Ministry of Environment
and Food of Denmark
Department

Derogation Report 2018

Danish Report
in accordance with the
Commission Decisions
2005/294/EC, 2008/664/EC,
2012/659/EU, 2017/847/EU,
and (C(2018) 8081)

March 2019

Ministry of Environment and Food of Denmark
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1. Introduction

With Commission Decisions 2005/294/EC, 2008/664/EC, 2012/659/EU, 2017/847/EU, and (C(2018) 8081), Danish cattle holdings are allowed to derogate from the general rules in the Nitrates Directive (91/676/EEC).

The aim of this report is to present maps showing the percentage of farms and percentage of agricultural land encompassed by the derogation in each Danish municipality for the planning period 2016/2017. Furthermore, compliance control results for the Danish derogation farms are reported for 2016/2017, and monitoring results for 2016/2017 are included.

This report does not include monitoring results for farms applying the derogation in 2016/2017 according to derogation decision 2017/847/EU. Monitoring results for that period will be included in the next monitoring report.

Decision 2017/847/EU is the relevant decision for the data reported in this report. According to this decision, cattle holdings could apply for authorisation to apply livestock manure corresponding to up to 2.3 livestock units (LU[1]) per hectare per year (corresponding to 230 kg N/ha), if more than 80 per cent of the area available for manure application was cultivated with beets, grass or grass catch crops. Furthermore, derogation holdings have to comply with several other conditions laid down in the decision.

According to decision 2017/847/EU, the Danish authorities shall submit the following information to the Commission for the derogation period 2016/2017:

- According to Article 7 (1) and 9 (a): maps, showing the percentage of cattle farms, percentage of livestock and percentage of agricultural land covered by the derogation for each municipality of Denmark.

- According to Article 9 (g), an evaluation of the implementation of the derogation conditions, on the basis of controls at farm level and information on non-compliant farms, based on the results of the administrative and field inspections.

- According to Article 9 (b, c, e), the results on ground and surface water monitoring as regards nitrate and phosphate, including information on water quality trends as well as the impact of derogation on water quality. Further results of model-based calculations from farms benefiting from an individual derogation.

- According to Article 9 (d and f), the results of the surveys on local land use, crop rotations and agricultural practices including tables showing the percentage of agricultural land under derogation covered by clover or alfalfa in grassland and by barley/pea, undersown with grass.

The latest derogation decision (C(2018) 8081) requires according to article 12 (h), to include trends in livestock numbers and manure production for each livestock category in Denmark and in derogation farms. Based on register data, it is already now possible to provide the data and it is included in this report.

Moreover, the latest derogation decision (C(2018) 8081) requires according to Articles 10 (2) and 12 (b), reporting of water quality data from reinforced monitoring on sandy soils and in an area, where at least 3% of all derogation farms are located. The first monitoring data is presented in this report.

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[1] One livestock unit is defined as 100 kg nitrogen in the livestock manure ex. storage.

Various Danish authorities and institutions have contributed to this report, edited by the Ministry of Environment and Food of Denmark. The respective authors, and hence responsible institutions for the different chapters, can be found under the heading to the respective chapters.

2. Maps of cattle holdings, arable land and livestock units in 2017

Lars Paulsen and Lene Kragh Møller, The Danish Agricultural Agency, Ministry of Environment and Food of Denmark, December 2018

For the planning period 2016/2017, the Danish Agricultural Agency received 35,059 fertilizer accounts containing key figures on the use of nitrogen (commercial fertilizer and livestock manure). The accounts were registered and reviewed. The maps (Figure 2.1 - Figure 2.3) are based on the number of agricultural holdings, number of livestock units (LU) and arable land used by derogation farms in 2016/2017. The fertilizer accounting year runs from 1st of August to 31st of July. Accounts for 2016/2017 were to be submitted to the Danish Agricultural Agency no later than 31st of March 2018.

In the fertilizer account the farmer states whether the derogation was used. This means that the individual farmer needs to apply for the use of derogation when the farmer submits the fertilizer quota and catch crops plan (at the latest 21st of April each year). The information about the application is automatically transferred to the fertilizer accounting system. The maps of cattle holdings, arable land and livestock units are based on the data reported by the farmers.

2.1 Map of derogation holdings 2016/2017

The map (Figure 2.1) shows derogation holdings in percentage of the total number of agricultural holdings registered in each respective Danish municipality.

In 2016/2017, 1,378 derogation holdings were encompassed by the derogation. This corresponds to 3.9 % of all registered fertilizer accounts. The applied amount of manure on these farms ranged from 170 to 230 kg N per hectare per year. If the production of manure on a derogation farm corresponds to more than 230 kg N per hectare, the farmer is obliged to deliver the excess manure to one or more contractual partner-farmers.

2.2. Map of arable land 2016/2017

The map (Figure 2.2) shows the share of arable land on derogation holdings in relation to the total agricultural area in each Danish municipality.

In 2016/2017 the arable land on cattle holdings encompassed by the derogation was 205,874 hectare at national scale. This corresponded to 8.4 % of the registered area used for agriculture in Denmark.

2.3. Map of livestock units 2016/2017

The map (Figure 2.3) shows the number of livestock units on derogation holdings as a share of the total number of livestock units in each Danish municipality.

In 2016/2017, the number of livestock units on cattle holdings encompassed by the derogation was 439,114 LUs in total. This corresponded to 19.3 % of all registered livestock units in Denmark.

2.4. Use of derogation

During the first three years where the derogation was used, i.e. 2002/2003, 2003/2004 and 2004/2005, an increase in the use of the derogation was registered both regarding the number of farms, the number of hectares and the number of livestock units (Table 2.1). This tendency was broken in 2005/2006, where a decrease was observed for all three measured parameters and the decreasing trend continued until the period 2008/2009. Between 2009/2010 and 2015/2016 an overall increase in the agricultural area using the derogation was observed, whereas the number of farms remained at a more constant level. The general trend of Danish farms becoming bigger is reflected in these numbers. Compared to the previous reporting period, in 2016/2017 there has been a minor decrease in the number of farms, the number of hectares and the number of livestock unit encompassed by the derogation.

Table 2.1: Development in use of the derogation for number of farms, agricultural area and livestock units (LU) from 2002/2003 until 2016/2017.

Year	Number of derogation farms	Share of total farms (%)	Area of derogation (ha)	Share of total Area (%)	Number of LUs	Share of total LUs (%)
2002/2003	1,845	4.0	123,068	5.0	213,617	10.6
2003/2004	1,927	4.0	128,523	5.0	225,586	10.6
2004/2005	2,331	5.0	134,780	5.0	277,330	12.9
2005/2006	1,779	3.4	115,336	4.2	220,839	10.3
2006/2007	1,610	3.2	111,845	4.0	211,765	9.5
2007/2008	1,296	2.8	92,282	3.9	186,313	8.3
2008/2009	1,115	2.4	90,647	3.6	176,588	8.2
2009/2010	1,507	3.3	134,698	6.1	276,765	11.9
2010/2011	1,607	3.9	164,353	7.4	341,781	14.1
2011/2012	1,652	4.0	175,783	7.1	365,887	15.5
2012/2013	1,481	3.7	162,176	6.7	334,508	14.5
2013/2014	1,482	3.8	189,495	7.7	397,014	17.1
2014/2015	1,500	4.0	205,165	8.2	425,102	18.6
2015/2016	1,466	4.2	210,061	8.6	443,134	19.4
2016/2017	1,378	3.9	205,874	8.4	439,114	19.3

The livestock density on derogation farms has remained at an approximately constant level, compared to the periods 2009/2010-2016/2017 (Table 2.2). The average number of livestock units per farm has increased over the years and this trend continued in 2016/2017.

By comparison, a total of 11,513 Danish agricultural holdings had cattle as livestock in 2016/2017. These holdings housed in total 1,186,790 LUs and covered an agricultural area of 922,596 ha. This gave an average of 103.1 LUs per cattle holding and an average livestock density of 1.29 LU/ha on all cattle Danish farms. Consequently, approximately 12.0 % of all cattle farms were derogation farms in 2016/2017, and the derogation (cattle) farms housed 37.0 % of all cattle-LUs in Denmark, covering 22.3 % of the total Danish cattle farm area.

Table 2.2: Average number of spread livestock units[2] (LU) per holding and per hectare under the derogation

Year	Average stocking size (LU/holding)	Average livestock density (LU/ha)
2002/2003	115.78	1.74
2003/2004	117.07	1.76
2004/2005	118.97	2.06
2005/2006	124.14	1.91
2006/2007	131.53	1.89
2007/2008	143.76	2.02
2008/2009	158.37	1.95
2009/2010	183.65	2.05
2010/2011	212.68	2.08
2011/2012	221.48	2.08
2012/2013	225.86	2.06
2013/2014	267.89	2.10
2014/2015	283.40	2.07
2015/2016	302.27	2.11
2016/2017	318.66	2.13

The maps (Figure 2.1 - Figure 2.3) illustrate that derogation cattle holdings are concentrated in the western parts of Jutland. A few holdings are located on Zealand and even fewer on Funen and the island of Bornholm. The one holding located in Copenhagen was taken over by a mortgage credit institution but has its production facilities in Jutland and on Funen.

[2] "spread LU" is the term used to describe the amount of livestock manure, which is being applied to agricultural land within the farm, as this amount can be different from the amount of livestock manure produced at farm level due to im- or export of livestock manure from/to other farms. 1 LU corresponds to 100 kg manure-N (ex storage) in the Danish system.

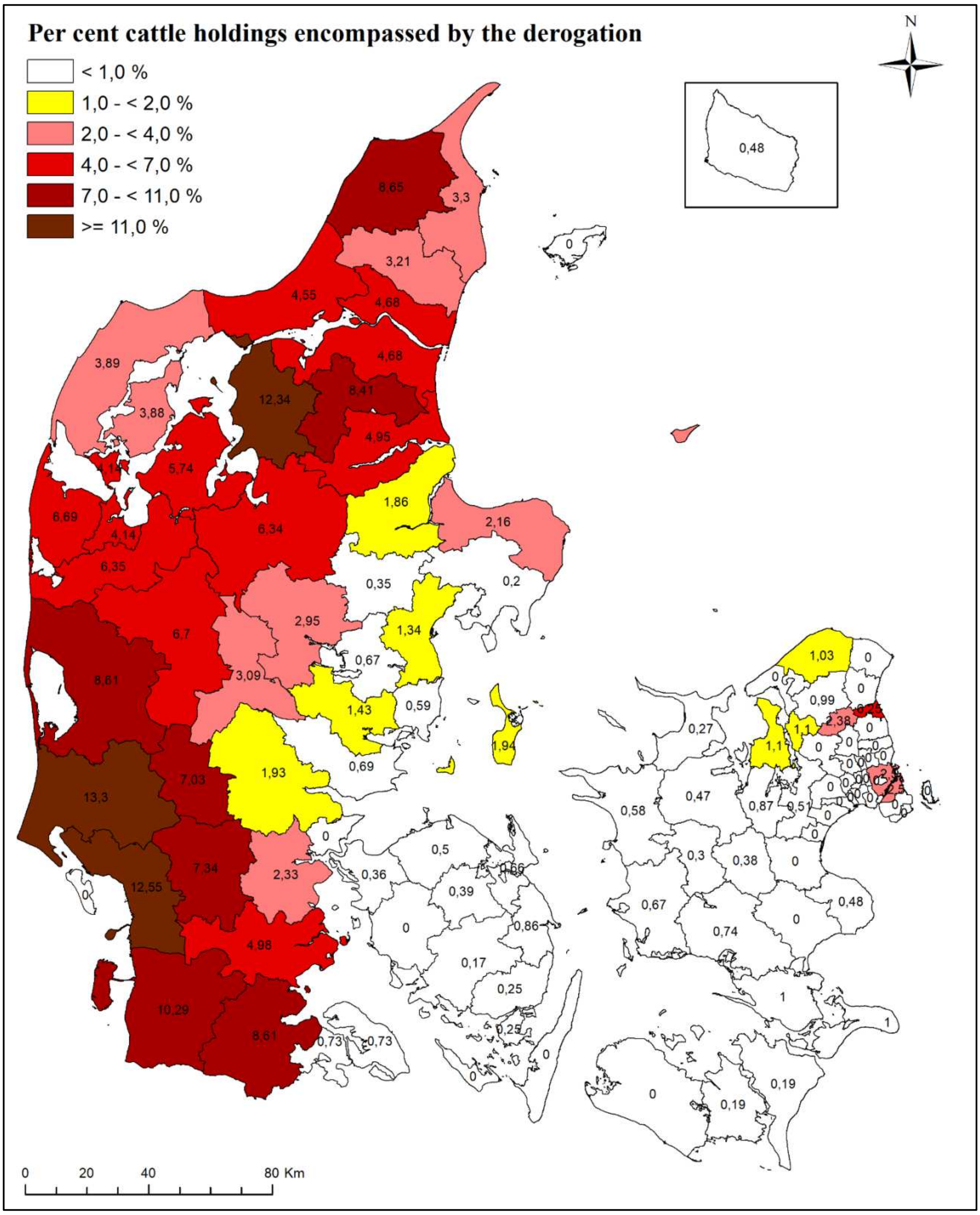

Figure 2.1: Derogation holdings in percent of total number of agricultural holdings in Denmark in 2016/2017. Location of holdings is determined by address of the owner. One derogation holding is located in Copenhagen, because it was taken over by a mortgage credit institute whereas its production facilities are in Jutland and on Funen.

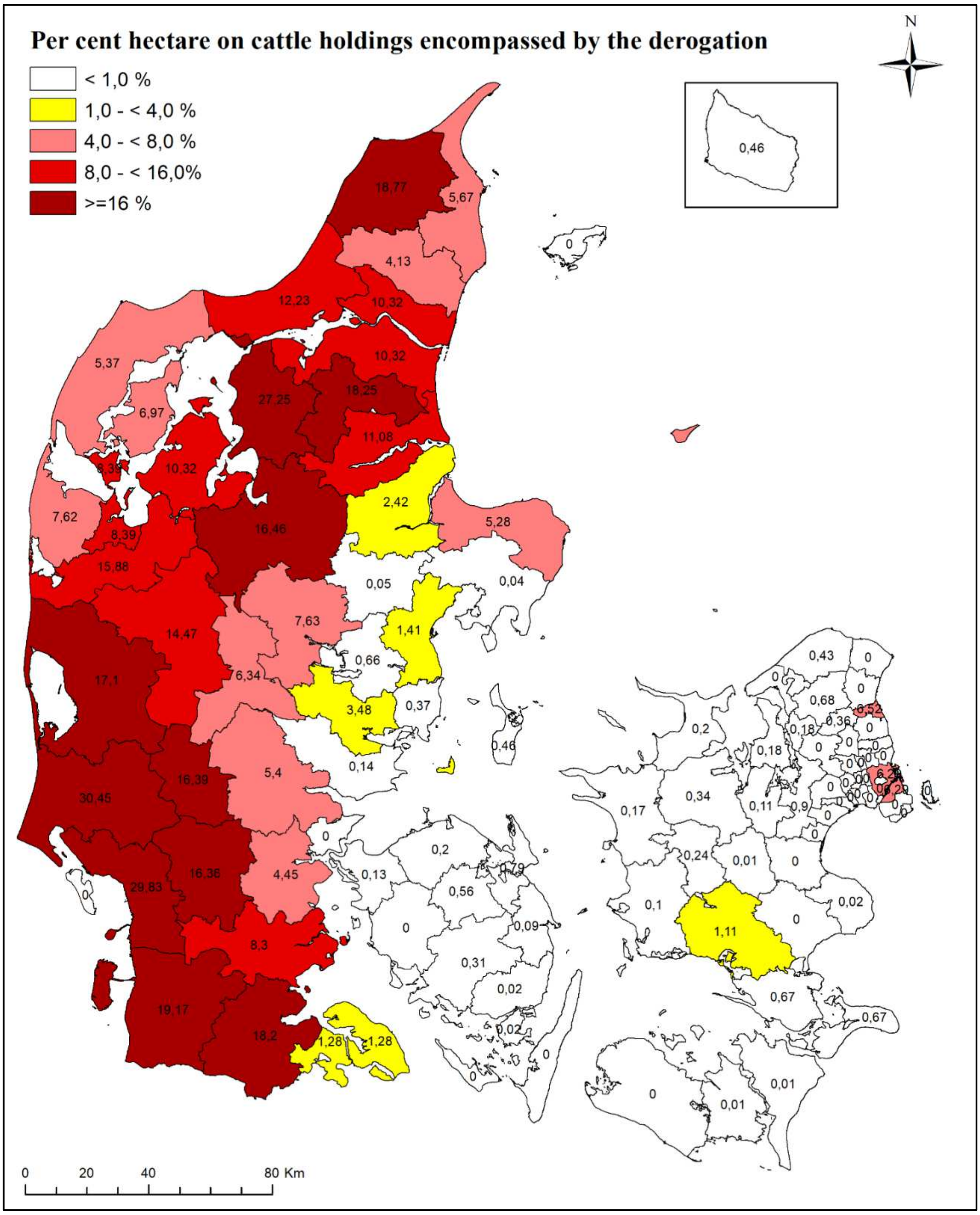

Figure 2.2: Agricultural land encompassed by the derogation in 2016/2017 in percent of the total agricultural area in Denmark. Location of holdings is determined by address of the owner. One derogation holding is located in Copenhagen, because it was taken over by a mortgage credit institute whereas its production facilities are in Jutland and on Funen.

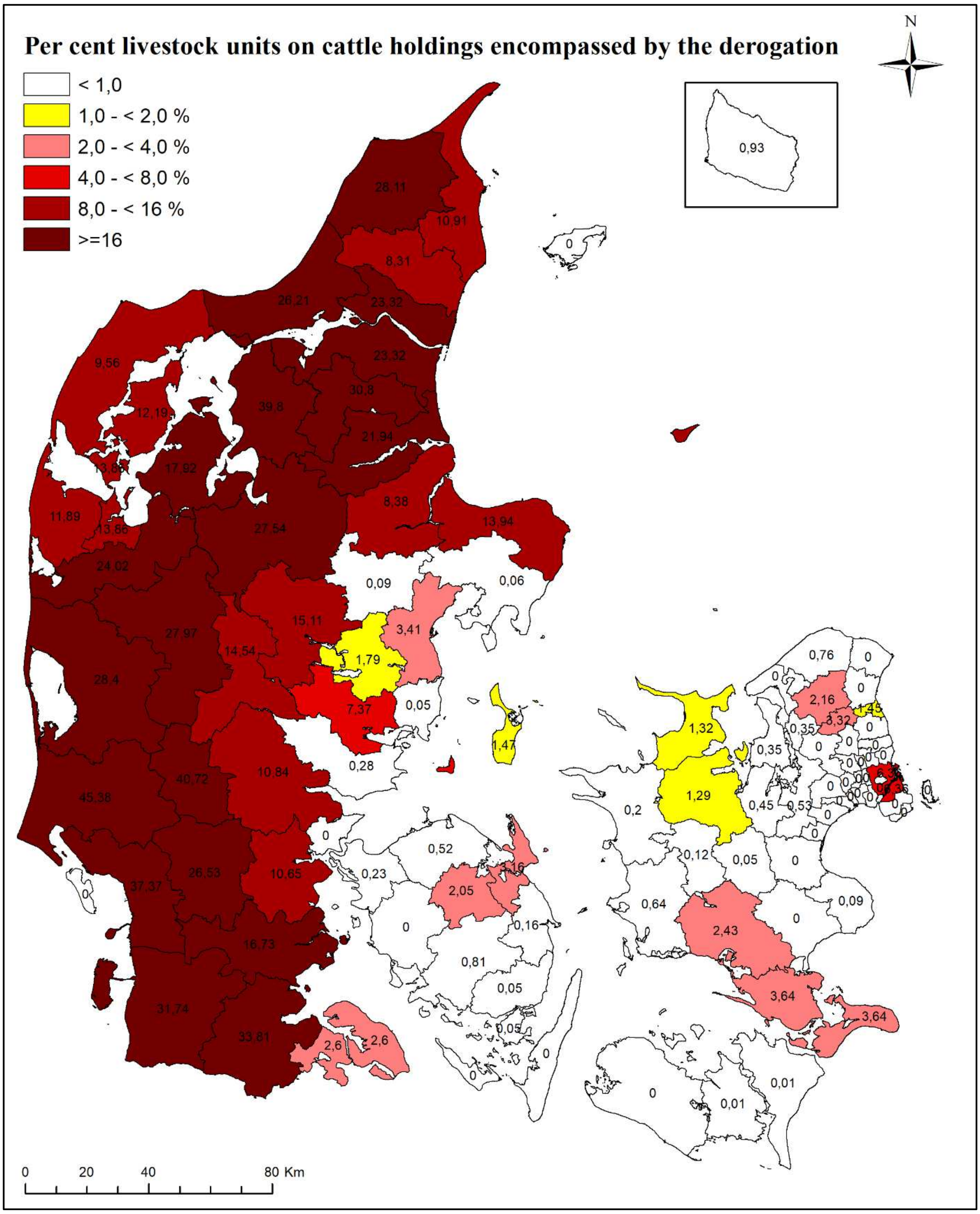

Figure 2.3: Livestock units spread on derogation farms in percent of total livestock units in 2016/2017 in Denmark. Location of holdings is determined by address of the owner. One derogation holding is located in Copenhagen, because it was taken over by a mortgage credit institute whereas its production facilities are in Jutland and on Funen.

