Danish Ministry
of the Environment
Environmental
Protection Agency

Danish Report
in accordance with the
Commission Decision
2005/294/EC, 2008/664/EC
and 2012/659/EU

March 2015
Danish Environmental Protection Agency
Danish Ministry of the Environment
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Contents

1. Introduction

With the Commission Decision 2005/294/EC, 2008/664/EC and 2012/659/EU Danish cattle holdings are allowed to derogate from the general rules in the Nitrates Directive (91/676/EEC). If 70 per cent or more of the area available for manure application is cultivated with beets, grass or grass catch crops cattle holdings can apply manure comparable to 2.3 livestock units (LU[1]) per hectare per year (Max. limit 230 kg N/ha). Furthermore cattle holdings shall comply with conditions laid in the decision. The implementation of Commission Decision 2012/659/EU into Danish legislation is shown in annex 1. The Danish derogation 2012/659/EU was renewed the 23 of October 2012. Some of the control of the implementation is based on the previous year's fertilizer accounts (2012/2013) and therefore this report will reflect the decisions from both the previous derogation and the renewed derogation.

The aim of the report is to present maps showing the percentage of farms and percentage of agricultural land encompassed by the derogation in each municipality for 2012/13, the control of compliance with the Danish derogation for 2011/12 and in January-March 2014, and monitoring results for 2012/13.

Every year the following shall be transmitted to the Commission according to 2012/659/EU:

- According to Article 7 (1) and 9 (a) of Commission Decision 2012/659/EU Denmark shall update two maps, showing the percentage of cattle farms and percentage of livestock and percentage of agricultural land covered by the derogation for each municipality of Denmark.

- According to Article 9 (g) of Commission Decision 2012/659/EU evaluation of the implementation of the derogation conditions, on the basis of controls at farm level and information on non-compliant farms, on the basis of the results of the administrative and field inspections.

- According to Article 9 (b, c, e) of Commission Decision 2012/659/EU the results on ground and surface water monitoring as regards nitrate and phosphate, including information on water quality trend as well as the impact of derogation on water quality, and results of model-based calculations from farms benefiting from an individual derogation

- According to Article 9 (d and f) of Commission Decision 2012/659/EU the results of the surveys on local land use, crop rotations and agricultural practices including tables showing

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

the percentage of agricultural land under derogation covered by clover or alfalfa in grassland and by barley/pea undersown with grass.

2. Maps on cattle holdings, arable land and LU in 2013

January 2015

Mette Thomsen and Lisbeth Gudik-Sørensen, The Danish AgriFish Agency

In 2013 the Danish AgriFish Agency received about 39.875 fertilizer accounts containing key figures on the use of nitrogen (commercial fertilizer and livestock manure). The accounts are registered and subject to inspection. The maps below are based on data on the number of agricultural holdings, number of livestock units (LU) and arable land in use in the year 2012/2013. A fertilizer account year runs from 1 August to 31 July. Accounts for 2012/2013 must be submitted to the Danish AgriFish Agency no later than 31 Marts 2014.

The data used in the maps are from these fertilizer accounts. In the fertilizer account the farmer has to state whether the derogation is used. The maps are drawn on the basis of these statements, which means on the basis of information reported by the farmers.

2.1 Map on Cattle Holdings 2012/2013

The map shows at municipality level cattle holdings encompassed by the derogation in percentage of the total number of agricultural holdings registered in the specific municipality.

For the year 2012/2013 1481 cattle holdings were encompassed by the derogation. This corresponded to 4 per cent of all registered accounts. The applied amount of manure on these farms ranges 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 must deliver the excess manure by contract to other farmers.

2.2. Map on Arable Land 2012/2013

The map shows at municipality level the arable land on cattle holdings encompassed by the derogation in percentage of the total agricultural area in the specific municipality.

For the year 2012/2013 the arable land on cattle holding encompassed by the derogation was 162,176 hectares. This corresponded to 7 per cent of all registered hectares.

2.3. Map on Livestock Units 2012/2013

The map shows at municipality level livestock units at cattle holdings encompassed by the derogation in percentage of the total number of livestock units in the specific municipality.

For the year 2012/2013 the number of livestock units on cattle holding encompassed by the derogation were 334,508 LU. This corresponded to 14.5 per cent of all registered livestock units.

2.4. Development in the use of the derogation

During the first three years where the derogation were in use, i.e. 2002/03, 2003/04 and 2004/05, an increase in the use of the derogation was recorded both regarding the number of farms, the number of hectares and the number of livestock unit. This tendency was broken in the period 2005/06, where a decrease was registered at all three measured parameters. In the period 2006/07 - 2008/09 a decrease in use of the derogation is seen for all parameters. Since then the number of derogations has increased every year. A reason for this can be that the calculation of LU was changed in 2008/09, which required more land for some derogation holdings. The period 2012-2013 shows a slight increase in the number of farms and a decrease in number of hectares and livestock units encompassed by the derogation. This could be explained by an increase in holdings splitting their activities into two holdings – one regarding the livestock and one regarding the arable land. See table 2.1 below.

