A8.1 Lower and upper limits on non-organic dairy farms for applied quantities of inorganic fertilisers, livestock manure, and other organic fertilisers, and total quantities of fertilisers applied (inorganic fertilisers + livestock manure + other organic fertilisers)

Nitrogen

Fertiliser type	Limit type	Available margin or value (kg ha^{-1})*	Factor
Inorganic fertiliser	Lower limit	0	
	Upper limit	SGR	2.5
Animal manure	Lower limit	0	
	Upper limit	GDM	2.5
Other organic fertilisers	Lower limit	0	
	Upper limit	SGR	2.5
Total fertiliser use	Lower limit	50	
	Upper limit	SGR	2.5

Phosphate

Fertiliser type	Limit type	Available margin or value (kg ha^{-1})*	Factor
Inorganic fertiliser	Lower limit	0	
	Upper limit	FGR	2.5
Animal manure	Lower limit	0	
	Upper limit	FGR	2.5
Other organic fertilisers	Lower limit	0	
	Upper limit	FGR	2.5
Total fertiliser use	Lower limit	25	
	Upper limit	FGR	2.5

* Available margin for nitrogen (SGR), available margin for livestock manure (GDM), available margin for phosphate (FGR), average per farm per hectare.

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 artificial 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 livestock 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, 2023). 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, 20223) 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 animal 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 various production units. The criteria about specialised dairy farms and the existence of other livestock 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 thirty 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).

Description of items		Calculation method	
		Quantity	**Inputs**
Farm inputs	Artificial fertilisers	Balance of all inputs, outputs and stock changes of artificial 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, 2024: table 11). 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 (CVB, 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 various soil type regions (data supplied by Eurofins).
	Livestock	Only imported livestock	Standard quantities based on Ministry of Economic Affairs (2015) and Netherlands Enterprise Agency (2024: table 5)
	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)	

Description of items		Calculation method	
		Quantity	Quantity
Farm outputs	Livestock	Balance of outputs and stock changes of livestock and meat	Netherlands Enterprise Agency (2024: tables 5).
	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, 2024: table 11). 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 CVB(2012).
	Other	Balance of all inputs, outputs and stock changes of all other products in the case of net production (output)	
	Livestock products (e.g. milk, wool and eggs)	Balance of all inputs, outputs and stock changes of all Livestock products	Netherlands Enterprise Agency (2024: tables 7).
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 RIVM (2024).	
	+ 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	

Description of items		Calculation method	
		Quantity	Quantity
		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	
Nitrogen surplus at farm level		**Farm input - / - Farm output**	
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., 2023a). Mineralisation and immobilisation of nitrogen in slurry and solid manure are taken into account (Van Bruggen et al., 2023a) - Ammonia emissions resulting from grazing are calculated as a percentage of the total quantity of ammonia nitrogen excreted on grassland (Van Bruggen et al., 2023). 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 (Bikker et al., 2019, Oenema et al., 2000; Groenestein et al., 2005, 2015; Tamminga et al., 2004). This factor depends on the type of livestock. - 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., 2023a).	

Description of items		Calculation method	
		Quantity	Quantity
		- 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 artificial fertilisers are based on Velthof et al. (2009) and Van Bruggen et al. (2023a). 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 is 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 2022

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ANNEX 10 Laboratory transition

A10.1 Introduction

From the inception of the LMM up to 2013, RIVM conducted its own laboratory analysis. At this point, both the laboratory staff and analytical equipment were transferred to the Netherlands Organisation for Applied Scientific Research (TNO). However, in compliance with European Tender Regulations, RIVM was required to place a tender in 2018, which was subsequently won by a consortium of Eurofins Scientific and TNO. This resulted in a second transition of the laboratory used for sample analysis, this time from TNO to Eurofins Scientific. A change in laboratories can, however, have significant consequences for the integrity of a long-term monitoring network such as the LMM. For such a network, it is important that a laboratory transition does not result in a break in trends. To maintain the integrity of the LMM and to minimise and quantify systematic errors arising from the transition in laboratories, a transition programme was initiated in 2018.