2.5 Trends in livestock

According to decision 2017/847/EU, the Danish authorities shall submit information about trends in livestock numbers and manure production for each livestock category in Denmark and in derogation farms according to Article 12 (h). All numbers have been brought to a round number in order to have a clearer picture.

The trends in livestock numbers (i.e. number of herds[3]) and manure production (i.e. number of LUs[4]) for each livestock category and in derogation farms can be derived from the data shown in table 2.3 From the planning period 2014/2015 to 2016/2017, the number of herds and LUs are decreasing for each livestock category - except for cattle, where the number of LUs was highest in 2015/16. The total number of livestock units has decreased by ca. 0.4 % in between the planning periods of 2014/2015 and 2016/2017.

Table 2.3: Number of Danish herds of livestock and of LUs per livestock category, rounded to the closest unit of 100

Livestock category Year	Cattle total	Hereof derogation cattle[5]	Pigs	Fur and poultry	Sheep and goats	Others	Total
2014/2015							
No. herds	12,300	1,500	4,100	2,000	2,400	6,100	26,900
No. LUs	1,164,700	425,100	905,300	190,500	12,200	19,100	2,291,800
2015/2016							
No. herds	11,800	1,500	3,900	2,000	2,300	5,800	25,800
No. LUs	1,193,400	443,100	881,300	178,000	10,500	18,800	2,282,000
2016/2017							
No. herds	11,500	1,400	3,600	2,100	2,200	5,600	25,000
No. LUs	1,186,800	439,100	883,700	183,000	10,600	18,100	2,282,200

[3] The total number of herds does not coincide with total number of holdings in Denmark. A herd includes only one type of livestock and some holdings keep more than one herd, ex. cattle and pigs.

[4] One livestock unit is defined as 100 kg nitrogen in the livestock manure ex. storage.

[5] The amount of derogation cattle herds and LUs are a part of “cattle total” and, thus, is not included in the summarization of herds and LUs in “total”.

3. Controls at farm level

Lars Paulsen and Lene Kragh Møller, The Danish Agricultural Agency, Ministry of Environment and Food of Denmark, December 2018

3.1 Control of compliance with the Danish derogation

According to Article 12 of Commission Decision 2017/847/EU, Denmark must submit a concise report on the evaluation practice, i.e. control at farm level, to the Commission every year.

The control of compliance with the Commission Decision 2017/847/EU follows two strategies:

1. Inspection of compliance with farm management, which is carried out during the year the farmer uses the derogation. This can include field inspections, when necessary.
2. Control of the amount of livestock manure applied per hectare per year (control of compliance with the harmony rules), which is carried out after the derogation year has ended. This control is carried out in two ways: 1) as an inspection of all parameters of the production at the farm and 2) as an administrative control of submitted fertilizer accounts.

3.2 Summary of inspection results 2018

Compliance with management conditions:

- Inspection at the farm: 90 inspections were carried out. 87 holdings complied with the derogation management conditions, 3 holdings got a remark in 2018.

Compliance with the harmony rules for holdings using the derogation:

- Inspection at the farm: 28 inspections were carried out. 24 holdings complied with the specific rules for derogation holdings. Two holdings got a fine and two holdings are still under investigation.
- Administrative control of the submitted fertilizer accounts: 61 inspections were carried out, out of which 46 holdings complied with the rules. 6 holdings got a remark and 9 holdings are still under investigation.

3.3 Inspection of compliance within the derogation year

The Danish Agricultural Agency has inspected the fulfilment of the Danish derogation conditions on derogation holdings from 2002/2003 through 2017/2018. The farmers are required to fulfil certain conditions in order to use the derogation. Some conditions have to be checked on site at the farm (physical inspection), for example certain ploughing conditions, which are checked in January and February.

During the inspection at the farm the inspector asks the following questions:

1. Does the farm have a yearly production of nitrogen in livestock manure above 300 kg of which at least 2/3 are from cattle (2/3 of the livestock units), i.e. is the farm mainly a cattle holding?
2. Has a plan been made for crops grown in the actual planning period?
3. Has the manager stated that the farm intends to comply with the 230 kg nitrogen per hectare per year (2.3 LU/ha) derogation in the crop rotation plan?
4. Does the plan contain leguminous crops, e.g. red and white clover?
5. Has a declaration about (omitted) manure application been made?
6. Does the plan include ploughing grassland or grass catch crops in the planning period?
7. If the answer is “yes” in question 6: Have the fields already been ploughed by the time of inspection?

The inspection is based on 1) an interview with the farmer, 2) an inspection of the farms crop rotation plan for the previous and coming growing season and 3) a visual inspection of fields designated for ploughing.

At the inspection, the inspector draws up a report, which includes answers to the abovementioned questions. At the end of the inspection the farmer is informed whether the holding is allowed to apply manure corresponding to 230 kg N/ha (2.3 LU/ha), i.e. whether the derogation can be used or not. If the holding is not complying with the derogation conditions, the holding is only allowed to apply livestock manure up to 170 kg N/ha. In this case the farmer has to find other legal means of disposing the surplus manure produced on the farm.

If a farmer informs the inspector that the derogation will not be used, the field inspection is not carried out. An administrative control of the farm is carried out instead by the time the fertilizer account has been submitted. This control is carried out to secure that no more than 170 kg N/ha was applied.

The inspection report is submitted by the inspector to the headquarters of the Danish Agricultural Agency for possible further administrative inspection where the data are verified. Additional remarks made by the inspector, if any, are examined. This includes a process where the parties of interest are allowed to make statements on the case if an infringement is discovered.

3.4 Results

From 1 January until 1 March 2018 the Danish Agricultural Agency carried out 91 inspections on cattle holdings to inspect whether the conditions requirements were met. The control refers to the fertilizer accounts of the year 2017/2018. Table 3.1 shows the results of the inspection for the last 15 years. Only very few remarks have been given and in general a good compliance with the rules has been noted.

Table 3.1: Development of results of on-site inspection of compliance within the derogation years during winter.

Control planning period[6]	Total number of inspections	Inspections without remarks	Inspections with remarks
2003/2004	35	29	6
2004/2005	46	46	0
2005/2006	50	49	1
2006/2007	50	49	1
2007/2008	54	54	0
2008/2009	47	46	1
2009/2010	51	49	2
2010/2011	50	50	0
2011/2012	54	52	2
2012/2013	49	49	0
2013/2014	47	46	1
2014/2015	49	49	0
2015/2016	48	48	0
2016/2017	49	48	1
2017/2018	90	87	3

3.5 General inspection of the harmony rules

Harmony rules

Control of the harmony rules (i.e. the amount of livestock manure applied per hectare per year) on derogation farms is carried out after the derogation year has ended. This control is carried out within the general inspection of the Danish harmony rules. The inspector visits the farm to inspect the production,

[6] The respective controls during the planning period 2017/2018, which have been performed in January and February 2018 are related to the fact that the farmer has made use of the derogation in the previous planning period, i.e. 2016/2017. This applies also to all previous control years.

based on various production and fertilizer account documents. Violation of the harmony rules is sanctioned. For minor violations the farmer is issued a warning. For more severe violations the farmer is fined. Farmers that receive a warning or a fine are reported for not complying with the cross compliance criteria.

Concerning the year 2015/2016, 379 livestock holdings (including derogation farms) have been inspected for violation of the harmony rules. Holdings are automatically selected for inspection, based on a previously agreed set of “risk criteria”. The Danish Agricultural Agency has therefore no direct influence on how many derogation holdings are selected for “harmony rules inspection”. Of the selected holdings 7.4 % (28 holdings) were derogation holdings. Out of these derogation controls, 85.7 % (24 holdings) were closed without remarks. Two holdings (7.1 %) got a fine (Table 3.2). One farmer had spread more nitrogen per hectare than permitted. One farmer had spread more LUs per hectare than allowed. Two holdings (7.1%) are still under investigation (Table 3.2). Of these, one farmer had spread more nitrogen from livestock manure per hectare than permitted, and one farmer had spread more nitrogen from livestock manure per hectare and also had more LUs per hectare than permitted.

Table 3.2 Results of inspection of compliance with the harmony rules for farms using the derogation.

Control year	Total number of inspections	Inspections without remarks	Inspections with minor violations	Inspections with fines	Inspections still under investigation
2006/2007	65	59	0	5	1
2007/2008	27	22	2	2	1
2008/2009	32	26	1	5	0
2009/2010	27	24	1	2	0
2010/2011	37	35	0	0	2
2011/2012	52	50	0	2	0
2012/2013	43	40	0	3	0
2013/2014	29	27	0	1	1
2014/2015	30	29	0	0	1
2015/2016	28	24	0	2	2

Soil analysis

If the derogation is used for four consecutive years, the farmer must provide a soil analysis where phosphorous and nitrogen levels in the soil are examined. One sample per five hectares must be provided.

In Denmark the soil analysis for phosphorus (the ”P-tal”) indicates the soil’s phosphorus status and hence approximates phosphorus in the soil available for uptake by the crop. Internationally the soil analysis is referred to as “Olsen-P”. Olsen-P is often expressed in mg P per kg soil. In Denmark however, the “P-tal” is expressed in mg P per 100 g soil. Olsen-P in Danish agricultural soil is in average around 40 mg P per kg soil (P-tal = 4.0). Only a part of the inorganic phosphorus available for the crop is extracted from the soil sample, when the phosphorus status is determined. This extractable part accounts for approximately 5 to 10 per cent of the total phosphorous content of the soil. A P-tal between 2 and 4 is generally accepted as a sufficient level for most crops and 2-2.5 is the lower critical soil P level. A P-tal above 6 is considered very high.

The N-total analysis is used to determine the amount of extra fertilizer to be added to meet the nutrient demand of the crop. The total soil N content (N-total) describes the N pool in the soil which potentially is available to the crops as a result of slow mineralization. In Denmark, depending on the C/N ratio in the soil, the standard N-total is 0.13 %. The farmer cannot expect any N-supply from mineralization, if the level of 0.13 % N-total is found. If the value is above 0.22 %, the level is high and expected mineralization is (accounted for with) 40 kg N in maize and cereals per hectare. The N-total standard for grass fields is 0.18-

0.22 %, and if the value is above 0.22 %, the expected mineralization is (accounted for with) 10 kg N per hectare.

Results of soil analyses from derogation farms
The inspection of derogation farms for 2015/2016 showed that 39.3 % used the derogation for the fourth consecutive year. These 11 holdings were obliged to provide soil analysis. No holdings got a remark regarding soil analysis.

The sampling and analyses shall be carried out at least once every three years and from 2012/2013 at least once every four years. The results of the development of compliance with the requirement of soil analysis are shown in table 3.3.

Table 3.3: Development of results of inspection of compliance with the soil analysis requirement.

Control year	Number of inspections with need for soil analysis	Inspections without remarks	Inspections with remarks/still under investigation
2004/2005	74	71	3
2005/2006	18	16	2
2006/2007	39	34	5
2007/2008	16	12	4
2008/2009	22	18	4
2009/2010	11	9	2
2010/2011	14	13	1
2011/2012	35	35	0
2012/2013	30	27	3
2013/2014	15	14	1
2014/2015	22	21	1
2015/2016	11	11	0

The results of the soil analyses for phosphorus and nitrogen on derogation farms are shown in Table 3.4.

Table 3.4: Phosphorus ("P-tal" after Olsen-P-extraction) and nitrogen levels in soil analyses, given as average of all inspected holdings (n=11 for P and n=11 for N in 2015/2016) and with the lowest and highest average values at holding scale, respectively.

Year		2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
P tal	**Average**	**4.36**	**4.60**	**4.33**	**4.60**	**4.62**
(mg P/100 g	Minimum	2.00	2.90	2.90	2.87	3.10
	Maximum	6.40	6.10	8.40	6.08	6.14
N-total	**Average**	**0.60**	**0.33**	**0.25**	**0.25**	**0.23**
(%)	Minimum	0.11	0.12	0.15	0.13	0.13
	Maximum	2.39	1.71	0.41	0.58	0.41
N in grass	**Average**	**0.36**	**0.24**	**0.48**	**0.24**	**0.24**
(%)	Minimum	0.01	0.17	0.16	0.16	0.17
	Maximum	1.10	0.35	2.00	0.51	0.33

3.6 Control of fertilizer accounts

Each year the farmers submit a fertilizer account to the Danish Agricultural Agency. The accounts include key data on:

- total arable land on the farm
- arable land available for application of livestock manure
- data on catch crops
- type and number of livestock (LU)
- production of livestock manure (kg N)
- usage of livestock manure including manure from contractors
- usage of fertilizers and organic matter other than livestock manure
- the farm's nitrogen quota
- information on whether the farmer has used the derogation or not

For the year 2015/2016, 774 (2.2 %) of the submitted fertilizer accounts were subject to administrative inspection. 195 fertilizer accounts remains to be investigated. The data was verified and the parties of interest were allowed to comment their cases. The accounts were selected based on different risk criteria. In 2015/2016, 61 (7.9 %) derogation holdings were selected for more thorough control. The holdings were asked to submit their updated and valid fertilization plan and to state their manure application. It was checked whether the crop rotation plan included at least 80 % crops with high N-uptake and long growing season as well as whether leguminous plants were included. If the derogation was used for four consecutive years, the farmer also had to submit the results of the soil analysis. The share of cattle- and other animal-LU on the farm was also controlled.

Results

Out of the 61 harmony controls, 46 holdings (75.4 %) were closed without remarks. 6 holdings (9.8 %) got remarks and 9 (14.8 %) inspections are still under investigation (Table 3.5).

Table 3.5: Results of administrative inspection of compliance with the harmony rules of farms using the derogation.

Control year	Number of inspections	Inspections without remarks	Inspections with remarks	Inspections still under investigation
2009/2010	38	34	0	-
2010/2011	68	68	0	-
2011/2012	40	39	1	-
2012/2013	62	58	1	3
2013/2014	34	24	4	6
2014/2015	62	30	4	28
2015/2016	61	46	6	9

4. Water quality

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February 2019

With Commission Decisions 2005/294/EC, 2008/664/EC, 2012/659/EU and 2017/2891/EC, Danish cattle holdings are permitted to derogate from the general rules in the Nitrates Directive (91/676/EEC). Cattle holdings encompassed by derogation shall cover 80% or more of the acreage available for manure application by cultivated crops having high nitrogen uptake and a long growing season.

According to Article 10(1), Article 10(2), Article 10(3), and Article 10(4) of Commission Decision 2017/2891/EC, Denmark shall each year

- deliver maps at municipality level, showing the percentage of farms, the percentage of the livestock and the percentage of agricultural land with derogation.
- provide continuous data about crop rotations and agricultural practices from farms with derogation.
- provide continuous analysis of level and trends in nitrate and phosphorus concentrations in root zone water, surface waters and groundwater within the framework of the agricultural national monitoring programme on sandy and loamy soils for farms under both derogation and non-derogation conditions.
- quantify the percentages of the land under derogation which is covered by: (a) clover or alfalfa in grassland; (b) barley and pea undersown with grass.

According to Article 10(2) the monitoring sites shall be representative of the main soil types, the prevalent fertilisation practices and the main crops. Reinforced monitoring shall be conducted in agricultural catchments on sandy soils. In addition, nitrate concentrations in surface and groundwater shall be monitored in at least 3% of all farms benefiting from authorisation of derogation.

The competent authorities shall carry out surveys and continuous nutrient analyses in the agricultural catchment national monitoring programme and shall provide data on local land use, crop rotations and agricultural practices on cattle farms benefiting from an authorisation

In Article 10(3), it is stated that competent authorities shall carry out surveys and continuous nutrient analyses in the agricultural catchment within the framework of the national monitoring programme and provide data on local land use, crop rotations and agricultural practices on cattle farms benefiting from an authorisation of derogation.

Moreover, information and data collected from nutrient analyses and from monitoring shall be used for model-based calculations of nitrogen and phosphorus losses from cattle farms benefitting from an authorisation of derogation

In Article 10(4) it is stated as mentioned before, that that competent authorities shall quantify the percentages of the land under derogation which is covered by: (a) clover or alfalfa in grassland and (b) barley and pea undersown with grass.

This chapter covers the requested reporting in Article 12 (b-f) on:

- the results of ground and surface water monitoring as regards nitrate and phosphorus concentrations, including information on water quality trends, for farms under both derogation and non-derogation conditions, as well as the impact of derogation on water quality, as referred to in Article 10(2).

- the results of soil monitoring as regards nitrogen and phosphorus concentrations in the root zone water, for farms under both derogation and non-derogation conditions, as referred to in Article 10(2).
- results of the surveys on local land use, crop rotations and agricultural practices, as referred to in Article 10(3).
- results of model-based calculations of the magnitude of nitrogen and phosphorus losses from farms benefitting from an authorisation of derogation, as referred to in Article 10(3).
- tables showing the percentage of agricultural land under derogation covered by clover or alfalfa in grassland and by barley/pea undersown with grass, as referred to in Article 10(4).

So far, model-based calculations of phosphorus losses from farms benefitting from an authorisation of derogation are not available, but measured Phosphorus concentration in root zone water on fields with average application of less and more than 170 kg organic N per hectare are presented.

As data in this chapter are from the year 2017, the Commission Decision 2017/2891/EC covers this period.

4.1 Introduction

Since the late 1980s, Denmark has yielded a comprehensive and efficient effort to improve the environmental state of groundwater and surface water by lowering nitrate concentrations, especially through reductions in nitrate leaching from agricultural sources. The first Action Plan on the Aquatic Environment was adopted in 1987 and has since then been followed by subsequent action programmes to ensure that sufficient efforts are made to reduce the loss of nitrogen and phosphorus to the aquatic environment.

In 1998, the Action Plan on the Aquatic Environment (APAE) II was accepted by the EU Commission as the Danish Nitrate Action Plan implementing the Nitrates Directive (1998-2003). In 2003, a final evaluation of Action Plan II was performed. The results showed a 48% reduction of the nitrate leaching from the agricultural sector, thus fulfilling the reduction target set in 1987. In the 5-year period 2001-2005, the total flow-normalised nitrogen load to marine waters ranged within the interval 62,000 to 70,000 t N.