Year	Number of farms	Number of farms, pct	Number of hectares	Number of hectares, pct	Number of livestock units	Number of livestock units, pct
2002/03	1,845	4	123,068	5	213,617	10.6
2003/04	1,927	4	128,523	5	225,586	10.6
2004/05	2,331	5	134,780	5	277,330	12.9
2005/06	1,779	3.4	115,336	4.2	220,839	10.3
2006/07	1,610	3.2	111,845	4.0	211,765	9.5
2007/08	1,296	2.8	92,282	3.9	186,313	8.3
2008/09	1,115	2.4	90,647	3.6	176,588	8.2
2009/10	1,507	3.3	134,698	6.1	276,765	11.9
2010/11	1,607	3.9	164,353	7.4	341,781	14.1
2011/12	1,652	4.0	175,783	7.1	365,887	15.5
2012/13	1,481	3.7	162,176	6.7	334,508	14.5

Table 2.1 Development in the use of the derogation regarding number of farms, hectares and LU

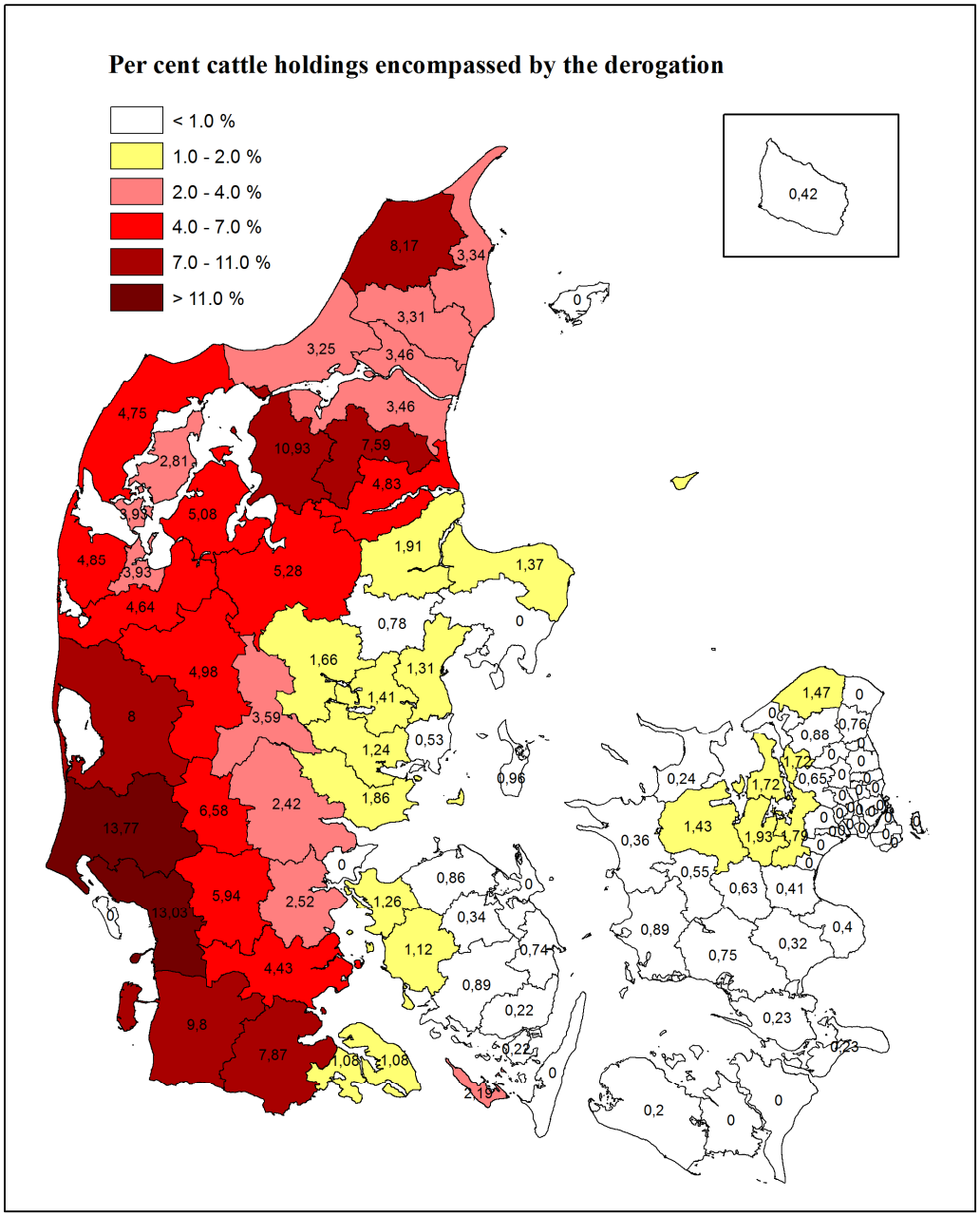
The average number of livestock units per farm has increased over the years and this also applies for 2012/2013, where a small increase is seen. The number of livestock units per hectare shows a slight decrease relative to the previous two years. See table 2.2.

Year	LU/holding	LU/hectare
2002/03	115.78	1.74
2003/04	117.07	1.76
2004/05	118.97	2.06
2005/06	124.14	1.91
2006/07	131.53	1.89
2007/08	143.76	2.02
2008/09	158.37	1.95
2009/10	183.65	2.05
2010/11	212.68	2.08
2011/12	221.48	2.08
2012/13	225.86	2.06