The transition programme consisted of multiple steps (Figure A10.1). The initial step in this transition were to formulate a programme of requirements which would include selection criteria, such as general performance characteristics, and to subsequently select the most suitable applicant based on the specified requirements. The second and third step are known as ‘Dubbelmeten’ which translates as ‘double analysis’. Within these steps, identical samples were analysed by both laboratories. The second step specifically compared the results of analysis performed by the laboratory that won the tender (Eurofins Scientific) and the current laboratory (TNO), and included a harmonisation process. This was accomplished by comparing and statistically analysing the results of analytical procedures to determine to what extent results differed for the various physicochemical parameters measured within the LMM sub-programmes. During this process, the results derived by TNO were used as a reference and the outcomes of Eurofins Scientific were calibrated to those of TNO. The third step was to quantify any systematic differences that were still encountered after harmonisation. Double analysis of samples was necessary despite both laboratories being accredited by the Dutch Accreditation Council, because differences in outcomes could still arise due to, for example, differences in laboratory personnel and analytical apparatuses.

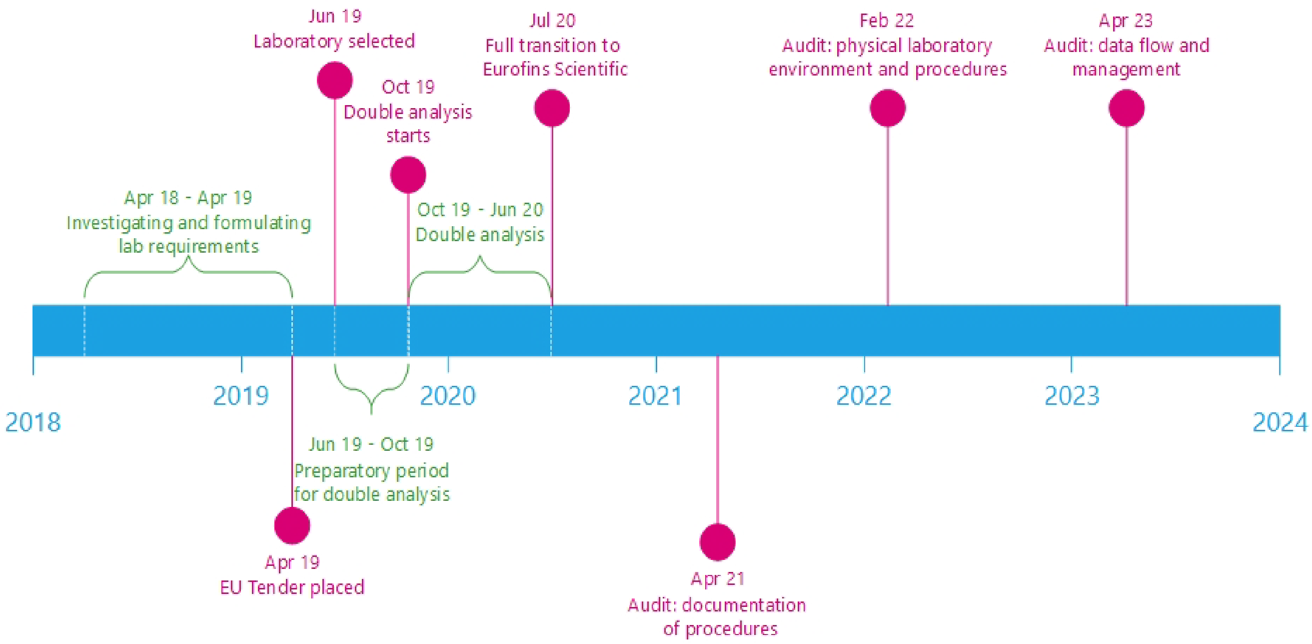

Figure A10.1 Timeline for the laboratory transition process.

A10.2 Goal of the transition programme

The transition programme had the overarching goal of preventing a break in trends by accurately quantifying and minimising deviations in analytical outcomes. To attain this general goal, three sub-goals were identified:

1. Determining the differences in performance features (e.g. limits of quantification, reproducibility of results, etc.) between laboratories that registered for the tender and TNO, and subsequently selecting an appropriate laboratory.
2. Determining the differences in the outcomes of analytical procedures between the selected laboratory and TNO when the same samples are analysed. The samples selected to fulfil this goal would reflect the diversity, in terms of matrix and origin, encountered in the LMM.
3. If differences in measured concentrations are detected, these need to be quantified and the causes must be determined. This process also considered differences in samples representing a particular matrix or soil type region.