In the subsequent action plans; the Green Growth Agreement from 2009, the first and the second River Basin Management Plan from 2014 and 2016. As well as the Food and Agricultural Agreement in December 2015, further mitigation measures and reduction targets for the N load to marine areas were suggested in order to fulfil the targets of the Water Framework Directive.

In 2015, Denmark implemented the EU Greening component under CAP direct payments (REG EU 1307/2013), implying that at least 5% of the arable land of farm holdings shall be appointed an ecological focus area with a greening element such as, for instance set-aside, catch crops etc.

Establishment of an obligatory buffer zone approximately 10 m from the edge of open streams and lakes larger than 100 m^2 was implemented in 2014. In these buffer zones, application of fertilizer is prohibited and soil cultivation must not take place. The area with buffer zones was adjusted from 50,000 ha to 25,000 ha in 2014, and from the beginning of 2016 the additional buffer zones are no longer mandatory and restricted to 2 m buffer zones along target streams and lakes larger than 100 m^2, amounting to approximately 6,000 ha.

The Political Agreement on Food and Agricultural Package from December 2015 includes a diverse package of measures aimed to change the environmental regulation of the agricultural sector. The first part of this political agreement was implemented as from 2016.

In 2016, farmers were allowed to use more fertilizer. According to the APAE II agreement, farmers were restricted in the application of fertilizer at a level that was lower than the economical optimum. This measure in APAE II was set to reduce the fertilizer application of nitrogen to 10% below this optimum. This rule was regulated so that the total national nitrogen quota was set to a fixed level but with the possibility of an adjustment relative to changes in crop cover. This adjustment made sense as crops having a high application standard also have a higher nitrogen uptake. If crops such as grass increase in cover, then the fertilizer application and N quota will increase as well. However, due to the suspension of set-aside in 2008, higher yields and increases in prices of cereals and proteins, the gap between the economic optimum and the national N quota increased, especially after 2008, amounting to 18% in 2015.

According to the Political Agreement on Food and Agricultural Package, which was implemented in 2016, extra fertilizer amounted to 2/3 of the gap between the economic optimum and the reduced N quota, and in 2017 famers were allowed to apply nitrogen up to the economic optimum level. Corrected for organic farming, i.e. farming without use of inorganic fertilizer, the potential extra consumption was estimated to 48,200 t N and 73,000 t N in 2016 and 2017, respectively (Jensen et al., 2015). Additional cover of catch crops and the greening element, for instance more catch crops and set-aside, were, among other measures introduced to counteract the potential increase in leaching due to the extra application of fertilizer in 2016.

Additionally, targeted catch crops of 145,000 ha were implemented in 2017 to counteract the potential increase in leaching due to the extra application of fertilizer in 2017. The targeted catch crops scheme was introduced to ensure that the status of coastal waters and groundwater does not deteriorate. Therefore, targeted catch crops are established in very small catchments where reduction of nitrogen is needed. Applicants for targeted catch crops could be all farmers who either own or lease such small catchments for cultivation.

The second River Basin Management Plans (RBMPII) were adopted in June 2016, proposing schemes for implementation of mitigation measures, such as re-establishment of riparian areas, construction of wetlands, set-aside of organic soils, afforestation and adjustment of greening elements, in order to obtain an annual reduction in the marine N load of 6,900 t N in the period 2015-2021. However, the actual decision on the which measures to initiate to reach an annual reduction of 6,200 t N has been postponed to after 2021.

The N load to marine waters has been reduced stepwise along with the successful implementation of measures for reduction of nitrogen leaching from point sources and agriculture. Approximately half of the Danish land area lies within catchments equipped with stream water gauging statins, where the N load to marine areas is regularly measured (Kronvang et al., 2008). The nitrogen load for ungauged catchments has been modelled using an empirical model (Windolf et al., 2011) showing that the annual load to marine waters varied between 55,000 and 59,000 t N, yielding an average of 57,000 t N for the five years (2010-2014), which was used as reference level in the RBMPII (SVANA, 2016).

The regulation and effects described in this chapter cover the period until and including 2017.

The remaining part of this chapter is divided into three parts:
First, the general development in agricultural practices at national level is presented for the period 2005-2017. This analysis is based on national register datasets from the Ministry of Environment and Food (previously part of the Ministry of Agriculture), i.e. the single payment register and the fertilizer accounts.

Second, modelled nitrate leaching, including crop distribution and nitrogen balances, is presented for various farm types and geographical areas, and the impact of derogation farms is analysed based on a dataset derived by linking data from the single payment register, including data on the crops on each field comprised by the holdings, and the fertilizer accounts. Both datasets cover agriculture in the year 2017.

Third, measurements of water quality from the National Monitoring Programme are presented for the period 1990/91-2016/17, with particular reference to the Agricultural Catchment Monitoring Programme (Blicher-Mathiesen et al., 2019). This section includes:

- Modelling of nitrate leaching in the monitoring catchments
- Measurements of nitrate in water leaving the root zone, including fields receiving more than 170 kg N ha^{-1} in organic manure
- Nitrogen in surface water, draining from agricultural catchments.

Modelling of nitrate leaching in this report is carried out by means of the latest version of the empirical model N-LES (version 4) from 2008 (Kristensen et al., 2008). This model is partly based on data from the Agricultural Catchment Monitoring Programme. The model requires input data for agricultural practises (N fertilization, cropping system), soil data and water percolation from the root zone. Percolation is calculated using the Daisy model and a standard climate from a 10 km grid net (Danish Meteorological Institute), representing weather measurements from 1990-2010. The climate dataset contains dynamic correction factors for rainfall (Refsgaard et al., 2011). Thus, modelled nitrate leaching represents the leaching in a standardised climate (water percolation). In contrast, all measurements from the Agricultural Catchment Monitoring represent nitrate leaching under the actual climatic conditions.

4.2 Development in agricultural practices at the national level from 2005 to 2017

Crop distribution
The development in crop distribution for 2005-2017 was analysed on the basis of the single payment registration. Figure 4.1 presents the results for cash crops, fodder crops and non-cultivated areas. The year 2005 was the first year with single payment, and it was anticipated that the reporting of areas for this first year would be overestimated. Hereafter, the total reported agricultural area, including set-aside, decreased from approximately 2,757,000 ha in 2006 to 2,600,000 ha in 2017.

The decrease in agricultural area of about 13,000 ha per year is due to road construction, afforestation, urbanisation etc. During the years 2006-07, set-aside comprised about 160,000 ha. As from 2008 the set-aside obligation was suspended, and in 2008 and 2009 set-aside areas were converted to cash crop, fodder crops and nature-like areas. Set-aside covered between 23,000 and 29,000 ha in the period 2015-2017, as set-aside is an element in the Danish implementation of the EU Greening. The area with cash crops and fodder crops has decreased slightly since 2012.

Catch crops
In Action Plan III, the requirement for growing catch crops was carried over from the former Action Plan, stipulating that farmers in 2005-2009 should grow catch crops on at least 6% of the potential catch crop area if they applied less than 80 kg organic manure N ha^{-1} and on 10% of the area if they applied more than 80 kg organic manure N ha^{-1}. From 2010, an additional catch crop area, equivalent to an extra 4% of the potential catch crop area, was implemented, yielding a total requirement of growing of catch crops of 10% or 14%, respectively. In 2008, the requirement for growing catch crops was raised to counterbalance the effects of the set-aside suspension.

During this period (2005-2010), farmers growing winter crops (wheat, rye, oilseed rape), preventing fulfilment of catch crop requirements, were granted a reduction in the required catch crop area. From 2011, this possibility ceased, and some farmers therefore had to alter their crop rotation from winter to spring crops.

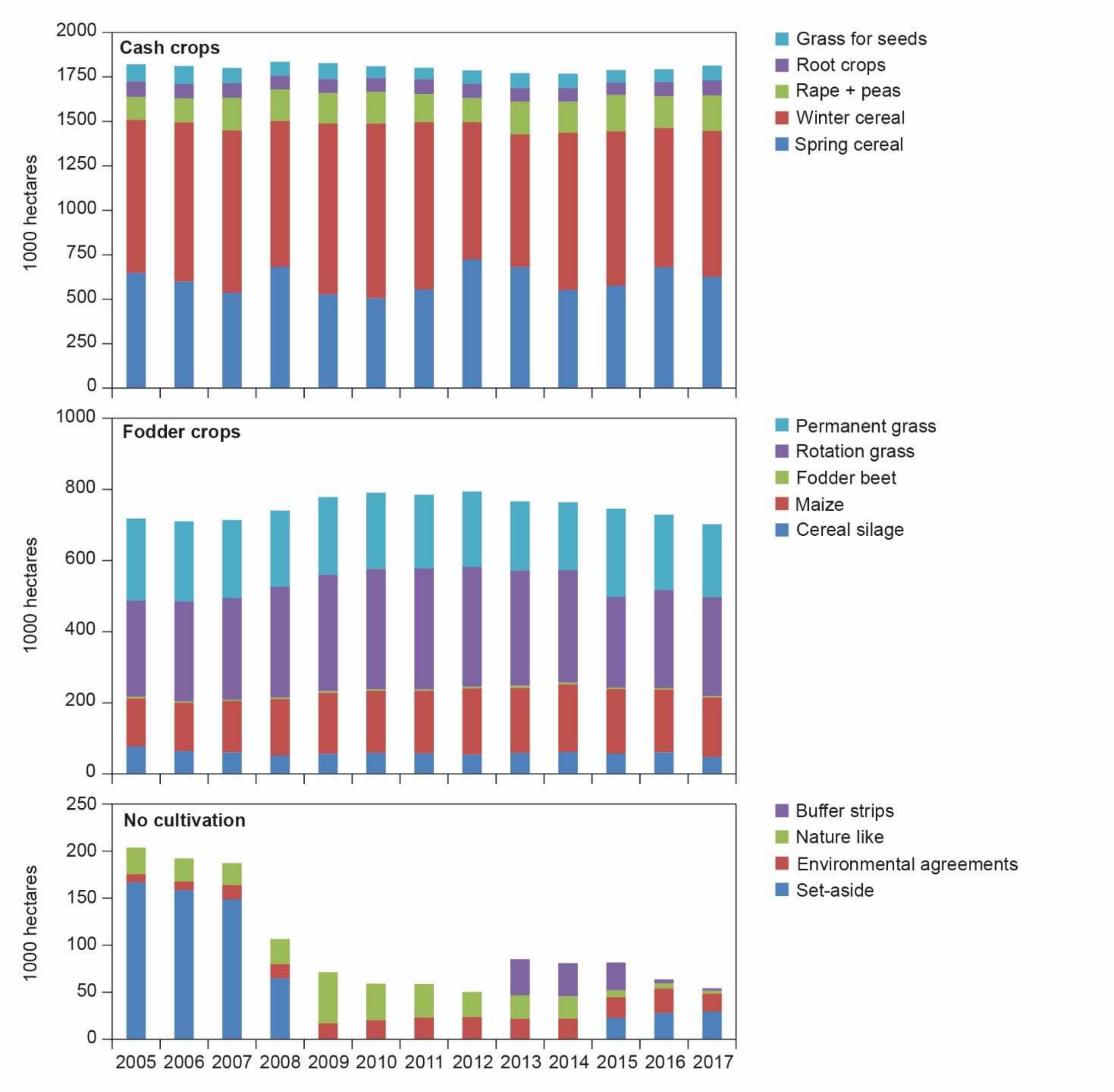

Figure 4.1: Development in crop distribution at the national level from 2005 to 2017, data from the single payment register.

At the same time, voluntary alternatives to catch crops were introduced such as:

- reduction in the farm nitrogen quota
- growing of special crops between harvest and sowing of winter crops
- growing catch crops on other farms
- establishment of energy crops
- separation and treatment (biogas and burning of the solid fraction of manure) of animal manure
- from 2015: substitution of one hectare of catch crop by four hectares of set-aside near riparian areas and located next to agricultural areas in rotation
- from 2014: substitution of one hectare of catch crop by five hectares of winter wheat, if sown earlier than September 7.

According to the Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources Danish legislation should include a combined targeted scheme for voluntary and mandatory catch crops for 2017 and 2018. To ensure non-deterioration of water quality, the scheme assured that obligatory provisions for catch crops will enter into force if the voluntary agreements for catch crops fail to deliver the environmental objectives. The areas under catch crops should be in addition to the national requirement for mandatory catch crops pursuant to the Danish Act on farms' use of fertiliser and on plant cover.

Data from the fertilizer accounts show that establishment of catch crops and catch crop alternatives increased from about 118,600-138,000 ha in 2005/06-2007/08 to about 443,700 ha of catch crop equivalents in 2017/18 (Table 4.1). The introduction and use of catch crop alternatives were equivalent to the effect of 13,900-44,000 ha catch crops in the period 2011/12-2017/18.

Table 4.1 Area with catch crops and catch crop alternatives (1,000 hectares of catch crop equivalents) reported by the farmers in the annual fertilizer account in the period 2005/06-2017/18.

	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18
Catch crops	138.0	118.6	127.2	196.6	183.0	211.0	211.0	224.0	295.7	321.1	390.0	353.1	415.2
Catch crop alternatives	0	0	0	0	0	0	28.6	44.0	13.9	43.3	37.6	36.1	28.5

Consumption of nitrogen fertiliser and nitrogen in manure
Data on the annual use of inorganic fertilizers and the use of nitrogen in animal manure are obtained from the fertilizer accounts (Table 4.22). In previous derogation reports, data on animal manure have been based on the manure production for different categories of livestock. As these data are no longer recorded, the manure application data are instead based on the data from the fertilizer account.

The application of animal manure underwent an annual decrease of approx. 1,150 t N from 2005 to 2017, with some year-to-year variations, though. The use of inorganic fertilizers amounted to about 181,000-202,000 t N year^{-1} in 2005-2007 and increased to 205,000 and 209,300 t N year^{-1} in 2008 and 2009, probably due to the cultivation of previous set-aside areas. This was expected to be a temporary effect as the procedure for setting the crop nitrogen standards implies that an increase in agricultural area with fertilizer requirements must be followed by an equivalent reduction in nitrogen standards. Administratively, however, this reduction is based on statistical data for the cultivated area, resulting in a delay of two years. Thus, in 2010-2014 the use of inorganic fertilizers decreased again, reaching the same level as in 2005-2007. The use of inorganic fertilizer increased from 210,000 t N in 2015 to 242,000 and 237,000 t N in 2016 and 2017, respectively, after the implementation of the Food and Agricultural Package, according to which farmers were allowed to use more fertiliser in the two years 2016 and 2017 respectively.

Table 4.2: Development in the use of inorganic nitrogen fertilizer and of nitrogen in animal manure as reported by the farmers in the annual fertilizer status accounts for the period 2005-2017 (1,000 t N a^{-1}).

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fertilizer	191	181	202	205	209	198	203	198	199	203	210	242	237
Animal manure	227	218	236	230	226	224	223	220	215	212	216	219	218

4.3 Modelled nitrate leaching for farm types and geographical areas and the impact of derogation farms at the national level – 2017 data

Modelled nitrate leaching demonstrates the effect of crop distribution, nitrogen input, soil type and water percolation through the soil. This section includes a presentation of all these parameters. The analyses are based on the national datasets from the single payment register and the fertilizer accounts. However, before data can be used for this purpose, a detailed compilation of the two datasets must be undertaken (Børgesen et al., 2009). The single payment register contains information on crops at field-block level, and the fertilizer accounts contain information on the use of nitrogen (inorganic fertilizer and organic manure) at farm level. The two datasets are linked by means of the common farm identity number, and the reported amounts of fertilizer and manure from the individual accounts are divided between the fields of each farm according to the crop nitrogen standards. Hereby, we obtain a dataset with coherent data on crops and nitrogen application at field level. We have no information on grass-ley from either dataset. Therefore, we estimate this parameter based on the area with rotation grass, assuming a conversion rate of three years. If there is not enough space in the crop rotation, the area with grass-ley is reduced accordingly. Data on catch crops are derived from the fertilizer accounts.

The field-blocks are geographically mapped, implying that each field can be linked to soil maps and to the meteorological grid net. Having established the soil type for each field-block, the standard harvest yield may be estimated. Furthermore, nitrogen fixation is included using standard values for each crop. This final dataset now contains all information necessary for geographically distributed computation of crop coverage and field nitrogen balances and for modelling nitrate leaching.

Farm type

The data are divided into three main groups of farm type – arable farming, pig farms and cattle farms. A pig farm is defined as a farm where more than 2/3 of the livestock units (LU) originate from pigs, and a cattle farm is defined as a farm where at least 2/3 of the LU originate from cattle. An arable farm is a farm with less than 2 LU, but the farm may import animal manure, which will appear in the fertilizer account and is therefore included in this analysis. Other farm types are not included in this analysis.

Figure 4.2 shows that arable farms and pig farms grew cereals, particularly winter wheat, on the majority of the agricultural area (63-76 %) in 2017. Other major cash crops were oilseed rape, peas, root crops (potatoes and sugar beet) and grass for seeds (18-22%). Cereal silage, grass and maize took up a minor part of the area (5-13%). Catch crops were grown on 15-18% and grass-ley on 2-3% of the agricultural area on arable and pig farms.

Cattle farms have a different crop rotation. Cereals and other cash crops were grown on only 37% of the area, whereas cereal silage, grass and maize were grown on 56% of the area. Fodder beet was grown on 1.2% of the area. In addition, grass-ley was found on 9% and catch crops on 17% of the area.

On arable farms, an average amount of about 48 kg N ha^{-1} from animal manure was applied. For pig and cattle farms the amounts were, respectively, 99 kg N ha^{-1} and 129 kg N ha^{-1} (Table 4.3).

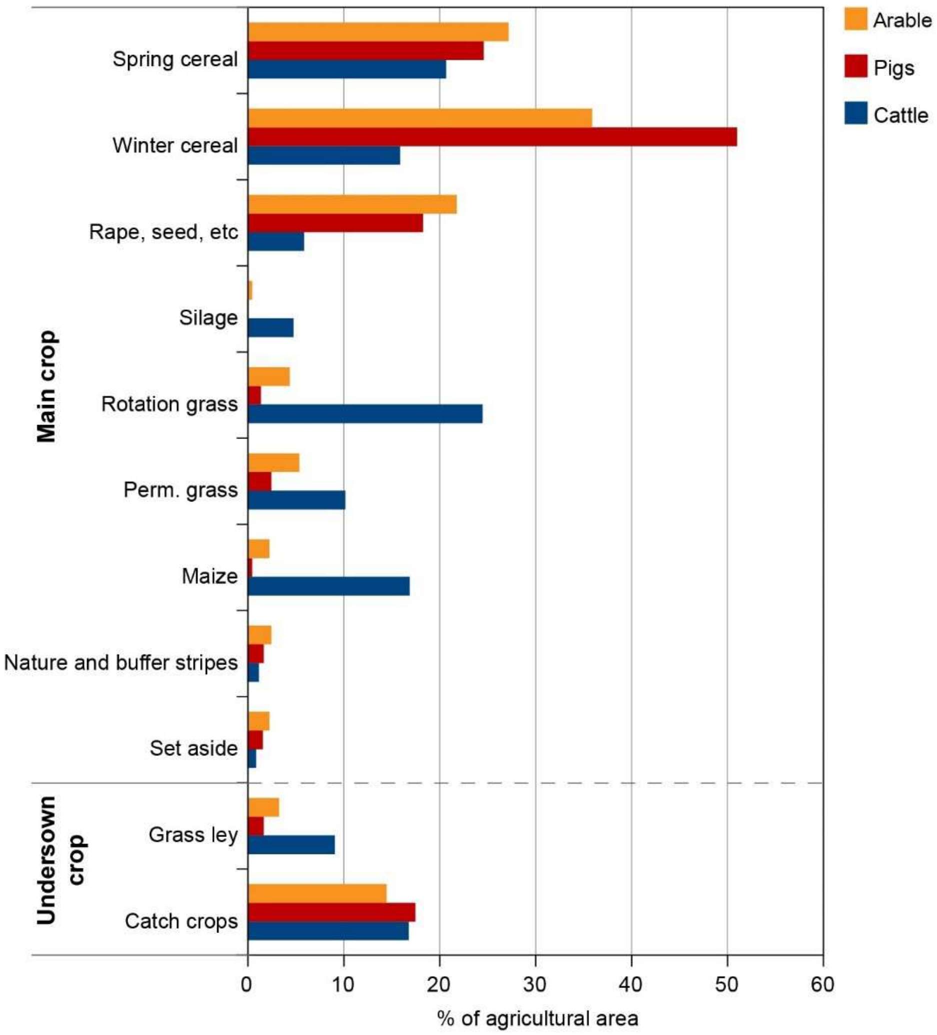

Figure 4.2: Crop distribution for three main farm types in 2017. Combined dataset from the single payment register and the fertilizer status accounts.