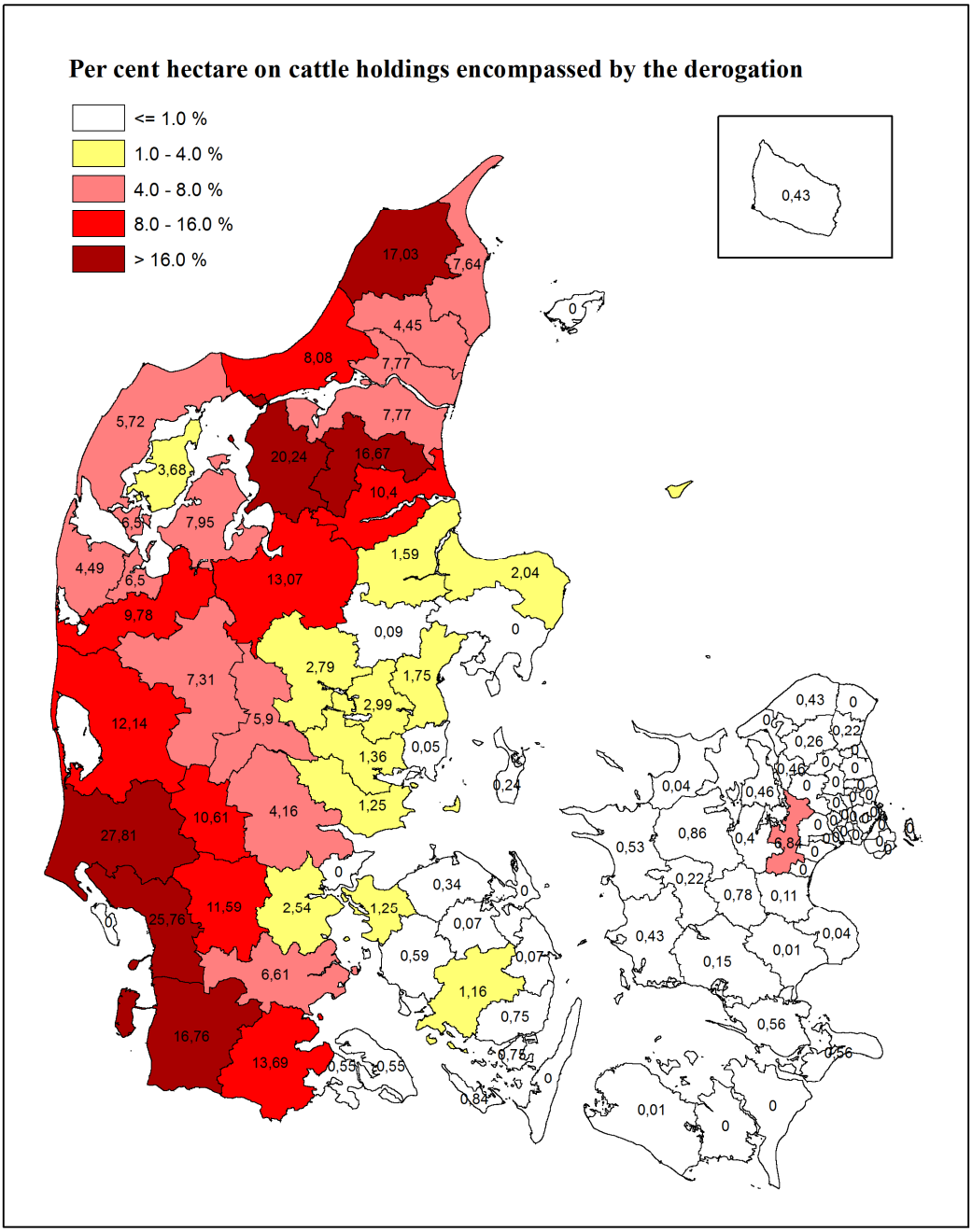
Table 2.2 Average number of livestock units per holding and per hectare under the derogation

The maps illustrate that cattle holdings encompassed by the derogation are concentrated in the western parts of Jutland, some on Zealand, and less on Funen and on the island of Bornholm.