A10. 3 Laboratory selection

The laboratory selection was based on previously defined criteria. The criteria used for the selection process were defined in a so-called Programme of Requirements. In addition to the criteria themselves, the weight given to each criterium was also defined in the programme. The criteria included in the Programme of Requirements covered criteria ranging from accreditation and limits of detection per parameter to data quality with regard to accuracy and precision. Laboratories were asked to deliver the results of ring trials for relevant physicochemical parameters, so that the distribution in results could be ascertained and compared to those arrived at by TNO. This entailed, for example, comparing standard deviations and z-scores for different physicochemical parameters analysed by the applying laboratories. The idea behind this comparison was that they would give a first order approximation of the differences that could be expected between the candidate laboratory and TNO. It would also yield a semi-quantitative indication for the magnitude of the trend break that could be expected if the laboratory started conducting analyses for the LMM.

A10.4 Double analysis programme

The laboratory that won the tender was the consortium of Eurofins Scientific and TNO. Within this consortium, the LMM analyses would be carried out at Eurofins Scientific. Upon selection, a preparatory phase commenced. Following this, field samples were collected and analysed by both Eurofins Scientific and TNO. Considerable effort was put into coordinating the analytical procedures used for sample analysis and collecting samples representative of the diversity encountered within the LMM. Following analyses, weekly meetings were scheduled at which results were discussed.

A10.5 Preparatory phase

During the preparatory phase, prior to the actual analysis of LMM samples, the first steps were taken to narrow the margins present in analytical outcomes. The goal of this phase was to decrease systematic errors as much as possible before the complexity present in the analysis of actual samples was added. For this phase, both Eurofins Scientific and TNO measured the concentrations in blanks and standard solutions with known concentrations. The outcomes of these tests were compared, evaluated and subsequently used to determine which adjustments needed to be made in procedures. Subsequently, the preparatory phase shifted to analysing LMM samples. The results of the analyses were used to take measures to improve the analytical performance of Eurofins Scientific.

A10.6 Sample collection design

Upon completion of the preparatory phase, actual LMM samples were used to compare the outcomes in results. The samples were collected during different periods within the year the programme was running, as seasonality can exert a significant influence on the chemical composition of aquatic systems. Ideally, samples would have been collected over a two-year period to account for annual variability. Due to financial constraints, however, this was not possible and both laboratories only analysed samples collected in a single year. During the sampling campaigns, samples representing different matrices and originating from different soil type regions were collected (Table A10.1). This was done to account for the natural variability present between matrices and soil type regions as much as possible. At each sampling site, two samples were taken, and each laboratory received one sample. In total, each laboratory received approximately 1,000 samples to be analysed. These samples were collected at different times of the year, from different soil type regions (i.e. Clay, Sand, Peat and Loess) and represent the various water types (i.e. ditch water, drain water, groundwater and porewater) considered within the LMM. The samples were analysed on various parameters (Table A10.2).

Table A10.3 Overview of the number of samples analysed per water type and soil region in the Double analysis project. For an explanation of analytical bundles, see Table A10.2.

Soil type region	Water type	Number of farms	Number of rounds sampled	Analytical bundle	Number of sampling points	Number of samples analysed
Loess	Porewater	50	1	1	800	100*
	Porewater	10	1	3	160	160
Clay	Groundwater	25	1	1	400	50*
	Drain water	70	1	1	70	70
	Drain water	70	1	1 and 4	70	70
	Ditch water	18	2	1 – 4	36	36
Peat	Groundwater	44	1	1	704	88*
	Drain water	17	2	1	34	34
	Drain water	17	2	1 – 4	34	34
	Ditch water	30	2	1 – 4	60	60
Sand	Groundwater	46	1	1	736	92*
	Drain water	48	1	1	48	48
	Drain water	11	2	1	22	22
	Drain water	48	1	1 and 4	48	48
	Drain water	11	2	1 and 4	22	22

* Composite samples

Table A10.4 Overview of the physicochemical parameters included in the analytical bundles.

Analytical bundle	Parameters
1	DOC, NO_3^- (neutral), NO_3^- (acidified), N-tot, NH_4^+, PO_4^{3-}, Cl, SO_4^{2-}, Al, As, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P-tot, Pb, Sr, Zn
2	EC(25), NO_2^-, NO_3^-, pH
3	Cl, NO_3^-, NH_4^+, SO_4^{2-}
4	N-tot (unfiltered), P-tot (unfiltered)

A10.6 Sample analysis and comparison

Sample analysis and sample collection took place concomitantly, so that samples were not stored for unreasonably long periods of time and no other potential sources of error could arise. During this period, the results on the laboratory analyses were continually compared and discussed (Figure A10.2). To facilitate this comparison process, maximum target deviations were identified for the various parameters prior to comparison. These target deviations (Table A10.3) constituted the primary criteria for comparison and were based on results of ring trials and expert judgement. The outcomes of the laboratory analyses were compared to the criteria and discussed. If the results were satisfactory for a parameter, and additional conditions (for example sufficient quality of calibration standards) were met, the laboratory was not required to take further steps. However, if unacceptable deviations were observed, the laboratory was required to find the cause, rectify it and prove that the undertaken action would result in acceptable outcomes. Examples for causes of deviation during this process are phosphate contamination due to the use of phosphate containing detergents and mistakenly mixing up samples.