Table 4.3: N inputs, N balances and nitrate leaching and nitrate concentration at bottom of the root zone for three main farm types in 2017. Combined dataset.

	N balance									Root zone water		
	Comm. fertiliser	Animal manure	Other org.	N fix.	N depos.	Seeds	Total input	Har-vest	N balance	Percol.	Nitrate leaching	NO_3^- conc.
	(kg N ha^{-1} a^{-1})									(mm a^{-1})	(kg N ha^{-1})	(mg l^{-1})
Arable	110	48	5.4	8.8	13	1.9	187	110	77	337	56	73
Pigs	89	99	1.2	5.2	13	2.1	210	113	97	380	66	77
Cattle	73	129	1.4	29	14	1.4	247	142	106	414	66	71

The use of inorganic fertilizers decreased with increasing application of animal manure. Total inputs of nitrogen from inorganic fertilizer, manure, other organic sources, N fixation and atmospheric deposition added up to 187, 210 and 247 kg N ha^{-1} for arable farms, pig farms and cattle farms, respectively. N balances, calculated as the difference between the total input of nitrogen and removal by harvested crops, were 77, 97 and 106 kg N ha^{-1} for arable farms, pig farms and cattle farms, respectively. As expected, modelled nitrate leaching was lower from arable farms (on average 56 kg N ha^{-1}) than from animal husbandry farms (66 kg N ha^{-1}). N leaching was, on average, similar for pig and cattle farms despite a larger N input and N balances for cattle farms than for pig farms. The reason is that cattle farms grow a high proportion of fodder crops that have a long growing season and therefore a larger N uptake.

On arable farms, the modelled nitrate leaching amounted to 73% of the N balance, which is a high relative to the 68% for pig farms and 62 % for cattle farms. An explanation may be that leaching on these soils with low input of organic manure is affected by mineralisation of the organic pool, i.e. depletion of the total soil N content. However, the high leaching fraction may also be caused by the uncertainties associated with the two separate calculations of the N leaching and N balance.

Water percolation through the soil is considerably higher on cattle farms than on arable and pig farms. However, this is not due to the differences in farm type but due to the fact that the cattle farms are located mainly in the western part of the country with more sandy soil and higher rainfall and a consequently higher percolation. The higher percolation on cattle farms leads to dilution of the nitrate concentration in the soil water. Thus, the modelled average nitrate concentrations in soil water were 73-77 mg NO_3 l^{-1} on arable and pig farms, respectively, and 71 mg NO_3 l^{-1} on cattle farms for the year 2017.

Geographical areas

Farm types are not evenly distributed throughout the country because of variations in farming conditions. Denmark has therefore been divided into five farming regions (Figure 4.3).

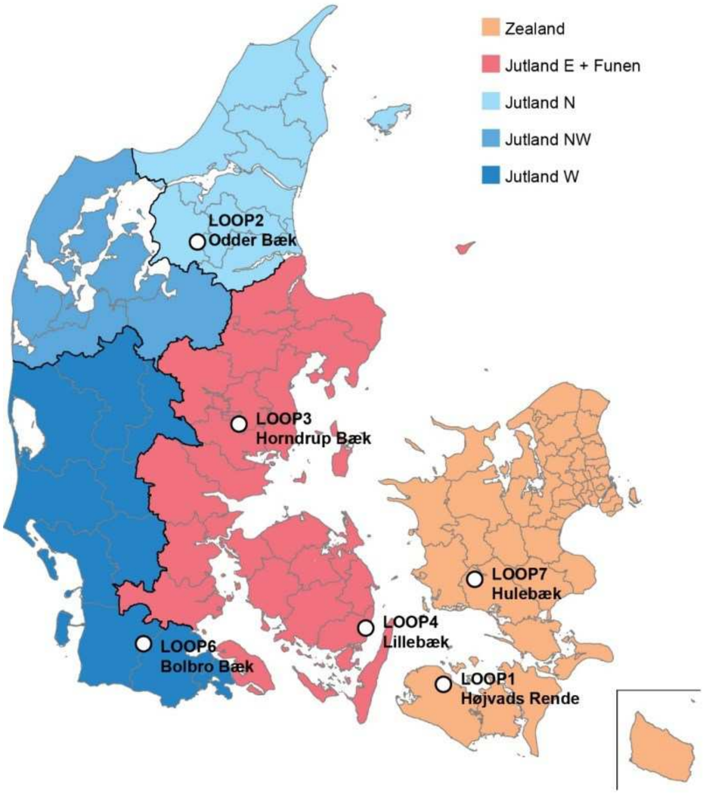

Figure 4.3: Farming regions in Denmark with different soil types, farming practices and rainfall and the position of the six monitored agricultural catchments.

Table 4.4 shows that Zealand is dominated by arable farming, whereas Eastern (E) Jutland and Funen are dominated by arable farming and pig production. Finally, North (N), North-West (NW) and West (W) Jutland have the highest density of cattle farming. Thus, arable and pig farms are located mainly in the eastern part of Denmark on loamy soils and with low rainfall, whereas cattle farms are located mainly in the northern and western parts on sandy soils and with higher rainfall, the rainfall increasing from north to south.

Table 4.4: Distribution of farm types and soil types and water percolation through the soils in Denmark divided into five main geographical areas – 2017.

	Arable	Pig	Cattle	Other	Sand	Loam	Organic soils	Percol.
	% of agricultural area				% of agricultural area			mm/year
Zealand	64	13	15	8	5	92	3	199
Jutland E+ Funen	42	26	25	7	26	70	4	335
Jutland N	35	17	37	12	80	10	10	365
Jutland NW	28	23	41	9	62	33	5	450
Jutland W	31	15	45	9	76	18	6	542

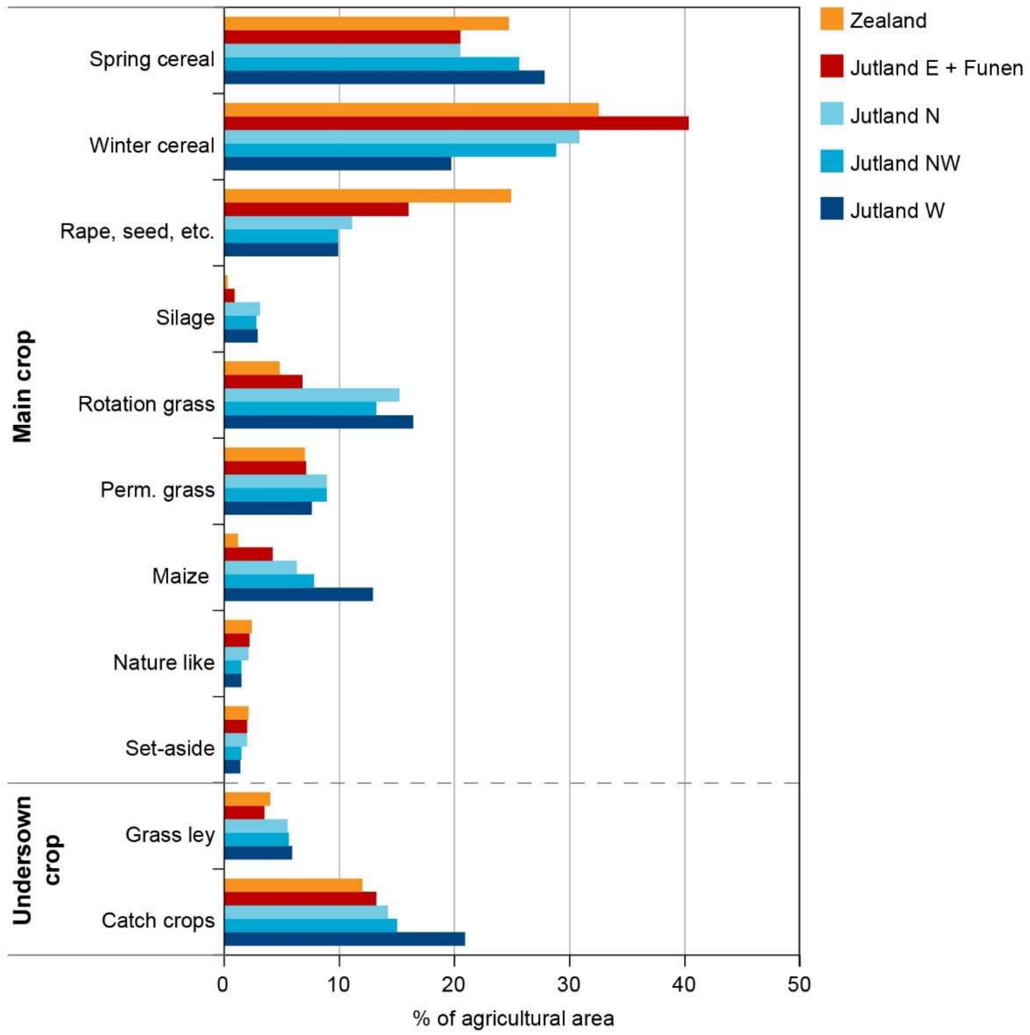

Figure 4.4: Crop distribution for five farming regions in Denmark in 2017. Combined dataset from the single payment register and the fertilizer accounts.

The crop distribution within the five farming regions of Denmark follows the same pattern as for farm types, i.e. mainly cereals and other cash crops on the islands and in Eastern Jutland and cereals and fodder crops in West and North Jutland (Figure 4.4).

The input of nitrogen with animal manure, the total nitrogen input and the field nitrogen balances are lowest on Zealand, higher in E Jutland and on Funen and highest in W, NW and N Jutland (Table 4.5). In the latter three areas, the nitrogen input varied between 213 and 230 kg N ha^{-1}. The modelled nitrate leaching generally increased from east to west due to increases in nitrogen input and percolation. Within the three western and northern parts of Jutland, the nitrate leaching increased from northern to southern Jutland, mainly due to increased water percolation through the root zone. Higher water percolation led to dilution of the nitrate concentrations of the soil water, resulting in an average nitrate concentration in soil water of 82, 75, 77, 71 and 64 mg NO_3 l^{-1} on Zealand, Funen + E and N Jutland, and NW and W Jutland, respectively.

Table 4.5: N inputs and N balances, nitrate leaching and nitrate concentration at the bottom of the root zone calculated for five geographical areas in Denmark in 2017. Combined dataset from the single payment register and the fertilizer accounts

	N balance									Root zone water		
	Comm. fertiliser	Animal manure	Other org. N	N-fix.	N-depos.	Seeds	Total input	Har-vest	N balance	Percol.	Nitrate leaching	NO_3^- conc
	kg N ha^{-1} a^{-1}									mm a^{-1}	kg N ha^{-1}	mg l^{-1}
Zealand	119	34	5.1	9.4	11	1.8	181	115	67	199	37	82
Jutl. E +Funen	98	75	2.6	11.7	14	1.8	202	117	86	335	57	75
Jutland N	75	102	1.9	19.9	12	1.6	213	119	94	365	64	77
Jutland NW	73	110	0.6	17.7	13	1.6	216	122	94	450	72	71
Jutland W	74	116	3.6	19.9	15	1.8	230	128	102	542	79	64

Derogation farms

Derogation farms are mainly located in N, NW and W Jutland where cattle farming is dominant (see chapter 2). The effect of the derogation was evaluated for these three geographical areas. The cattle farms were grouped into four livestock density groups: 0-1.0, 1.0-1.4, 1.4-1.7 LU ha^{-1} and derogation farms, 1.7-2.3 LU ha^{-1}.

The crop distributions for the three geographical areas were found to be almost identical, with some differences in cover between spring and winter cereals and more maize in W Jutland (Figure 4.5). There was a clear trend towards a decrease in nitrate leaching in areas with cereals and other cash crops with increasing livestock density and, in turn, an increase in the area with fodder crops with increasing livestock density. The area with roughage amounted to 55, 72 and 72 % for the three groups, 0-1.0, 1.0-1.4, 1.4-1.7 LU ha^{-1}, respectively, whereas derogation farms grew roughage on an average of 84% of the area.

The effect of derogation on nitrate leaching was evaluated separately for the three geographical areas. The nitrogen input as well as the field nitrogen balances increased with increasing livestock density (Table 4.6). Modelled nitrate leaching is a combined effect of two opposing mechanisms – an increase in leaching due to increased nitrogen input and a decrease in leaching due to an increased area with roughage. Table 4.6 shows that modelled nitrate leaching generally increased with increasing livestock density and hence with increasing nitrogen input. Thus, differences occurred in the modelled annual nitrogen leaching of 3, 5 and 10 kg N ha^{-1}, respectively, between derogation farms and farms using 140-170 kg N ha^{-1} of organic N in the three Jutland regions. Similarly, nitrate concentrations in the soil water leaving the root zone were 7 mg NO_3 l^{-1} higher for derogations farms than for cattle farms using 140-170 kg organic N ha^{-1} in the three regions.

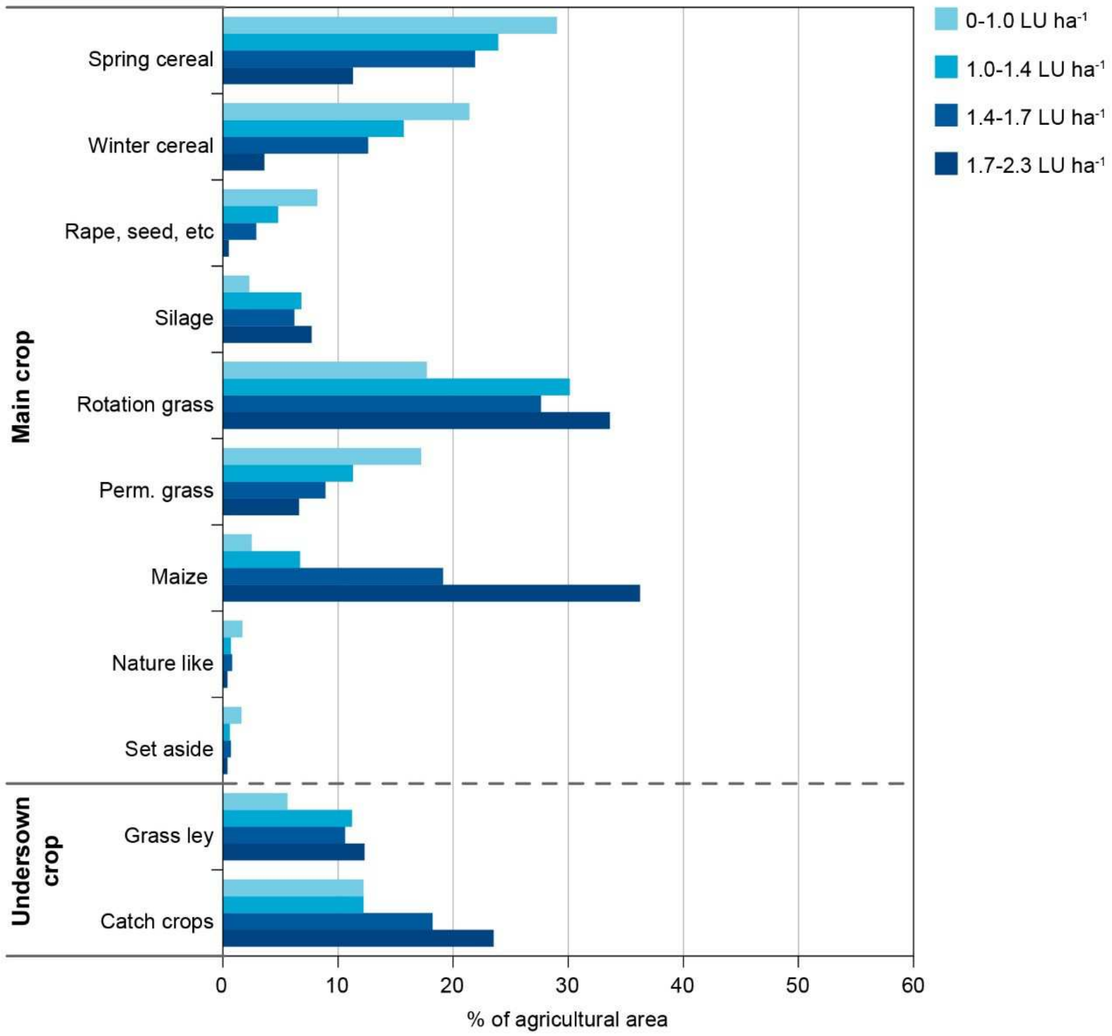

Figure 4.5: Average crop distribution for four groups of livestock density in N, NW and W Jutland in 2017. Combined dataset from the single payment register and the fertilizer accounts.

The use of legumes (clover, alfalfa, peas) in grass and cereal silage is shown in Table 4.7. The general trend is that derogation farms grow less legumes than non-derogation farms (Table 4.7). Thus, clover or alfalfa (max. 50% share) in rotation grass was used on 76% of the rotation grass area for derogation farms and on 83-93% for non-derogation farms. For permanent grass, the equivalent values were 19% for derogation farms and 23-38% for non-derogation farms. Cereal silage with peas amounted to 10% of the silage area for derogation farms and 19-21% for non-derogation farms.

Table 4.6: N inputs, N balances and nitrate leaching and nitrate concentration at the bottom of the root zone calculated for four groups of livestock density at cattle farms and for three geographical areas in Jutland, Denmark, 2017. Combined dataset from the single payment register and the fertilizer accounts.

Region	Live-stock density	N balance									Root zone water		
		Comm. fertiliser	Animal manure	Other org.N	N fix.	N depos.	Seeds	Total input	Harvest	Balance	Percol.	Nitrate leaching	NO_3^- conc
	LU/ha	kg N ha⁻¹ a⁻¹									mm a⁻¹	kg N ha⁻¹	mg l⁻¹
Jutland N	0-1.0	91	56	2.5	19	12	1.3	182	109	73	359	56	69
	1.0-1.4	44	124	0.3	45	12	1.0	227	133	94	355	54	67
	1.4-1.7	72	151	0.3	37	12	1.3	275	152	123	360	67	83
	1.7-2.3	70	202	0.1	40	13	1.3	326	177	148	349	70	90
Jutland NW	0-1.0	82	63	1.5	21	13	1.4	182	111	71	434	60	61
	1.0-1.4	53	123	0.4	35	13	1.2	226	132	94	449	65	64
	1.4-1.7	70	151	0.0	33	13	1.4	269	153	116	449	78	77
	1.7-2.3	62	199	0.1	36	13	1.5	313	173	140	435	83	84
Jutland W	0-1.0	79	60	6.6	21	15	1.5	184	110	73	526	62	52
	1.0-1.4	41	126	1.4	45	15	1.1	229	136	94	539	68	56
	1.4-1.7	70	152	1.9	31	16	1.5	272	154	118	544	83	68
	1.7-2.3	73	205	0.5	29	15	1.6	324	179	144	550	93	75

Table 4.7: Use of legumes in grass and cereal silage at cattle farms for derogation and non-derogation farms 2017.