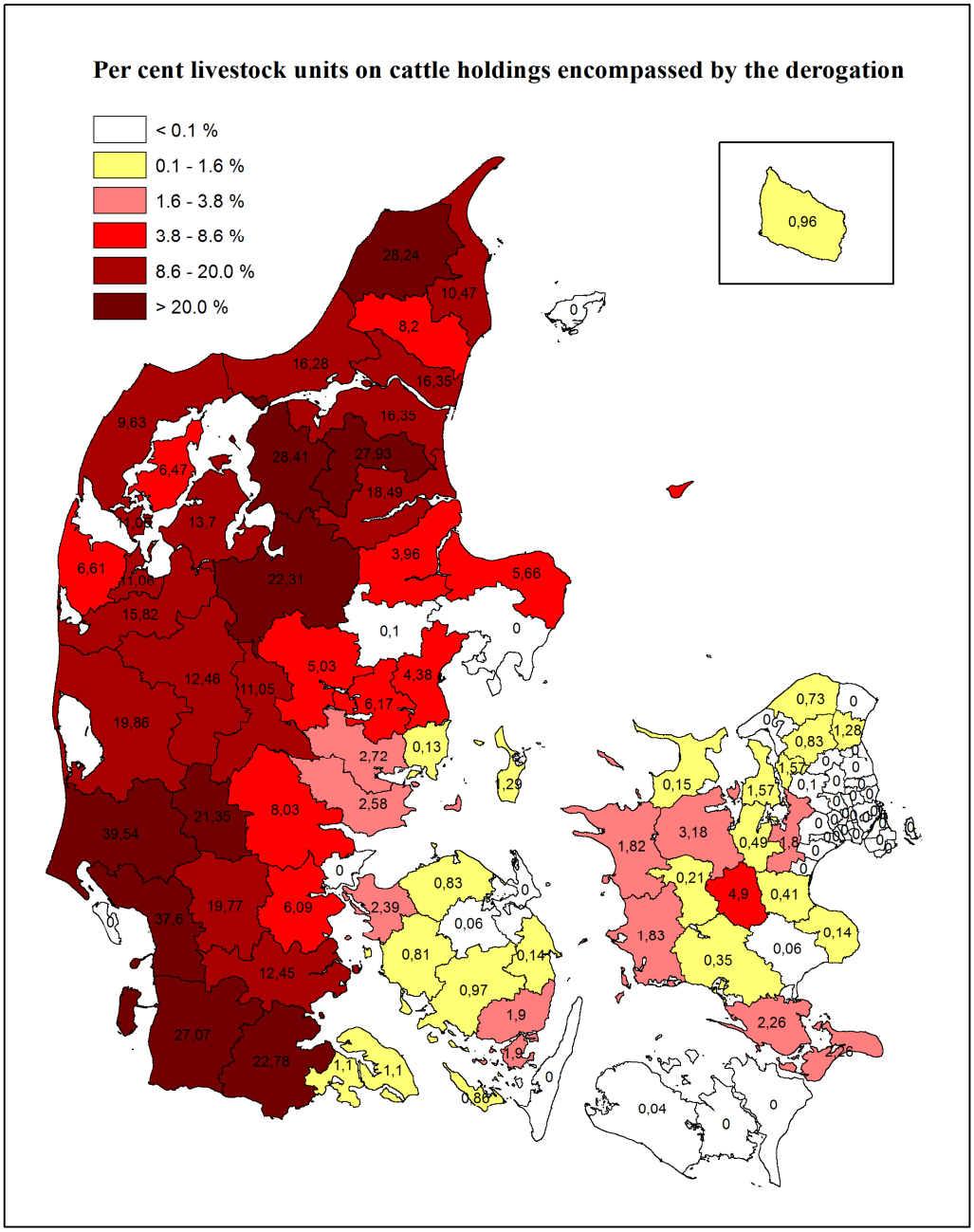
Year 2012/13 Cattle holdings encompassed by the derogation in percent of total number of agricultural holdings in Denmark



Year 2012/13 Arable land encompassed by the derogation in percent of total agricultural land in Denmark



Year 2012/13 Applied livestock units on farms encompassed by the derogation in percent of total applied livestock units in Denmark



3. Controls on farm level

January 2015

Mette Thomsen and Lisbeth Gudik-Sørensen, Danish AgriFish Agency,

3.1. Control of compliance with the Danish derogation

According to Article 8 of Commission Decision 2012/659/EC a concise report on evaluation practice (control at farm level) shall be transmitted every year to the Commission

Control of compliance with the Commission Decision 2012/659/EC follows two strategies.

1. Inspection of compliance with management conditions, which is carried out within the year the farmer uses the derogation. This includes 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: as a control at the farm of all parameters of the production and as an administrative inspection of submitted fertilizer accounts.

3.2. Summary of results of inspections in 2014

Compliance with management conditions:

- Inspection at the farm: 49 inspections were carried out. All farms complied with the derogation management conditions.

Compliance with the harmony rules for farms using the derogation:

- Inspection at the farm: 52 inspections were carried out. All farms complied with the specific rules for derogation farms, but 2 farms applied more manure than allowed.
- Administrative inspection: 40 inspections were carried out. 39 farms complied with the rules, and 1 farm did not.

3.3. Inspection of compliance within the derogation year

The Danish AgriFish Agency has carried out inspections of the Danish derogation on specific cattle holdings concerning the years from 2002/2003 until 2013/2014. The use of the derogation is based on the condition that the farmer complies with certain conditions. Some conditions have to be checked on site at the farm for example certain ploughing conditions. Therefore a physical inspection is carried out in January and February.

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

1. Do cattle make up 2/3 of the livestock units i.e. is the farm mainly a cattle holding?
2. Has a plan for crops grown in the actual planning period been drawn up?

3. Has the manager in the crop rotation plan stated that the farm intend to comply with the 2.3 LU per hectare derogation?
4. Does the plan contain leguminous and other crops fixing nitrogen, e.g. red clover and white clover?
5. Has a statement about manure application been made?
6. Does the plan include ploughing fields with grass or grass catch crops in the planning period?
7. If the answer is Yes in question 6: Are the fields ploughed at the time of inspection?

The inspection is based on an interview with the farmer, on inspection of the farm's crop rotation plan for the previous and coming growing season and on a visual inspection of fields viable for ploughing.

At the inspection the inspector draws up a report, which includes answers to the above mentioned questions. At the end of the inspection the farmer is informed whether the holding is allowed to apply manure comparable to 2.3 LU per hectare 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 per hectare. In this case the farmer has to find other 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. Instead an administrative control of the farm is carried out when the fertilizer account has been submitted. This control is carried out to secure that no more than 170 kg N per hectare was applied.

The inspection report is submitted by the inspector to the headquarters of the AgriFish 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 2014 the AgriFish Agency carried out 49 inspections on cattle holdings to inspect whether the conditions were met. The control refers to the fertilizer accounts of the year 2013/2014. Table 3.1 shows the results of the inspection for the last 10 years. Only very few remarks have been given and generally a good compliance with the rules can be seen.