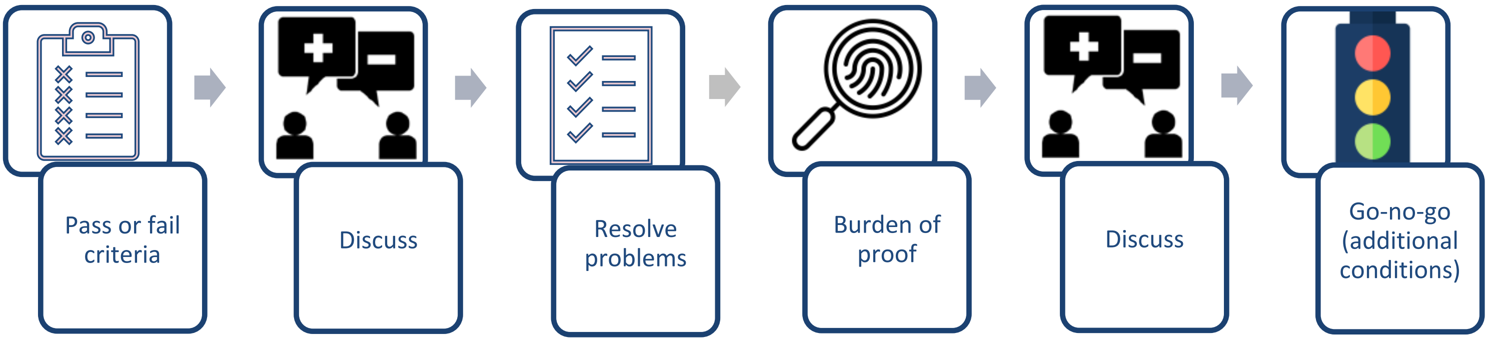

Figure A10.2 Process used to compare the analytical outcomes per parameter.

During the process of comparison, consideration was given to the effect that measurements below the limit of quantification (LOQ) would have on comparison. This is because concentrations close to or below the LOQ cannot be compared to each other with certainty. Therefore, a distinction was made in the statistical methods used to compare parameters for which this was the case. For these parameters, values below the LOQ were excluded, and values closer to the LOQ were given less weight when comparing results. For parameters where concentrations in all samples were close to or below LOQ, no comparison was conducted at all. This entire process of comparison was iterative and continued until the established criteria were met for all parameters. Once the criteria for parameters were met, the transition process was complete, and Eurofins Scientific started analysing samples for the LMM. This full transition took place on June 24 2020 and marked the end of the Double analysis programme.

Table A10.5 Criteria established for the various parameters. The criteria permissible deviations expressed in percentages.

Parameters		**Criteria**
Priority compounds	NH_4^+, NO_3^-, N-tot, PO_4^{3-}, P-tot, SO_4^{2-}	3%
Macro elements/parameters	Ca, Cl, DOC, K, Mg, Na	3%
Heavy metals I	As, Ba, Fe, Mn, Ni, Sr	3%
Heavy metals II	Al, Cd, Cr, Cu, Pb, Zn	6%

A10.7 Audits

Upon completion of the Double analysis programme, multiple audits were conducted. Due to the COVID-19 pandemic, the first audit, which was conducted in 2021, was limited to a document audit.. In this audit, documentation regarding the laboratory procedures and statistical methods used by the laboratory were inspected. The second audit, which took place in 2022, was a physical audit where RIVM visited the laboratory used by Eurofins Scientific to analyse the LMM samples. In addition to the methods used by the technicians, the laboratory environment was inspected. The final audit, which took place in 2023, consisted of a data audit. This involved inspecting how the data resulting from analyses is stored, controlled, aggregated and digitally transferred to RIVM.

At the time of writing of this report, all audits that needed to be conducted by RIVM have been completed. Additionally, as part of their regular procedures, Eurofins Scientific conducts annual internal audits and the laboratory is also audited by the Council of Accreditation. The results of such audits are to be discussed with RIVM at least once a year.

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