	Livestock density (LU ha⁻¹)			
	0-1.0	**1.0-1.4**	**1.4-1.7**	**1.7-2.3**
	share of agricultural area (%)			
Rotation grass	13.2	27.7	24.8	32.4
	share of rotation grass (%)			
No clover/alfalfa	16	6	13	24
< 50% clover/alfalfa	83	93	86	76
> 50% clover/alfalfa	1	1	0	0
	share of agricultural area (%)			
Permanent grass	15.0	10.7	8.1	5.8
	share of permanent grass (%)			
No clover/alfalfa	62	71	77	81
< 50% clover/alfalfa	38	29	23	19
> 50% clover/alfalfa	0	0	0	0
	share of agricultural area (%)			
Cereal silage	1.4	6.0	5.2	7.2
	share of cereal silage (%)			
No legumes	76	50	68	90
< 50% legumes	19	21	20	10
100% legumes	6	29	12	0

4.4 Development in modelled nitrate leaching in the Agricultural Catchment Monitoring Programme 1990-2017

This section deals with the general development in nitrate leaching from 1990/91 to 2017/18. Information on agricultural practises is derived from the Agricultural Catchment Monitoring Programme. This programme includes six small agricultural catchments situated in various parts of the country in order to cover the variation in soil type and rainfall and hence in agricultural practises (Figure 4.3). The farmers are interviewed every year about livestock, crops and fertilization and cultivation practises. Nitrate leaching is modelled for all fields in the catchments, based on the information on agricultural practises and standard percolation values, calculated on the basis of the climate for 1990-2010.

In 2017, 126 farmers participated in the investigation. Of all the investigated farms, 26 were cattle holdings, and six of these were registered as derogation farms. These derogation farms covered 17% of the total area in the Agricultural Monitoring catchments in 2016/17. This is considerably higher than derogation farm area at national level in 2016/17, which amounted to 8.4% of the agricultural area.

The modelled nitrate leaching from the agricultural area in the catchments from 1990 to 2017 (representing the hydrological years 1990/91 to 2017/18) is shown in Figure 4.6 as an average for sandy and loamy catchments, respectively.

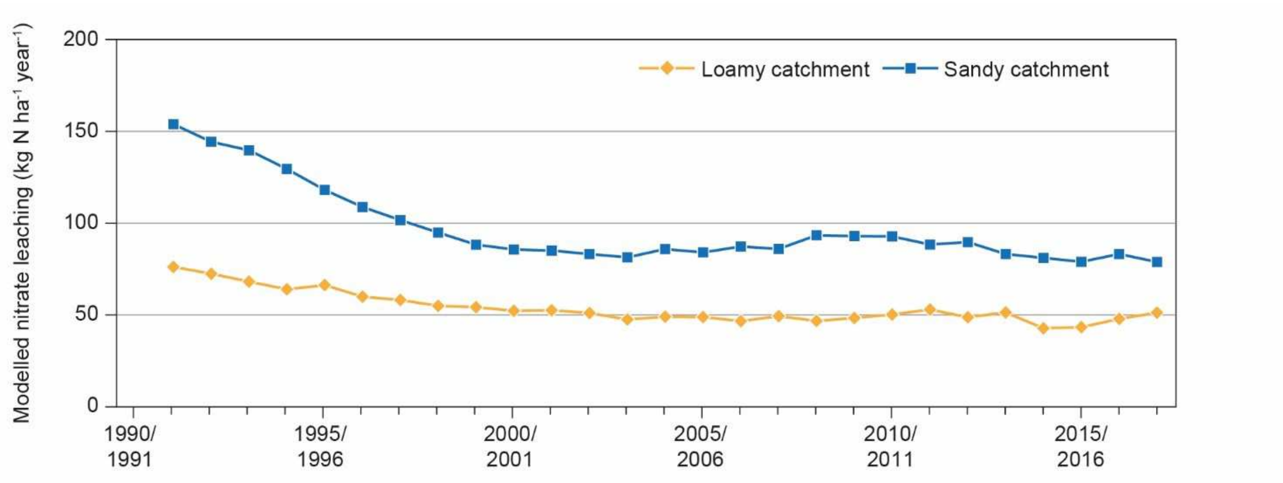

Figure 4.6: Modelled nitrate leaching in a standard climate for the fields of the Agricultural Catchment Monitoring Programme 1990/91-2017/18.

Seen relative to the distribution of the main soil types in Denmark, the modelled nitrate leaching decreased by 43% during the period 1991 to 2003 due to the general improvement in agriculture and fertilization practises (Action Plan I+II). After 2008, there was a small increase in nitrate leaching, particularly on sandy soils, probably caused by suspension of the set-aside obligation. At the national level, about 120,000 hectares of set-aside were cultivated in 2008 and 2009, leading to a change in crop rotation towards a higher leaching potential and a temporary increase in fertilizer application. After 2011, the modelled nitrate leaching for the sandy catchments decreased again and reached the same level as before 2008.

For the loamy catchments, the modelled annual nitrate leaching was less affected by the change in set-aside. The nitrate leaching was relatively stable around 50 kg N ha^{-1} during 2003-2013, decreasing with app. 8 kg N ha^{-1} in 2014 and 2015 and increasing again to the level of 2003-2013 in 2016 and 2017.

For the sandy catchments, the annual leaching varied between 79-81 kg N ha^{-1} in the period 2014-2017, which was 14 kg N ha^{-1} lower than the leaching of 93 kg N ha^{-1} in 2008 and 2009, but at the same level as the leaching in 2003. The lower leaching in these four years is mainly due to a higher effect of catch crops on cereals and maize. The calculated effects of catch crops on maize and cereals are identical in the model as no measurements of the effects of catch crops on maize were available when the empirical model was developed. During the last six years, farmers and researchers have intensified their focus on the management and effects of catch crops on maize (Blicher-Mathiesen et al., 2016). When maize was cropped without catch crops 2014/15-2017/18, the average modelled annual leaching for the sandy catchments was approx. 5 kg N ha^{-1} higher for those years.

The purpose of the root zone modelling is to show the effects of measures introduced to mitigate nutrient losses from agriculture. The modelling is therefore carried out for normalised growth conditions, i.e. averaging the model output for a 20-year period: The model is run for each year in the 20-year period and model outputs are then averaged for the period. The climatic data used cover the period 1990-2010. Actual measurements of nitrate leaching will show higher annual variations than the climatic average of the modelled values as the measurements depend on the actual climate.

Certain forms of soil cultivation and ploughing of grass fields in autumn were prohibited as from autumn 2011. This circumstance is not considered in the leaching model due to lack of actual measurements that could otherwise have been applied in the model development. It is estimated that postponed soil tillage will reduce root zone leaching by 2,400 t N at the national level corresponding to an average effect of about 1 kg N ha^{-1} (Børgesen et al., 2013).

4.5 Measurements of nitrate in water leaving the root zone

In five of the six Agricultural Monitoring Catchments, water samples are collected regularly at 30 sites. One of the sites is covered by forest and is therefore not included in the data on nitrate concentrations measured in agricultural areas. Measurements were ceased on a sandy site in 2011 as the farmers did not want to participate in the monitoring. Two sites on a loamy catchment are located very close to the edge of the field, and tractor transport in and out of the fields results in high damage to crops, uneven fertilizer application and very high values of measured nitrate leaching. Out of the remaining 27 sites on agricultural areas, 14 are located on loamy soils and 13 on sandy soils and the data on these are deemed valid for use in the trend analysis of the loamy and sandy catchments. The samples represent the root zone water (approx. 1 m depth – 30 samples per year) and the upper oxic groundwater (1.5-5 m depth – 6 samples per year). The measured concentrations are shown as annual average values for loamy and sandy soils, respectively, for the period 1990/91-2016/17 (Figure 4.7).

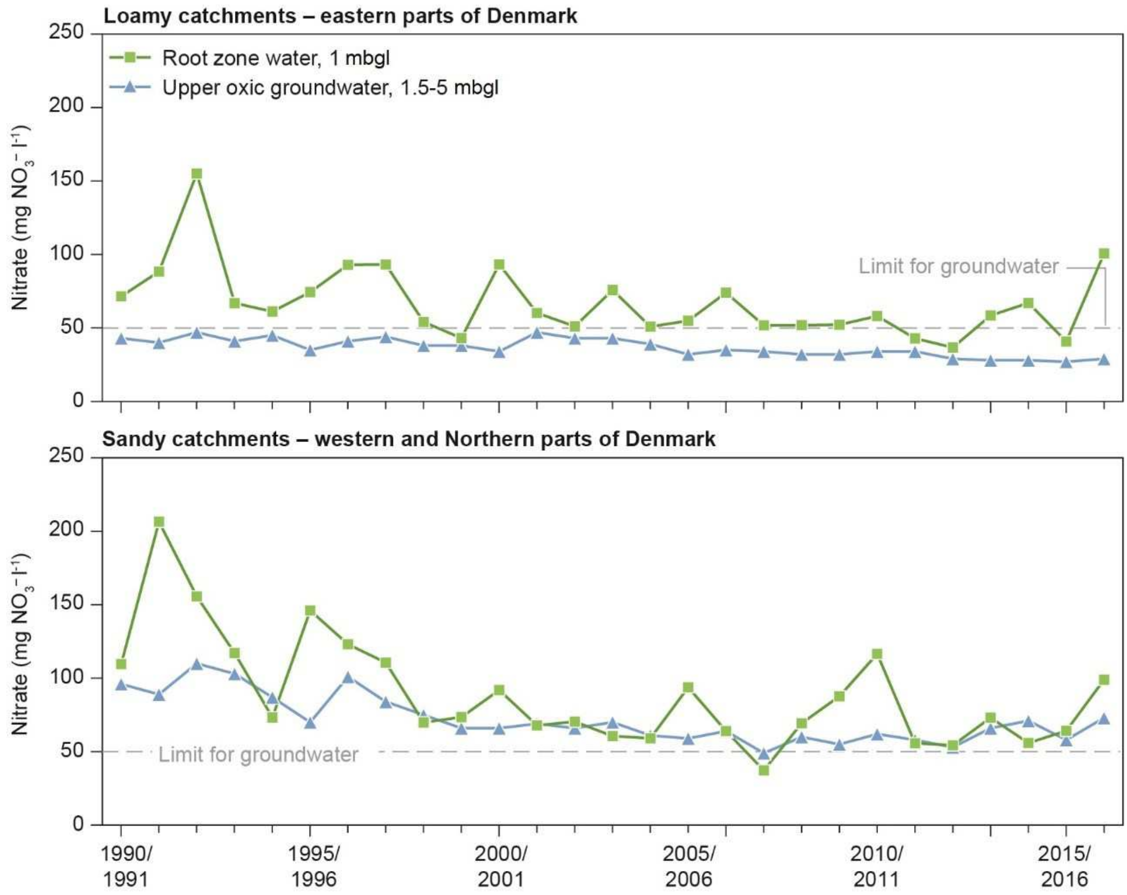

Figure 4.7: Annual flow-weighted nitrate concentrations measured in root zone water (1 m below ground level) and annual average nitrate concentrations measured in upper oxic groundwater (1.5-5 m below ground level), the Agricultural Catchment Monitoring Programme 1990/91-2016/17.

Generally, measured data for nitrate leaching from the root zone on only 27 sites cannot be used directly for estimating the effect of a single variable as the input of fertilizer or manure because of the high variability in actual fertilizer and manure practice between the monitoring fields and measured years. Instead, the data were used for the development of the nitrate leaching model, N-LES4, which was subsequently used for calculating the leaching from all the fields in the catchments relative to agricultural practises (Figure 4.6). The measurements are also used for calculating statistical trends for the monitoring period.

General trend for nitrate concentrations in water leaving the root zone

There is strong inter-annual variation in the measured nitrate concentrations due to differences in rainfall and temperature. Therefore, a long time series and a large number of measuring points are needed to detect any statistically significant trend. Such data series are available from the Danish Monitoring Programme. A statistical trend analysis, a Mann-Kendall test, incorporating annual variations in the mean annual flow-weighted nitrate concentrations for water leaving the root zone, showed that concentrations significantly decreased by 1.2 and 2.6 mg NO_3 l^{-1} a^{-1} for the measured sites on loamy and sandy soils, respectively, and for the whole 26-year monitoring period from 1990/91 to 2015/16.

On loamy catchments, the measured nitrate concentrations in root zone water decreased from 61-155 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 37-66 mg NO_3 l^{-1} in the 5-year period 2011/12-2015/16 and increased to 101 mg NO_3 l^{-1} in 2016/17. The high nitrate concentrations are seen in years with low percolation as observed on loamy soils in 2004/05, 2010/11 and in 2016/17. On sandy catchments, the nitrate concentration decreased from 73-207 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 54-73 mg NO_3 l^{-1} in the 5-year period 2011/12-2015/16 and increased to 99 mg NO_3 l^{-1} in 2016/17 (Figure 4.7).

After 2003/04 (Action Plan III + Green Growth), no statistically significant change in measured nitrate concentrations in soil water leaving the root zone has been recorded. However, before 2011/12, high concentrations were temporarily observed for sandy soils. This is most likely due to growth of crops with high leaching potential on these fields, such as turnover of grassland, followed by cereals with no catch crops the following years, growing of maize and winter rape etc.

It should be noted that the measurements of nitrate leaching originate from a small number of sampling stations (27 stations). Furthermore, the measurements are affected by high crop yields, in particular in 2009, and effects of crop rotation, especially of grass in rotation. These conditions induce higher inter-annual variations than seen in the modelled nitrate leaching, which covers a larger area including approx. 126 farms (Figure 4.6).

In the upper groundwater (1.5-5.0 m below ground level), nitrate concentrations were lower than in the root zone water, indicating nitrate reduction in the aquifer sediment between the bottom of the root zone and the uppermost groundwater (Figure 4.7).

On loamy catchments, the measured nitrate concentrations in the upper oxic groundwater decreased from 40-47 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 27-29 mg NO_3 l^{-1} in the 5-year period 2012/13-2016/17. On sandy catchments, the nitrate concentration decreased from 87-110 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 53-73 mg NO_3 l^{-1} in the 5-year period 2012/13-2016/17.

Nitrate concentrations in water leaving the root zone for cattle holdings

Two to three of the monitoring sites belong to cattle holdings that, on average, used between 130 and 170 kg organic manure N ha^{-1} in the period 2000/01-2016/17 and four to five sites belong to holdings that, on average, used more than 170 kg organic manure N ha^{-1} at the monitoring sites. Measurements of nitrate in water leaving the root zone are shown annually for each site for the period 2000/01-2016/17. At one of the sites, station "st 604", the manure input changed from a high annual input, above 170 kg N ha^{-1} until 2008 (data shown in Figure 4.8 bottom), to a lower input, below 170 kg N ha^{-1}, in the following years (data shown in Figure 4.8 top). Suction cups at site "st 203" were re-established in 2012, meaning that no measurements for this site were available for 2012/13 and 2013/14. The annual manure input at site "st 202" changed to a much lower level of 78 and 178 kg N ha^{-1} for 2012 and 2013, respectively, and the nitrate concentration in the root zone water is therefore not shown for these two years.

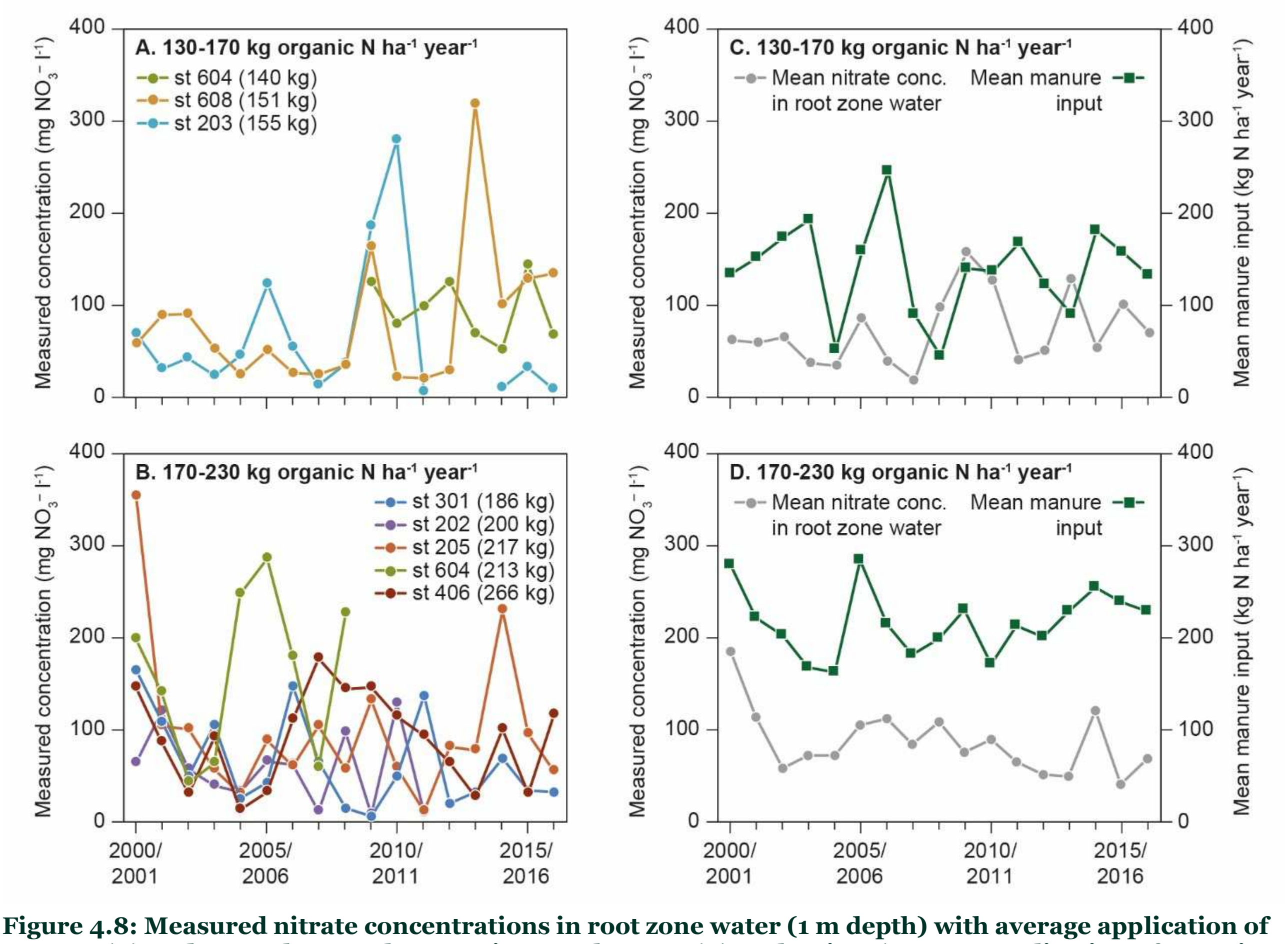

Figure 4.8: Measured nitrate concentrations in root zone water (1 m depth) with average application of 130-170 (A) and more than 170 kg organic N per hectare (B) at the sites (average application of organic manure N is shown in brackets). Figures for annual averages for the measured stations, average application of 130-170 (C) and more than 170 kg organic N per hectare (D). All data from the period 2000/01-2016/17 are shown.