Control year	Total number of inspections	Inspections without remarks	Inspections with remarks
2003	35	29	6
2004	46	46	0
2005	50	49	1
2006	50	49	1
2007	54	54	0
2008	47	46	1
2009	51	49	2
2010	50	50	0
2011	54	52	2
2012	49	49	0
2013	47	46	1
2014	49	49	0

Table 3.1 Development in results of Inspection of Compliance within the derogation year

3.5. General inspection of the harmony rules

Harmony rules

Control of 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, where the inspector visits the farm to inspect the production based on various documents. Violation of the harmony rules, i.e. the allowed amount of applied livestock manure per year, is sanctioned. For minor violations the farmer is imposed a warning. For more severe violations the farmer is imposed a fine. Both the farmers who receive warnings and the farmers who receive fines are reported for not complying with the cross compliance criteria.

Concerning the year 2011/2012 439 livestock holdings have been inspected for violation of the harmony rules, including the farms using the derogation. 11,8 % (52) holdings used the derogation. Of these derogation controls 96 % (50 holdings) were closed without remarks, 2 (3,8 %) is still under investigation. Both farms comply with the derogation rules, but has used to much manure. If a farm receives a warning or a fine it will be reported for not complying with the cross compliance criteria.

Control year	Total number of inspections	Inspections without remarks	Inspections with minor violations	Inspections with fines	Inspections still under investigation
2007	65	59	0	5	1
2008	27	22	2	2	1
2009	32	26	1	5	0
2010	27	24	1	2	0
2011	37	35	0	0	2
2012	52	50	0	2	0

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

Soil analysis

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

In Denmark the soil analysis for phosphorous (the phosphorous value) describes the soil's phosphorous status available for the plant. Internationally this equals to the Olsen-P. Olsen-P is often expressed in mg per kg soil. In Denmark phosphorous value is expressed in mg per 100 g soil. On average Olsen-P in Danish agricultural soil is around 40 mg P per kg soil (Pv. 4.0). When determining the phosphorous value only part of the plant's available content of inorganic phosphorous is extracted, this equals around 5-10 per cent of the total phosphorous content of the soil. A phosphorous value 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 phosphorous value level above 6 is considered very high.

The N-total is used to determine the crop demand, and describes the slow mineralization. In Denmark, depending on the C/N ratio in the soil, the standard is 0.13 %. If the level of N-total is 0.13 % the farmer cannot expect any N-supply from the mineralization. If the value is above 0.22 %, the level is high and expected mineralization is 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 10 kg N per hectare.

Results of soil analyses on farms using the derogation

For the year 2011/2012 the inspection of farms using the derogation showed that 67 % of the farmers used the derogation for the third consecutive year. Those farmers, 35 holdings, were

obliged to provide soil analysis. One holding got a remark regarding soil analysis and is still under investigation.

The results of the development of compliance with the requirement of soil analysis, when the derogation has been used for three consecutive years, are shown in table 3.3.

Control year	Number of inspections with need for soil analysis	Inspections without remarks	Inspections with remarks
2004/05	74	71	3
2005/06	18	16	2
2006/07	39	34	5
2007/08	16	12	4
2008/09	22	18	4
2009/10	11	9	2
2010/11	14	13	1
2011/12	35	35	0

Table 3.3 Development in results of Inspection of Compliance with the soil analysis requirement

The results of the soil analyses for phosphorous and nitrogen are shown in table 3.4.

Year		2008/2009	2009/2010	2010/2011	2011/2012
P value	Average	4.71	4.48	4.25	4.36
	Minimum	3.50	2.34	1.54	2.00
	Maximum	6.00	6.82	5.60	6.40
N-total	Average	0.25	0.25	0.4	0.60
	Minimum	0.18	0.11	0.17	0.11
	Maximum	0.52	0.86	1.35	2.39
N in grass fields	Average	0.32	0.21	0.52	0.36
	Minimum	0.31	0.13	0.19	0.01
	Maximum	0.32	0.55	0.85	1.10

Table 3.4 Phosphorous and nitrogen levels in soil analyses.

3.6. Control of fertilizer accounts

Each year the farmers submit a fertilizer account to the Danish AgriFish 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),
- consumption of livestock manure including manure contracts,
- consumption of fertilizers and organic matter other than livestock manure,
- the farm's nitrogen quota[2] and
- information on whether the farmer has used the derogation or not.

For the year 2011/2012 856 (2,1 %) of the submitted fertilizer accounts were subject to administrative inspection. 55 fertilizers accounts remains to be investigated. The data was verified and the parties of interest were allowed commenting on the case. The accounts were selected based on different risk criteria. In 2011/2012 40 (4.5 %) holdings using the derogation were selected for more thorough control. They were asked to submit the crop rotation plan and a statement about manure application. It was controlled whether the crop rotation plan included 70% nitrogen consuming crops with long growing season and whether it didn't include leguminous or other plants fixing atmospheric nitrogen. If the derogation has been used for three consecutive years the farmer must submit the results of soil analysis. Also the share of cattle on the farm was controlled.

Results

Of the 40 controls based on harmony risk criteria, 39 holdings (98 %) were closed without remarks, 1 holdings (2%) were fined because of severe violations. The farm receiving a fine has been reported for not complying with the cross compliance criteria.

All of the holdings using the derogation met the criteria.

Control year	Number of inspections	Inspections without remarks	Inspections with remarks
2009/10	38	34	0
2010/11	68	68	0
2011/12	40	39	1

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

[2] The allowed nitrogen quota for the crops is set to a level at least 10 per cent lower than the economical optimal level.