Annual variations in measured concentrations at the individual monitoring stations were expected, partly due to crop rotation and variations in yield and meteorological conditions.

The sites that annually received an average of 130-170 kg N in manure ha^{-1} in the period 2000/01-2016/17 had high average nitrate concentration in the six years 2005/06, 2008/09-2010/11, 2013/14 and 2015/16 (Figure 4.8 top left). At some of the sites that annually received, on average, more than 170 kg N in manure ha^{-1} in the same period, nitrate concentrations were very high, for instance at "st 604" in five out of six years between 2004/05 and 2009/10. However, other sites receiving high manure input showed relatively lower soil water concentrations (Figure 4.8 bottom). The average flow-weighted nitrate concentration in root zone water at three specific sites that, on average, received 186-266 kg organic manure N per hectare varied between 41-120 mg NO_3 l^{-1} for the hydrological years in the period 2012/13-2016/17.

High nitrate concentrations are most likely a result of crop rotation, especially turnover of clover grass in rotation, followed by cereals without catch crops or high N input to maize, and they cannot, therefore, be linked to the level of manure input alone.

Phosphorus concentrations in the water leaving the root zone are shown in Figure 4.9. Generally, the concentrations varied between 0.005 and 0.050 mg PO_4-P l^{-1}, irrespective of the use of organic manure. However, on one field receiving an average of 148 kg organic N ha^{-1} (st 608), P concentrations were much more variable. The soil texture in this field is coarse sand and it is located in an area with high rainfall.

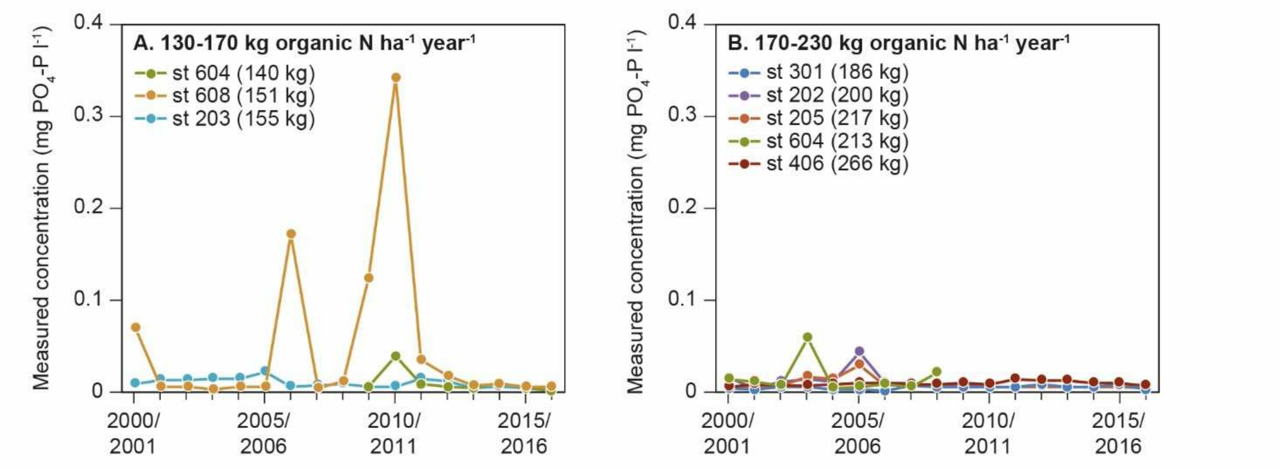

Figure 4.9: Measured phosphorus concentrations as dissolved orthophosphate (PO4-P) at soil water stations (1 m depth) with average application of 130-170 (A) and more than 170 kg organic N per hectare (B) at the sites (average application of organic manure N is shown in brackets). All data for the period 2000/01-2016/17 are shown.

4.6 The nitrogen flow to surface water in agricultural catchments

When percolating water leaves the root zone, it is partitioned into a component that discharges to surface water and a component that discharges to groundwater from where it will eventually – often some years later – drain into the streams. The pathways for water and nutrients in agricultural catchments are analysed in the Agricultural Catchment Monitoring Programme. Nitrate concentrations are measured in soil water and in water from tile drains from three loamy catchments and two sandy catchments.

The monitoring programme does not allow a specific evaluation of the effect of derogation farms on the nitrate transport in the streams since measurements at the catchment outlet integrate the effects of all activities in the catchment. However, the monitoring programme will provide an overview of the general trend for surface water, including the effect of any derogation farms in the catchment.

This chapter gives an overview of the nitrogen pathways in the hydrological cycle and describes the trends for nitrate in water for the period 1990-2017. Continued monitoring within the framework of the Agricultural Catchment Programme and the Stream Programme will provide indicators for the future development.

Table 4.8: Partitioning of water flow in streams into three components – rapid, intermediate and slow responding water. The analysis included three loamy catchments and two sandy catchments (1989/90-2002/03)

	Flow response		
	Rapid	**Intermediate**	**Slow**
Loamy catchments	41 %	16 %	43 %
Sandy catchments	20 %	23 %	57 %

The hydrological pathways
An analysis of the water flow in the streams of the five agricultural catchments has shown that it can be conceptually divided into three components – rapid, intermediate and slow response to precipitation (Table 4.8). These components may be regarded as flow from the upper soil layers (including tile drainage), from the upper oxic groundwater and from deep groundwater.

In loamy catchments, the flow path is characterised by relatively rapidly responding water (from upper soil layers), whereas there is a larger proportion of slowly responding water (from deeper groundwater) in sandy catchments.

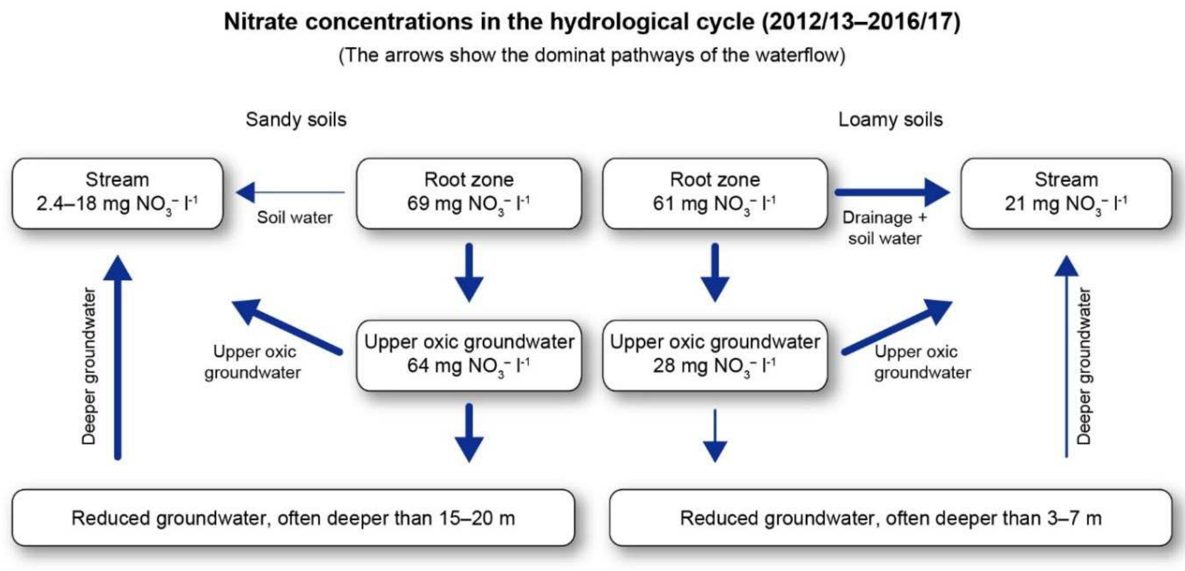

Figure 4.10: Measured nitrate concentrations in the hydrological cycle in three loamy catchment and two sandy catchments in the Agricultural Catchment Monitoring Programme. The values are calculated as an annual mean for the period 2012/13-2016/17.

Figure 4.10 illustrates measurements of nitrate concentrations in soil root zone water (mg NO3 l-1), upper oxic groundwater (1.5-5 m below ground level) and in streams. When water percolates from the root zone to the upper groundwater, denitrification processes take place. Thus, nitrate concentrations in the upper groundwater are lower than in the root zone water. When the water passes through the deeper aquifers, it will usually reach the redox cline where the remaining nitrate will be removed by biological and geo-chemical reduction processes.

As sandy catchments are characterised by the groundwater flow, the water discharging to the streams has been exposed to reduction processes. Thus, nitrate concentrations in the stream water are relatively low. In loamy catchments, the discharging water has mainly passed through the upper soil layers and through the drainage system where there is less nitrate reduction. Hence, nitrate concentrations in the streams are higher than in sandy catchments.

In this context, it should be noted that cattle farms, and hence the derogations farms, are mainly located in the western and northern parts of Jutland characterised by sandy soils and deep groundwater flow, leading to high nitrate removal and low nitrogen concentrations in the streams.

Trends in nitrate concentrations in the hydrological cycle

The development in nitrate concentrations in root zone water, upper oxic groundwater and stream water is shown in Figure 4.11. Statistical analyses incorporating the annual variations showed that the nitrate concentration in water leaving the root zone decreased significantly by 1.2 and 2.6 mg NO_3 l^{-1} a^{-1} at the measured sites on loamy and sandy soils, respectively, and calculated for the 26-year monitoring period from 1990/91 to 2015/16. However, as mentioned before, nitrate concentrations increased to 101 and 99 mg NO_3 l^{-1} on loamy and sandy soils, respectively, in 2016/17 (see section 4.5). In the Stream Monitoring Programme, the development is analysed for a larger number of streams. This programme showed that during the period 1989-2017 an average reduction of 44% in total nitrogen transport took place in 52 agricultural catchments representing both loamy and sandy soils (Thodsen et al., 2019).

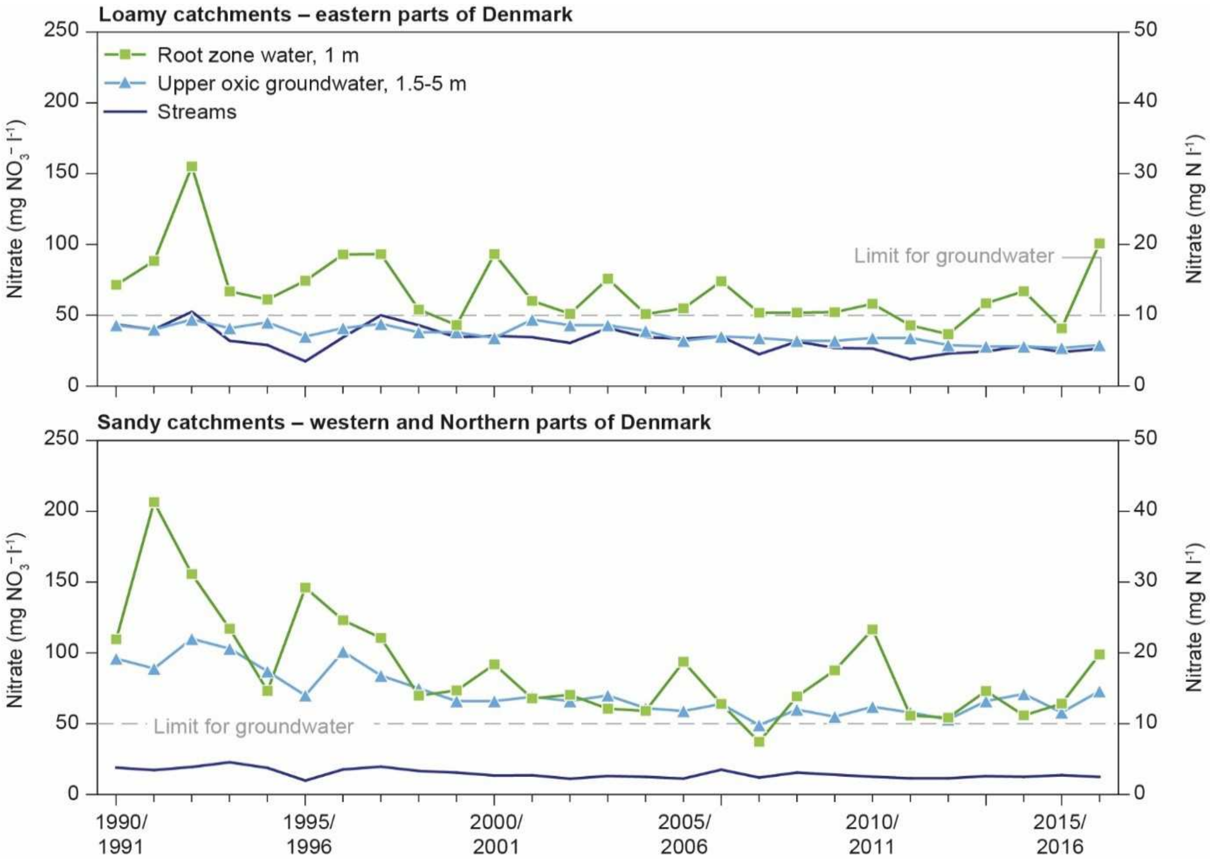

Figure 4.11: Nitrate concentration in root zone water, upper groundwater and in streams for three loamy catchments and two sandy catchments according to the Agricultural Catchment Monitoring Programme, 1990/91-2016/17.

The general conclusions to be drawn from the Agricultural Catchment Monitoring Programme are that:

- Measured nitrate concentrations in root zone soil water (1.0 m below ground level) decreased steadily from 1990/01 to 2015/16, albeit with annual variations. In 2016/17, the concentration increased. On loamy catchments, the measured nitrate concentrations in the root zone soil water decreased from 61-155 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95 to 37-66 mg NO_3 l^{-1} in the 5-year period 2011/12-2015/16, but increased in 2016/17 to 101 mg NO_3 l^{-1}. High nitrate concentrations are seen in years with low percolation as observed on loamy soils in 2004/05, 2010/11 and in 2016/17. On sandy catchments, the nitrate concentrations were 73-207 mg NO_3 l^{-1} in the 5-year period 1990/91-1994/95, decreased to 54-73 mg NO_3 l^{-1} in the 5-year period 2011/12-2015/16, but increased to 99 mg NO_3 l^{-1} in 2016/17.
- Measured nitrate concentrations in the upper oxic groundwater (1.5-5.0 m below ground level) decreased to a level well below the limit of 50 mg NO_3 l^{-1} for loamy catchments and to a level between 53 and 73 mg NO3 l^{-1} for the two sandy catchments in the period 2012/13-2016/17.
- Measured average flow-weighted nitrate concentrations in root zone water at three to four specific sites receiving, on average, -266 kg organic manure N per hectare varied between 41-120 mg NO_3 l^{-1} in the hydrological years in the period 2012/13-2016/17.
- Modelling of nitrate leaching for three loamy and two sandy catchments:
  - For the loamy catchments, modelled annual nitrate leaching was relatively stable around 50 kg N ha^{-1} during 2003-2013, after which it decreased by app. 8 kg N ha^{-1} in 2014 and 2015 and increased again to the level of 2003-2013 in 2016 and 2017.
  - For the sandy catchments, the modelled annual leaching varied between 79 and 81 kg N ha^{-1} in the period 2014-2017, which is 14 kg N ha^{-1} lower than the high leaching of 93 kg N ha^{-1} in 2008 and 2009 but at the same level as the leaching in 2003. The lower leaching in these four years is mainly due to a higher effect of catch crops on cereals and maize.

5. Reinforced monitoring in areas characterized by sandy soils

Wibke Christel & Johnny Machon, Ministry of Environment and Food of Denmark, based on selected data from the National Monitoring Programme of Water and Nature (NOVANA), provided by the Danish Environmental Protection Agency, and data on derogation farm location, provided by the Danish Agricultural Agency

5.1 Introduction

So far, the derogation report with respect to data on water quality has been based on data from the national agricultural catchment monitoring programme. This programme combines detailed information on both agricultural practice and crop rotation as well as data on water quality in root zone water, uppermost groundwater and small local streams. Monitoring takes place in five agricultural catchments throughout the country, of which three are located in parts of Denmark characterized by loamy soils and two in the western part, where sandy soils predominate. The latest, relevant results from the programme are reported in chapter 4 of this report.

Due to the limited size of the area monitored within the national agricultural catchment monitoring programme, only very few derogation farms are located in the five catchments. The majority of derogation farms are found in the western part of Denmark, especially in the western part of middle and southern Jutland, as shown on the maps in chapter 2 of this report. This part of Denmark is also characterized by predominantly sandy soils.

The derogation decision from 2017 (2017/847/EU) introduced the requirement that water quality should be reported using data from reinforced monitoring. The reinforced monitoring is carried out on sandy soils and in an area that comprises fields belonging to at least 3% of all derogation farms. The latest derogation decision from 2018 (2018/1928/EU) specifies in Article 10 (2) that, in addition to the monitoring obligations in prior derogation decisions, "[...] *Reinforced monitoring of water quality shall be carried out in areas with sandy soils. In addition, nitrates concentrations in surface and groundwater shall be monitored in at least 3 % of all holdings covered by an authorisation*."

In chapter 5 of the preceding derogation report, sent to the EU Commission in December 2017, an approach to comply with the reinforced monitoring requirements was proposed. However, as a consequence of the subsequent dialogue with the Commission, an alternative approach has been developed in cooperation with the Danish Environmental Protection Agency. The details of this alternative approach were presented to the Commission in the summer of 2018.

5.2 Method

Selection of relevant monitoring stations

Besides the results from the national agricultural catchment monitoring programme (see chapter 4), which so far has formed the basis for annual reporting according to the derogation decision, Danish authorities also collect data through a number of other national monitoring programmes. As part of the "National Monitoring Programme of Water and Nature" (NOVANA), data from approximately 500 water quality stations in streams and rivers are collected on a regular basis. The primary purpose is to determine nutrient loads to sensitive recipients, i.e., coastal waters and lakes. Water samples from more than 1,000 groundwater monitoring stations are also analysed on a regular basis; the sampling frequency varies from several times annually to once during a multi-year period, according to the monitoring and reporting requirements of the Nitrates Directive and the Water Framework Directive. One of the usual parameters that both groundwater and surface water samples are analysed for is nitrate concentration.

Simultaneously, the Danish Agricultural Agency registers which fields belong to derogation farms.

The approach is based on the identification of either surface water or groundwater monitoring stations located in close proximity to a field belonging to a derogation farm. More precisely, the GIS-analysis is based on the coordinates of the surface water or groundwater monitoring station as well as the surrounding area within a fixed 15-metre radius. This circle allows for an overlap between the position of the monitoring station and any fields in close proximity.

Only water course and groundwater monitoring stations located within 15 metres of a field registered to a derogation farm are selected. To determine whether this criterion is met, the latest registry data from the Danish Agricultural Agency is used.

If a groundwater monitoring well fulfils the location criterion but contains several monitoring stations at different depth ("multi-filter wells"), only one of these stations is selected; typically, the station that has the largest number of prior nitrate concentration samples.

Groundwater monitoring stations at a depth of 80 metres or more have been excluded from the data set, as data from the national groundwater monitoring ("GRUMO") programme shows that nitrate levels are no longer quantifiable (<1 mg/L) at these depths.

Only surface water monitoring stations that are part of the national programme monitoring "Transport of nutrients in streams" have been considered for the reinforced monitoring. A few mobile stations used for lake monitoring that would have fulfilled the proximity criterion have been excluded from the data set, as their locations typically change every year, making it impossible to create time series. Monitoring stations that have been installed in water courses to monitor the outflow from constructed wetlands have also been excluded.