4. Water quality

Gitte Blicher-Mathiesen, Department Bioscience, University of Aarhus, February2015

According to Article 7(2) and Article 7(3) of Commission Decision 2012/7182/EC Denmark shall deliver maps at municipality level showing the percentage of farms with derogation, their number of livestock and crop cover. For level and trends in nitrate and phosphorous concentrations survey and continuous analysis shall be carried out in the national monitoring program on sandy and loamy soils providing data on local land use, crop rotations and practices on cattle holdings. These data can be used for model-based calculations of the magnitude of nitrate leaching from fields where up to 230 kg nitrogen in livestock manure is applied.

According to Article 7(2) a network of sampling of soil water and streams and of shallow groundwater established as agricultural catchment monitoring sites under the national monitoring program shall be maintained to provide data on state of nitrate and phosphorous content in water leaving the root zone and entering the groundwater system, in order to prove that the derogation will not jeopardise the objective of the national action program and the Directive.

According to Article 9 maps at municipality level showing the percentage of farms with derogation, their number of livestock and crop cover and the results of the monitoring shall be transmitted every year to the Commission with a concise report on water quality evolution (based on monitoring of root zone leaching, surface/ground water quality and on model-based N-leaching calculations).

4.1 Introduction

Action Plan II

With the aim of fulfilling the obligations pursuant to the Nitrates Directive (91/676/EEC) the National Action Plan II 1999-2003 (Action Plan II for the Aquatic Environment) was adopted in 1998. In 2003 a final evaluation of Action Plan II showed that the annual nitrate leaching from agriculture was reduced from 311 000 to 162 000 tonnes N during the period 1985-2003, corresponding to a reduction of 48 % (table 4.1) and thus fulfilling the reduction target set in 1989.

Table 4.1. Overview of reduction in nitrogen use in agriculture and modelled nitrogen leaching during the period 1985-2003. Statistical data were available for 1985-2002, and monitoring data for 1990-2002 whereas the effect for 2003 was based on a prognosis.

	Reduction in nitrogen
Evaluation of Action Plan II, 1985-2003	
Modelled nitrate leaching, based on agricultural data, 1985-2002	42%
Prognosis for further reduction in nitrate leaching 2003	6%
Prognosis, 1985-2003	48%
Agricultural statistics (national level 1985-2002)	

Reduction in use of inorganic fertilisers	49%
Reduction in total nitrogen surplus in agriculture	37%

Action Plan III and Green Growth Agreement

In 2004 the Action Plan III for the aquatic environment was adopted, the aim being a further reduction in nitrate leaching of 13% compared to the N-leaching in 2003. The target was to be attained by 2015. The measures for nitrogen included among others further restoration of wetlands and tightened requirement to grow catch crops.

In 2008 a midterm evaluation of Action Plan III was performed. It included a recalculation of the nitrate leaching for 2003 using updated modelling systems. The revised estimate was a nitrate leaching at the national level of 161,000 tonnes N in 2003. Furthermore, the evaluation showed that there was not yet any significant decrease in modelled nitrate leaching during 2003-07, and that it was unlikely that the aim would be fully attained in 2015 (table 4.2).

Table 4.2 Midterm evaluation of Action Plan III in 2008, showing the aim and the prognosis for nitrate leaching in 2015.

	Aim of VMP III 2004-2015		**Prognosis 2004-2015**	
	Area assignment (ha)	**Reduced N-leaching (tons N)**	**Area (ha)**	**Red. N-leaching (tons N)**
General development in agriculture		11.200		2,000
Afforestation	22,800	900	22,800	0
Restoration of wetlands (required N reduction 200-500 kg N/ha)	4,000	1,050	4,000	980
Environmentally friendly agriculture (wetlands required N reduction 100 kg N/ha)	4,000	400	-	150-250
Strengthened requirement to grow catchcrops	125,000	4,600	70,000	2,000
Strengthened requirement to utilize nitrogen in mink-slurry		100		130
Total		Ca. 18,000		Ca. 5,300
Technical possibility to increase the utilisation of nitrogen in manure and slurry by 4,5-5%		2,900		1,600
Cultivation of previous set-aside				-(300-500)

As a consequence, the Action Plan III was replaced by the Green Growth Agreement in June 2009. This plan demonstrates a new concept for nutrient regulation. The previous action plans provided goals for the reduction of nitrogen leaching from the root zone whereas the aim of Green Growth Agreement is to reduce the annual export of nitrogen to marine waters by 19,000 tonnes N, and to reduce the annual emission of phosphorus from agriculture by 210 tonnes P. Following measures are to reduce nitrogen export by 9,000 tonnes N in 2015:

- establishment of further 140,000 ha targeted catch crops

- tightened regulation on existing catch crops, from the harvest year 2011
- restoration of further 10,000 ha wetlands for N reduction (+ 3,000 ha for P reduction), continuous process
- establishment of 10 m buffer zones along rivers and lakes, equivalent to app. 50,000 hectares agricultural land, from the autumn 2012
- ban on certain forms of soil cultivation in the autumn, from the autumn 2011
- ban on ploughing grass fields at certain periods of the year, from the autumn 2011

The measures have been implemented stepwise from the autumn 2011 and onwards (table 4.3). The modelled nitrate leaching was calculated to be 163,000 – 165,000 tonnes N in the period 2007-2011 giving no further reduction for this period (Børgesen et al., 2013). For the same period the annual N-surplus for the agricultural production has decreased by 32,000 tonnes N, the differences between the two estimates are mainly allocated to an actual increase in harvest products from the

Table 4.3 Effect of implemented measures from Green Growth on nitrate leaching in the period 2007-2011 and prognosis for planned measures also in Green Growth in the period 2012-2015.

	2007-2011		Prognosis 2012-2015	
	Area (ha)	Red. N-leach. (tonnes N)	Area (ha)	Red. N-leach. (tonnes N)
Reduction in N-quota/decrease in the agri. Area	8,300	417	33,800	1,690
Afforestation	1,700	83	6,200	310
Conversion to bioenergy crops	1,600	63	2,300	72-92
Catch crops, alternatives included	112,500	3,717	140,000	4,600[1]
Ordinary catch crops	83,900			
Alternatives to catch crops (effect in hectare catch crop) :	28,600			
Reduction in farm N-quota	12,720			
Crop between harvest and sowing of the next crop	14,924			
Catch crop implemented on other farms	2,163			
Crops for energy production	5,736			
Separation and burn of the fibre fraction in manure	20			
Ban on soil cultivation in autumn			124,000	1,200
Ban on ploughing grass fields at autumn			32,000	1,200
Conversion to organic farming	26,000	240-480	26,000	240-480
Protection of areas for drinking water and nature	5,100	-26		143
Wetlands	1600	218	11,600	1,312
Re-established streams, lakes, riparian areas	n.d.	563		
Regulation of livestock				240-270
Establishment og 10 m buffer zones along rivers			52,000	1,300-2,500

agricultural area in this period (Blicher-Mathiesen et al., 2014). Increase in harvest yield for grass is allocated to a better utilization of the nitrogen in grass as management has changed from grazing to cutting. Modelled nitrate leaching was performed at average yield and climatic conditions and therefore the increase in harvest product was not included in data for the modelled nitrate leaching.

The 2nd April 2014 the Danish government published the political agreement "Growth Plan for Food". This plan included halving the area with buffer strips along water courses and lakes plus a change of the targeted catch crops from GGA into a general rule for all farmers. This lowered the number of catch crops from 140,000 to 60,000 ha.

This chapter consists of three parts:
First, a general development in agricultural practices at the national level is presented for the period 2005-2013. This analysis is based on national registry data sets from the Ministry of Agriculture, i.e. the single payment register and the fertilizer accounts.

Second, modelled nitrate leaching, including the crop distribution and the nitrogen balances are presented for various farm types and geographical areas, and the impact of derogations farms are analysed. This analysis is based on a data set originating by a linkage of data from the single payment register and the fertilizer accounts for 2013.

Third, measurements of water quality from the National Monitoring Programme are presented for the period 1990/91-2012/13, with particular reference to the Agricultural Catchment Monitoring (Blicher-Mathiesen et al., 2015). 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 flow to surface water in 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. The model requires input data for agricultural practises (N fertilisation, cropping system), soil data and the water percolation from the root zone. The 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 at a standardised climate (water percolation). In contrast, all measurements from Agricultural Catchment Monitoring represent nitrate leaching under the actual climatic conditions.

4.2. Development in agricultural practices at the national level from 2005-2013

The development in crop distribution for 2005-2013 was analysed on basis of the single payment registration. The results are shown in figure 4.1 for cash crops, fodder crops and non-cultivated areas. The year 2005 was the first year with the single payment and it is anticipated that the reporting of areas was overestimated. Hereafter, the total reported agricultural area including set-aside has decreased from approximately 2,757,000 ha in 2006 to 2,681,000 ha in 2013.