In all, this selection method has identified a total of 54 monitoring stations. 34 stations of these (63 %) are groundwater monitoring stations, while 20 stations (37%) are located in water courses. The distribution between station types is a direct consequence of the higher density of groundwater as opposed to surface water monitoring stations throughout Denmark.

The locations of the 54 monitoring stations are presented in Figure 5.1, which also depicts all fields registered to derogation farms. Due to the scaling of the map, it would not have been meaningful to show only fields in close proximity to the monitoring stations.

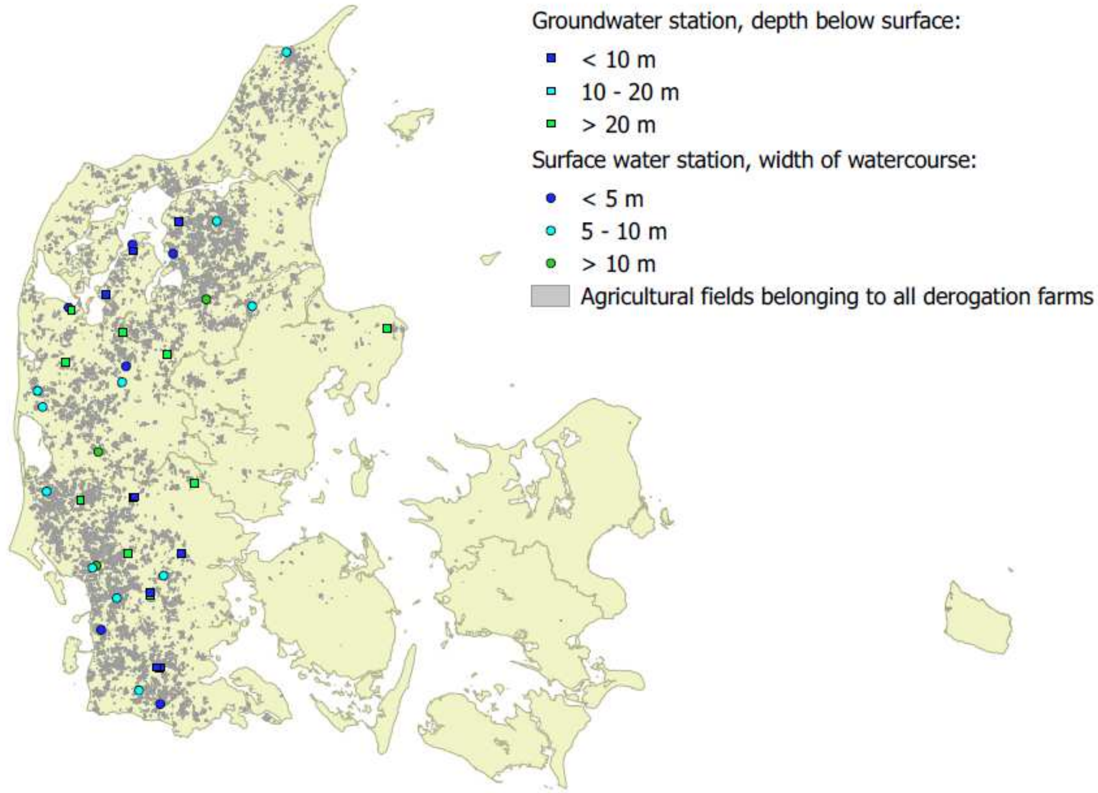

Figure 5.1: Map showing the locations of the 54 monitoring stations selected as the reporting basis for the reinforced monitoring. The squares show the location of in total 34 groundwater monitoring stations at different depth - these may overlap due to the scale of the map. The circles show the location of the 20 water course monitoring stations. Grey shading indicates all fields belonging to Danish derogation farms.

The majority of derogation farms are located in the northern and southern parts of the peninsula of Jutland, also illustrated in chapter 2 of this report. These parts of the country are characterized by sandy soils, whereas loamier soils dominate the more eastern parts of the country. Consequently, the described approach of linking the locations of monitoring stations to fields belonging to derogation farms results in a considerable enlargement of the data basis for reporting of water quality in sandy areas.

The geological map in Figure 5.2 illustrates the soil substrates throughout Denmark.

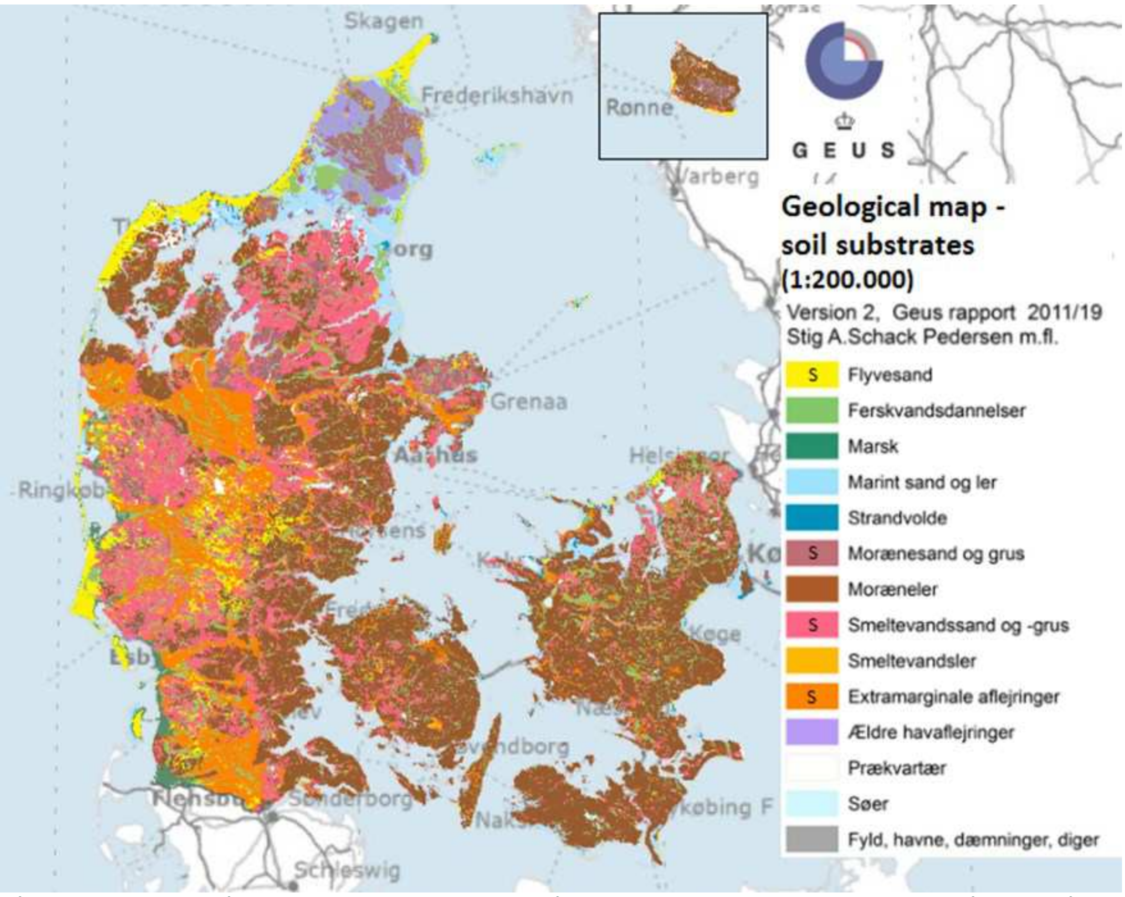

Figure 5.2: Geological map of Denmark showing the substrates that are the basis for soil development. Modified from a map produced by GEUS. The legend is only available in Danish, but the four main soil substrate types that can be categorized as "sand" have been marked with a "S" in the legend.

Coverage of Danish derogation farms

The locations of the 54 monitoring stations have been linked to 66 fields, which in turn belong to 48 different derogation farms. The number of stations exceeds the number of derogation farms, as some farms own several fields in proximity to a monitoring station, and as there may be more than one monitoring station located very close to a given field. Out of the 48 farms, 21 are subject to the reinforced monitoring due to the proximity of their fields to a water course monitoring station, while 26 farms are included owing to proximity to groundwater monitoring stations. One derogation farm has fields located close to both groundwater and surface water monitoring stations. The total number of farms encompassed by the reinforced monitoring corresponds to approximately 3.5% of all holdings that make use of the derogation.

5.3 Characterization of monitoring stations and data analysis

Groundwater

As indicated on Figure 5.1, the selected groundwater monitoring stations are located at depths below the surface ranging from 1.75 m to 72 m.[7] The majority of the stations monitor water quality in comparatively shallow groundwater, at an average depth of 21.6 m and a median depth of 14.0 m. Of the selected groundwater monitoring stations, 64.7 % are located less than 20 metres below surface. For 29.4% of the stations, the samples are of very shallow groundwater from a depth of less than 10 m.

[7] For available data up until 2017, the deepest selected monitoring station was located at 62 m below the surface. Data from the deeper groundwater is expected to be included in future reports, when water from these stations will be sampled and analysed for nitrate again.

The majority of groundwater monitoring stations will be sampled at least once per year in the future. Historic data since 2002 – the year Denmark obtained a derogation from the Nitrates Directive for the first time – have been included to the extent that they are available. If groundwater was sampled more than once per year at a monitoring station, the annual average nitrate concentration has been calculated for the station for each sampling year.

For the purpose of presenting the data in the results section below, the stations have been grouped into three different categories, also reflected in Figure 5.1: stations at a depth of less than 10 m below surface, stations at 10 to almost 20 m depth and stations at 20 m depth or deeper. Annual average nitrate concentrations have been calculated for each depth category for each year since 2002, based on the actual number of stations sampled in the respective year.

Surface water
The monitored water courses vary considerably in size and flow rate. The widths of the water courses at the monitoring station vary from 2 m to 23 m. The average water course width at the monitoring station is 7.0 metres, while 6 out of the 20 stations are located in small streams of less than 5 metres' width.

Samples from water courses are generally analysed for Nitrite- and Nitrate-Nitrogen (N). Nitrite-N-concentrations are typically negligible, and under this assumption, nitrate concentrations in the water samples could be calculated by multiplying the Nitrate-N concentration by a factor of 4.4268. In this chapter, the surface water concentration is generally given in Nitrite- and Nitrate-Nitrogen. Historic data since 2002 is included to the extent that it is available. Only data from monitoring stations that have been sampled at least 8 times annually in the period before 2017 are displayed in the results. In 2017, each water course monitoring station has been sampled more frequently, from 13 to 19 times annually.

For the purpose of presenting the data in the results section, stations have been grouped based on the approximate width of the water course at the sampling station site into three different categories, as also displayed in figure 5.1: less than 5 m, 5 to 10 m and more than 20 m width. Average nitrate concentrations have been calculated for each category for each year since 2002, based on the actual number of stations sampled in the respective year.

As a consequence of the political agreement on the Food and Agricultural Package from December 2015, the number of water course monitoring stations has been significantly increased. Nine out of the 20 water course stations selected for the reinforced monitoring were established in 2016 as a consequence of the agreement.

5.4 Results and Discussion

Groundwater
Figure 5.3 shows the nitrate concentration of each groundwater monitoring station selected for reinforced monitoring, as well as the average nitrate concentrations per sampling year for the period 2002 to 2017 for each of the depth categories. The quality limit value of 50 mg nitrate per litre is also shown.

The data generally shows great variability in nitrate concentrations from one year to another in water samples from individual monitoring stations. Especially in the shallowest groundwater (Figure 5.3 (A)), absolute concentration changes of up to more than 80 mg nitrate per litre can be observed from one sampling year to the other.

The average nitrate concentration remains below the quality limit value for each depth category throughout the whole period 2002 until 2017, with the exception of 2010 for the deepest category. However, this value is only based on a single monitoring station, as none of the others was sampled in 2010.

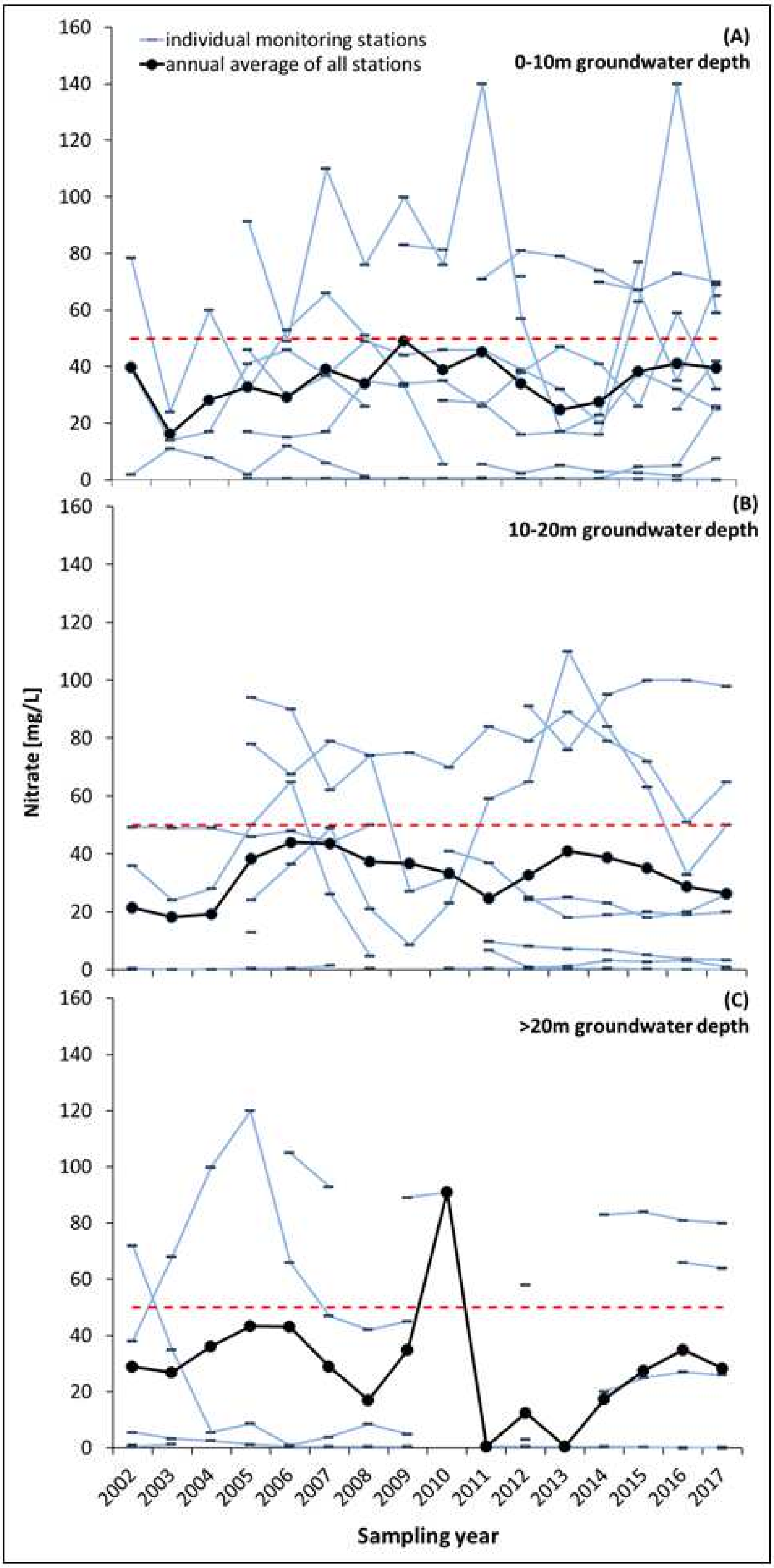

Figure 5.3: Nitrate concentration of the individual groundwater monitoring stations selected for the reinforced monitoring, as well as the average nitrate concentrations per sampling year for the period 2002 to 2017 for each of the three depth categories of groundwater stations: (A) stations at less than 10 m depth; (B) stations at 10-20 m depth and (C) stations at 20 m depth and deeper below the surface. A red dashed line at 50 mg nitrate per litre is inserted in each figure.

No clear trend in the average nitrate concentration can be observed over time for any of the three depth categories. Due to the limited number of stations and samples per year, the annual average values are highly influenced by the variability in nitrate concentration in the water sampled from some individual stations.

Table 5.1 shows the average nitrate concentration of all stations for each year in the period 2002 to 2017, irrespective of their depth and the number of stations sampled (n) in the respective year that form the basis of this calculation. The annual average nitrate concentration varies between 20.9 mg/L, as sampled in 2003 (n=11), and 41.9 mg/L in the groundwater samples from 2009 (n=13).

Table 5.1: Annual average nitrate concentration of all stations in reinforced monitoring in the period 2002-2017 and number of stations sampled

Sampling year	Average nitrate concentration [mg/L]	Number of sampled stations (n)
2002	29.2	11
2003	20.9	11
2004	27.0	10
2005	37.0	18
2006	38.1	18
2007	37.8	18
2008	32.1	16
2009	41.9	13
2010	40.7	13
2011	28.7	18
2012	28.8	23
2013	29.2	18
2014	28.8	23
2015	35.1	21
2016	35.2	22
2017	31.9	26

When calculated across the entire period from 2002 to 2017, the (non-weighted) mean value of the annual average concentrations is 32.6 mg/L. The data used to calculate the 2017 average concentration for groundwater is based on the largest number of sampled stations so far (n=26). The 2017 average is slightly lower than the mean value for the whole 2002-17 period. As all groundwater monitoring stations are being sampled each year in the future, the basis for data analysis is expected to increase.

Surface water

Figure 5.4 shows the Nitrite- and Nitrate-Nitrogen concentration of the individual water course monitoring stations selected for reinforced monitoring, as well as the average nitrate concentrations per sampling year for the period 2002 to 2017 for each of the width categories. The quality limit value for groundwater of 50 mg nitrate per litre, which corresponds to approximately 11.3 mg Nitrate-N per litre, is also shown.

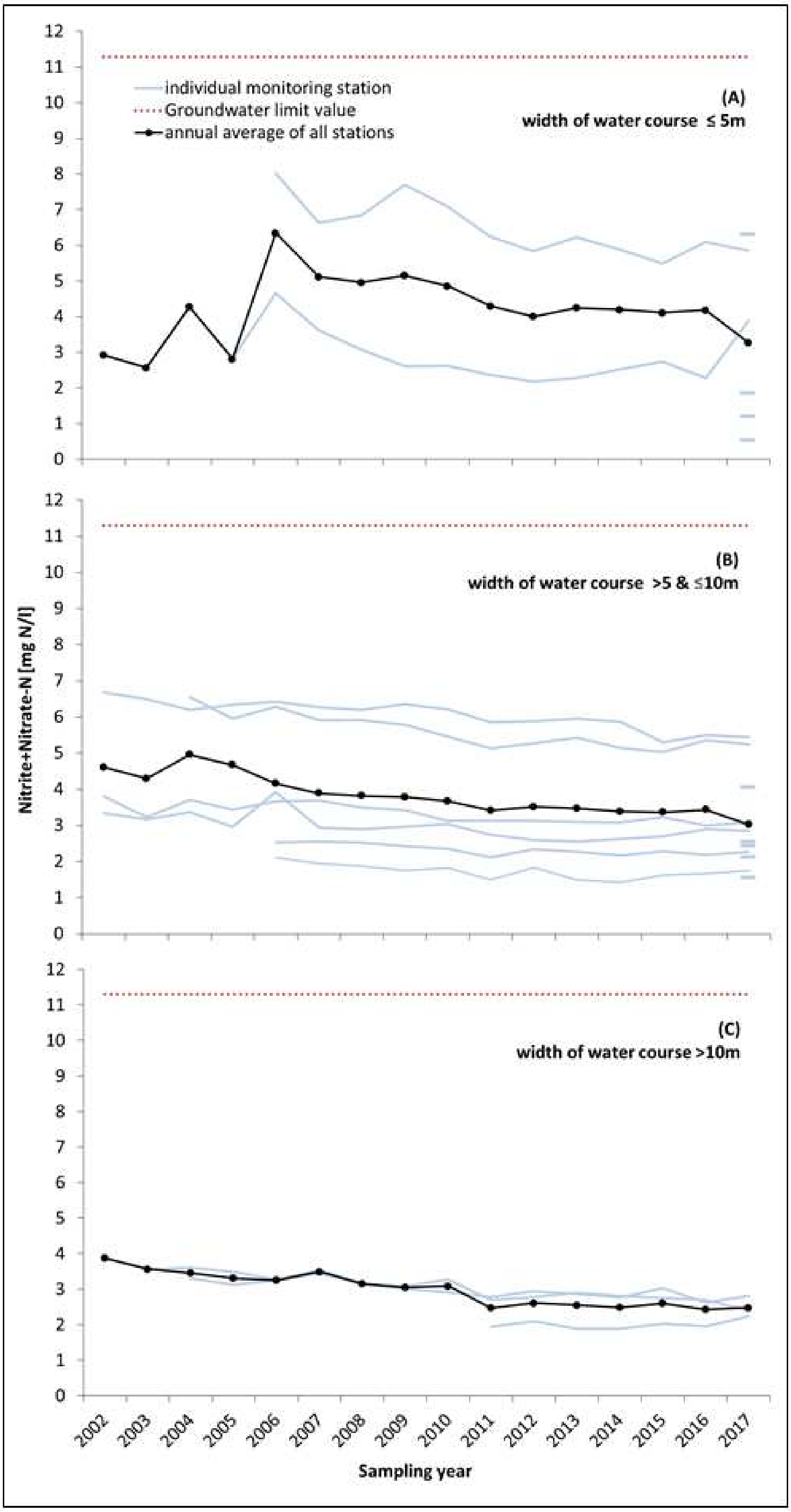

Figure 5.4: Nitrite- +Nitrate-Nitrogen (N) concentration of the individual surface water monitoring stations selected for reinforced monitoring, as well as the average nitrate concentrations per sampling year for the period 2002 to 2017 for each of the three width categories (determined at sampling site): (A) less than 5 m wide; (B) 5 to 10 m wide and (C) wider than 10 m. A red dashed line is inserted in each figure at 11.3 mg Nitrate-N/L, corresponding to approx. 50 mg nitrate per litre.

At the level of the individual monitoring station, nitrite- + nitrate-nitrogen concentrations can vary significantly from year to year mainly due to variation in amount and timing of precipitation. The fluctuations in absolute concentration are up to 1.84 mg/L, corresponding to more than 8 mg nitrate per litre. Nevertheless the year-to-year variations are not as pronounced as those seen in groundwater samples. Generally the smallest water courses show greater variability (Figure 5.4 (A)).

For all water course categories it is, however, important to underline that the N transport is not determined by the nitrogen concentration alone, but also by the water flow in the water course, which can significantly vary due to the specific and local weather conditions of a given year. In low flow rate situations, nitrogen levels may be relatively high while total N transport remains unchanged, and vice versa. As smaller water courses typically have a smaller catchment area than rivers, variations in local weather conditions are expected to have a greater impact on the nitrogen concentration in water sampled from the small water course.

For all individual water course monitoring stations, nitrate-N concentrations remain well below the quality limit for groundwater and drinking water throughout the whole period from 2002 to 2017. The highest measured concentration among the stations was equivalent to approximately 35.6 mg nitrate per litre in the year 2006 (see figure 5.4, (A)). Absolute concentrations tend to be higher in the smaller water courses than in the larger ones, which is likely to be a result of nitrate being removed through natural processes along the course of the water. Overall, the annual average for each category has been steadily decreasing over the last 10 years of the period shown.

Table 5.2 shows the annual average nitrite- and nitrate-N concentration in water sampled at all water course stations – irrespective of their width – and the number of stations sampled in the respective year (n). The annual average nitrite- + nitrate-N concentration has decreased from 4.4 mg/L in the early years of the reported period (e.g. 2006, n=10) down to 3.3 mg/L in 2016 (n=11). In 2017, 9 additional water course monitoring stations have been established, improving the data basis significantly. The average concentration in 2017 for all water course stations was 3.0 mg/L.

Table 5.2: Annual average nitrite- + nitrate-N concentration in water sampled at all stations selected for reinforced monitoring, as well as the number of stations sampled in each year

Sampling year	Average nitrite- +nitrate-N concentration [mg/L]	Number of sampled stations (n)
2002	4.1	5
2003	3.8	5
2004	4.4	7
2005	4.0	7
2006	4.4	10
2007	4.1	10
2008	3.9	10
2009	3.9	10
2010	3.8	10
2011	3.3	11
2012	3.4	11
2013	3.4	11
2014	3.3	11
2015	3.3	11
2016	3.3	11
2017	3.0	20

General discussion
It is important to highlight that the reinforced monitoring does not provide data that can be used to examine any potential effect on water quality that might be the result of the use of the derogation. A range of other fluctuating factors influence nutrient concentrations in the aquatic environment, and as such, it would not be possible to identify or isolate such an effect.

Because the reinforced monitoring method is based on linking the locations of monitoring stations to fields belonging to derogation farms in a two-dimensional way: The approach does not account for the actual catchment area and subsurface water paths for the respective monitoring stations. Hence, it is only to a very limited degree possible to get a picture of the effects of land use on surface water and groundwater quality. A clearer picture would require a catchment-based approach, which takes into account that water quality in the recipient water is affected by land use in the whole catchment area.

The present method does not include a reference group of monitoring stations that are not located in proximity to fields belonging to derogation farms.

However, by including the data from this selected set of the surface water and groundwater monitoring stations, the data basis for water quality in sandy areas is considerably enlarged in addition to the two sandy catchments within the national agricultural catchment monitoring programme (see chapter 4), which has so far formed the basis for reporting and provides comprehensive data on land use at farm-level.

6. Indicator system for application of phosphorus in Denmark in 2017

Hans Kjær & Irith Nør Madsen, Ministry of Environment and Food of Denmark

6.1 Introduction

In consultation with the European Commission, the Ministry of the Environment and Food has agreed that Denmark must monitor the use of phosphorus (P) in organic fertilizer and commercial fertilizer, so that it is ensured that the average use does not exceed the national phosphorus ceiling. The monitoring is based on data from the fertilizer accounts, which is only available approximately one year after a planning period is completed. The first planning period with limiting phosphorus use corresponding to the specific ceilings at farm level was 2017/2018, and the fertilizer accounts from that period will not be available until April 2019. Therefore, monitoring with quality-assured data will at the earliest be available for the first time in June 2019.

In the meantime, as a supplement to monitoring, it has therefore also been agreed that an "indicator system" must established, where data from the NOVANA monitoring program in Agricultural Catchments (LOOP) in combination with available data on livestock production and sales of fertilizer and other phosphorus sources can provide an updated overview of the average amount of phosphorus used in Danish agriculture.

6.2 Results

Table 6.1 shows the phosphorus inputs as reported in the report "Landovervågningsoplande 2017" from February 2019. The table shows an increase in the use of phosphorus in 2017. As a direct consequence of the new P-ceiling regulation, in the coming years both the farm-specific P-ceilings and the national P-ceiling will be decreased to a lower level, so the increase in the use of phosphorus is not expected to continue.

Table 6.1: P-input from different sources to Danish agricultural areas in 2012-2017[8]

	2012	2013	2014	2015	2016	2017
Input of P (1,000 tons P) from different sources:						
- Chemical fertilizer	11,800	11,300	13,000	13,300	13,300	20,800
- Animal manure	45,800	45,300	46,100	46,100	44,300	43,000
- Seed	1,000	1,000	1,000	1,000	1,000	1,000
- Sludge	2,400	2,400	2,400	2,400	2,400	2,400
- Waste from industry	3,100	3,100	3,100	3,100	3,100	3,100
- Deposition	264	263	262	263	263	259
Total input (1,000 tons P)	**64,400**	**63,400**	**65,900**	**66,200**	**64,400**	**70,500**
Agricultural area (1000 ha)[9]	**2,641**	**2,625**	**2,617**	**2,656**	**2,598**	**2,587**
Average P application (kg P/ha)	**24.4**	**24.1**	**25.2**	**24.9**	**24.8**	**27.3**
National P-ceiling (kg P/ha)					**[32.2][10]**	**35.2**

[8] Source, unless otherwise mentioned, is: Blicher-Mathiesen *et al.* (2019): *Landovervågningsoplande 2017*. Aarhus University. Can be found here: https://dce2.au.dk/pub/SR305.pdf

[9] Source: SEGES (2019): Oversigt over landsforsøg 2018. Can be found here: https://www.landbrugsinfo.dk/planteavl/landsforsoeg-og-resultater/oversigten-og-tabelbilaget/sider/pl_oversigten-over-landsforsoegene-2018.aspx

[10] This figure indicates the average phosphorus protection level in 2016 expressed as a theoretical P-ceiling, before the P-ceilings were introduced, and is included for comparison.

In the dialogue with the EU Commission, it was expected that the development in livestock production should be monitored via data from the CHR register, since Denmark previously prepared an annual status on the size of livestock production in various catchments. This annual status is now done instead on the basis of the fertilizer accounts, which is why the best data material on the development in livestock production is the annual status of the livestock population, which is made by Statistics Denmark. The relevant data from Statistics Denmark for 2016 and 2017 can be seen in Table 6.2.

Table 6.2: The development in the livestock production according to Statistics Denmark in 2016 and 2017[11]

	% of total livestock units (LU) for key livestock types	Number of animals 2016, all farms	Number of animals 2017, all farms	% change in total number of animals 2016-2017
Cattle and dairy cows (all kinds)	48.6	1,568,289	1,545,417	-1.5
Pigs (all kinds)	43.1	12,383,000	12,307,667	-0.6
Poultry (all kinds)	3.7	18,503,000	21,483,698	16.1
Mink (all kinds and other furbearers)	4.6	3,268,984	3,429,472	4.9
Overall change (weighted by LU share)				-0.1

There is no indication that a larger amount of livestock manure will be produced in 2017 or that the average phosphorus application in Denmark will exceed 25-28 kg P/ha. This level is well below the average phosphorus ceiling of 35.2 kg P / ha in 2017 and as aforementioned, the national phosphorus ceiling will be reduced continuously from 2018 onwards.

[11] Data from Statistics Denmark. Can be found here: https://www.dst.dk/da/Statistik/emner/erhvervslivets-sektorer/landbrug-gartneri-og-skovbrug/husdyr

7. Targeted catch crops scheme

Peter Byrial Dalsgaard, The Danish Agricultural Agency, Ministry of Environment and Food of Denmark, December 2018

As part of the political agreement on the Food and Agricultural Package of December 2015, the reduction of the nitrogen application standards has been removed and Danish government has introduced an intermediate initiative to reduce N-losses through promoting the establishment of additional catch crops in 2017 and 2018. The scheme is designed to protect both groundwater bodies and coastal waters. The scheme consists of a voluntary phase, were farmers apply for participation in the scheme, and a subsequent mandatory requirement for catch crops if the voluntary scheme does not reach the predefined targets. The latter requirement is uncompensated whereas the voluntary part is compensated with de minimis support.

After the deadline for application in the voluntary crop scheme, the farmer is bound by the commitment for the voluntary catch crops as well as the obligatory requirement for additional catch crops and will no longer be able to opt-out of any of these requirements without consequences. The voluntary catch crops must be additional to the national mandatory requirement for catch crops on 10 or 14% of the farms crop base area, and they cannot be established on the same area used for catch crops to meet the EFA requirement under direct payments.

If the farmer opts out afterwards, or non-compliance is detected during control, the fertilizer norm for the farm is reduced corresponding to the non-compliance with the voluntary and/or obligatory requirement and according to a conversion factor between the nitrogen reduction effect of catch crops and the fertilizer norm reduction for the planning period. This norm reduction will contribute to meeting the objectives of the Nitrates Directive. Furthermore, if the reduced fertilizer norm is exceeded, he will be in breach of the Fertilizer Act and will be sanctioned accordingly cf. Annex III point 1.3 of the Nitrates Directive. This is similar to the current practice for the general catch crop requirements and additional catch crop requirements for holdings using organic manure.

Results from 2017 and 2018

Prior to 2017 and 2018, respectively, the ministry calculated the need for further nitrates efforts for each of the years, which can be expressed as the amount of additional catch crops required in the individual water catchment areas, in terms of hectares and as a percentage of the crop base area. The calculation is based on the estimated need for reductions in the nitrates contents of groundwater bodies and coastal waters, adjusted by the estimated soil nitrates retention in the water catchment area.

In 2017 the need for further nitrates efforts was calculated to **137.560** ha. By the application deadline the farmers had applied for a total of **144.220** ha of catch crops. Geographically, however, the catch crops were not optimally placed in relation to the effort needed. Calculations revealed that an additional **3.253** ha catch crops were needed in order to reach the target. A political decision was made to postpone this residual effort until 2018.

In 2018 the need for further nitrates effort was calculated to **114.300** ha (including the postponed 3.253 ha). By the application deadline the farmers had applied for a total of **105.000** ha of catch crops. It was furthermore decided to postpone the effort related to aquaculture (fish farming, mariculture, etc.), as extensions of existing aquaculture facilities had not been approved. Calculations revealed that an additional **3.000** ha catch crops were nevertheless needed in order to reach the target. This has been implemented as a mandatory uncompensated requirement in 2018.

8. Conclusions

Cattle holdings and controls on farm level

In 2016/2017 a total of 1,378 cattle holdings made use of the derogation. This corresponds to 3.9 % of the total number of agricultural holdings in Denmark. The number of livestock units on these derogation cattle holdings was 439,114 LU corresponding to 19.3 % of the total number of livestock units. The arable land encompassed by the derogation in year 2016/2017 was 205,874 hectares corresponding to around 8.4 % of the total arable area. Compared to the previous reporting period, in 2016/2017 there has been a decrease in the number of farms, the number of hectares and the number of livestock units encompassed by the derogation. The average number of livestock units per farm has increased over the years and this trend continued in 2016/2017.

In January – February 2018, 90 inspections of compliance with the derogation management conditions were carried out. 87 inspections were closed without remarks and in 3 inspections the holdings got remarks.

For the year 2015/2016 379 inspections (1.1 % of all Danish holdings) taking place at the holding were made concerning compliance with the harmony rules (amount of livestock manure applied per hectare). 28 of the inspected farms use the derogation. 24 of these inspections were closed without remarks, 2 holdings got a fine and 2 holdings are still under investigation.

All 35,059 fertilizer accounts submitted in 2015/2016 (100 %) were automatically screened by the IT-system according to normal procedure. Of these, 774 (2.2 %) were subject to administrative control. In all, 61 of these holdings used the derogation. Of the inspections of derogation farms, 46 (75.4 %) were closed without remarks, 6 (9.8 %) were closed with remarks and 9 (14.8 %) are still under investigation.

In total approximately, 7.0% of derogation farms were selected for physical inspections. More derogation farms have in total been subjected to controls due to the aforementioned administrative controls. As holdings are automatically selected - based on a previously agreed set of "risk criteria" - for both physical inspection and administrative control, the Danish Agricultural Agency has no direct influence on the share of holdings using the derogation that are inspected each year. Therefore, the share of derogation farms that have in some way been subjected to controls varies from year to year.

Water quality

In 1998 the Action Plan for the Aquatic Environment (APAE) II was accepted by the EU Commission as the Danish Nitrate Action Plan implementing the Nitrate Directive (1998-2003). In 2003, a final evaluation of Action Plan II was performed, showing a reduction of 48% of the nitrate leaching from the agricultural sector, fulfilling the reduction target set in 1987.

Further mitigation measures in the following Action Plans, APAE III from 2008 were implemented to reduce N leaching from the root zone and the Green Growth Agreement from 2009, the first and second River Basin Management Plan from 2014 and 2016, respectively as well as the Food and Agricultural Agreement in December 2015 suggests measures or reductions target for N load to marine areas in order to fulfil the targets in the Water Framework Directive.

Modelling of the nitrate leaching from the root zone at the national level showed an average concentration of 75-90 mg NO_3 l^{-1} for cattle holdings using 170-230 kg organic manure N in 2017.

Measured average flow-weighted nitrate concentration in root zone water at three to four specific sites that on average received 186-266 kg organic manure N per hectare varied between 41-120 mg NO_3 l^{-1} for the hydrologic years in the period 2012/13-2016/17.

In the upper oxic groundwater (1.5-5.0 m), nitrate concentrations are lower than in the root zone water, indicating that nitrate reduction occurs in the aquifer sediment between the bottom of the root zone and the uppermost groundwater. In loamy catchments the measured nitrate concentration in the upper oxic groundwater decreased from 40-47 mg NO_3 l^{-1} in the five year period 1990/91-1994/95 to 27-34 mg NO_3 l^{-1} in the five year period 2011/12-2015/16. On sandy catchments the nitrate concentration decreased from 88-110 mg NO_3 l^{-1} in the five year period 1990/91-1994/95 to 53-71 mg NO_3 l^{-1} in the five year period 2011/12-2015/16.

The general conclusions to be drawn on trend in measured nitrate concentrations in root zone water and upper oxic ground from the Agricultural Catchment Monitoring Programme are that:

- Nitrate concentrations in root zone soil water (1.0 m below soil surface) have decreased steadily from 1990/01 to 2015/16 but the concentration increased in 2016/17. On loamy catchments the measured nitrate concentration decreased from 61-155 mg NO_3 l^{-1} in the five year period 1990/91-1994/95 to 37-66 mg NO_3 l^{-1} in the five year period 2011/12-2015/16, but increased in 2016/17 to 101 mg NO_3 l^{-1}. On sandy catchments the nitrate concentration was 73-207 mg NO_3 l^{-1} in the five year period 1990/91-1994/95 and decreased to 54-73 mg NO_3 l^{-1} in the five year period 2011/12-2015/16 but increased to 99 mg NO_3 l^{-1} in 2016/17.
- Nitrate concentrations in the upper oxic groundwater (1.5-5.0 m below soil surface) decreased to a level well below the limit of 50 mg NO_3 l^{-1} for loamy catchments and to a level between 53 and 73 mg NO3 l^{-1} for the two sandy catchments in the period 2012/13-2016/17.

Targeted catch crops

For the year 2017 a total of app. 144.000 ha voluntary targeted catch crops were established, and a further effort of 3.250 ha were postponed to 2018. In 2018 a total of app. 105.000 ha voluntary catch crops were established, and in addition an obligatory effort of app. 3.000 ha has been applied (uncompensated).

The reinforced monitoring

The reinforced monitoring does not provide data that can be used to examine any potential effect on water quality that might be the result of the use of the derogation. A range of other fluctuating factors than proximity to a derogation farm influence nutrient concentrations in the aquatic environment. However, by including the data from the selected set of the surface water and groundwater monitoring stations, the data basis for water quality in sandy areas is considerably enlarged. The total number of farms encompassed by the reinforced monitoring corresponds to approximately 3.5% of all holdings that make use of the derogation.

The phosphorus indicator system

There has been an increase in the use of phosphorus in 2017. As a direct consequence of the new P-ceiling regulation, in the coming years both the farm-specific P-ceilings and the national P-ceiling will be decreased to a lower level, so the increase in the use of phosphorus is not expected to continue.

There is no indication that a larger amount of livestock manure will be produced in 2017 or that the average phosphorus application in Denmark will exceed 25-28 kg P/ha. This level is well below the average phosphorus ceiling of 35.2 kg P / ha in 2017.