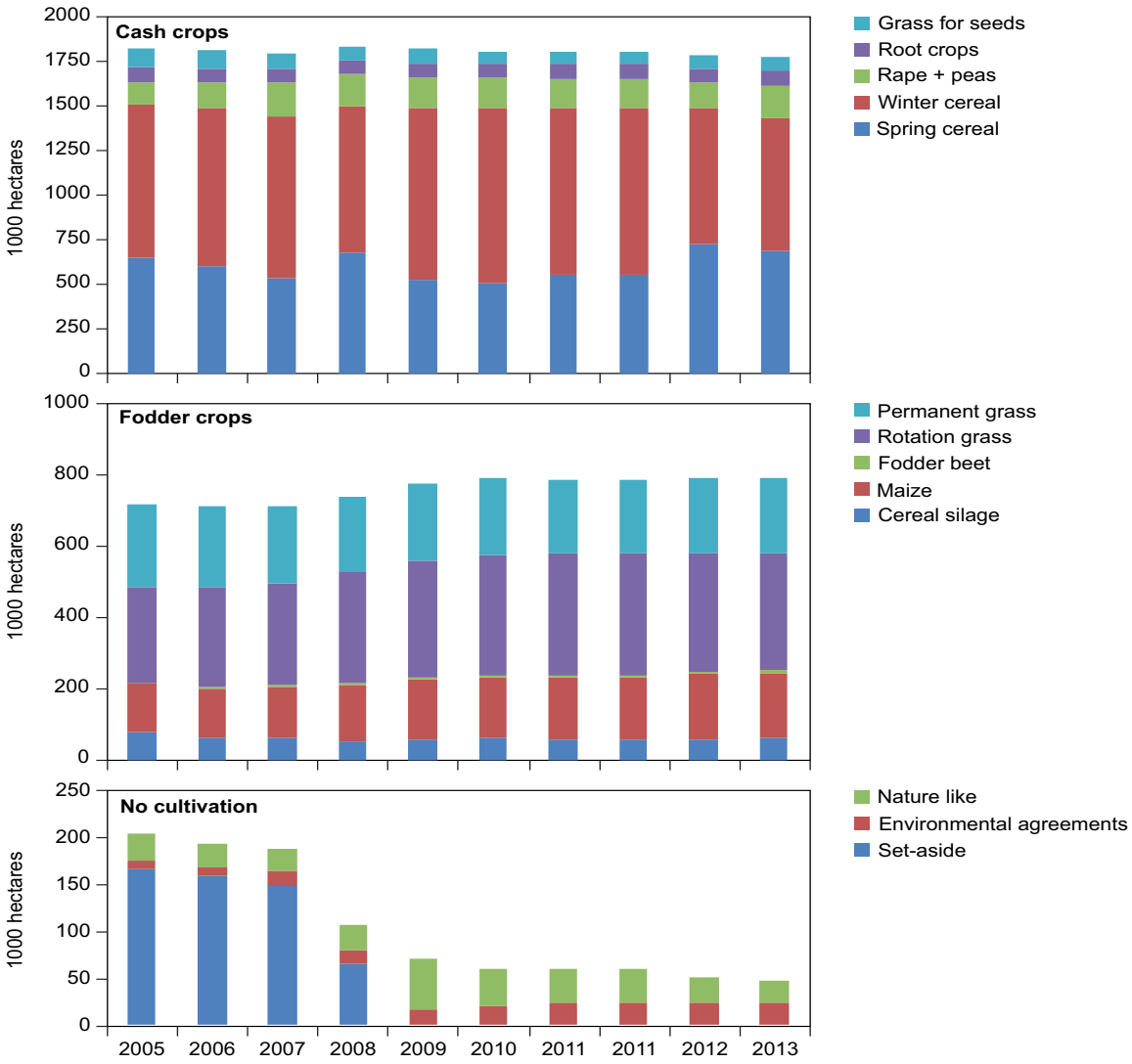


Figure 4.1. Development in crop distribution at the national level 2005-2013, data from the single payment register.

The decrease of about 12,600 ha per year is due to assignment of area for road-networks, towns etc. During the years 2006-07 set-aside comprised about 160,000 ha. From 2008 the set-aside obligation ceased and in 2008 and 2009 this area was converted to cash crop, fodder crops and nature-like areas. This has resulted in an increase in the area with fodder crops (about 80,000 ha), particularly in rotation grass and maize, and an increase in nature-like areas (about 25,000 ha) from 2007 to 2010. The area with cash crops has decreased slightly over the years as a result of area taken out for road-networks, etc. In 2012 the area with spring cereal was considerably higher and the area with winter cereal correspondingly smaller than in the previous years. This is due to a very wet autumn in 2011, preventing the farmers from sowing of winter cereal.

In Action Plan III the demand on growing catch crops was continued from the former Action Plan and stipulated that farmers in 2005-2009 must grow catch crops on at least 6% of the potential catch crop area if they apply less than 80 kg organic manure N ha^{-1} and on 10 % of the area if they apply more than 80 kg organic manure N ha^{-1}. From 2010 a further requirement of 4 %-point was planned. However, this strengthened requirement to grow catch crops was stepped up in 2008 in order to counterbalance the effect of the cease of the set-aside obligation. On the other hand, during this period (2005-2010), farmers who grew winter crops (wheat, rye, oilseed rape) so that the requirements to establish catch crops could not be fulfilled were granted a reduction in the required catch crop area. From 2011 this possibility ceased. This implied that some farmers had to alter their crop rotation from winter to spring crops. At the same time also 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 animal manure

Data from the fertilizer accounts show that establishment of catch crop has increased from about 118,600-138,000 ha in 2005/06-2007/08 to about 224,000 ha in 2012/13 (table 4.4). In 2011 the introduction and use of catch crop alternatives resulted in an equivalent of further establishment of 28 600 and 44 000 ha catch crops in 2011/12 and 2012/13, respectively.

Table 4.4. Development in area with catch crops and catch crop alternatives (hectares) reported by the farmers in the annual fertilizer account in the period 2005/06-2012/13s.

	2005/06	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**2010/11**	**2011/12**	**2012/13**
Catch crops	138,000	118,600	127,200	196,600	183,000	211,000	211,000	224,000
Catch crop alternatives	0	0	0	0	0	0	28,600	44,000

Data for use of nitrogen in animal manure is calculated on the basis of fodder utilisation per livestock and the number of livestock (Statistics Denmark) whereas the annual use of inorganic fertilizers is obtained from the fertiliser accounts (table 4.5).

The analysis shows that the use of animal manure was almost constant throughout the years, 2005-2011, though there were some year to year variations. The use of inorganic fertilizers amounted to about 181,000-202,000 tonnes N $year^{-1}$ in 2005-2007, and increased to 205,000 and 209,300 tons 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 fertiliser requirements must be followed by an equivalent reduction in nitrogen standards. However, this reduction must be based on statistical data for the cultivated area resulting in a delay of two years. Thus, in 2010-2013 the use of inorganic fertilizers has decreased again to the same level as in 2005-2007.

Table 4.5. Development in use of inorganic nitrogen fertiliser as reported by the farmers in the annual fertilizer status accounts and the use of nitrogen in animal manure as stated in the national statistics for the period 2005-2013 (1000 tonnes N per year)

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Fertiliser	198	181	202	205	209	198	203	198	199
Animal manure	227	219	237	230	226	224	228	*	*

**Data not yet available*

4.3 Modelled nitrate leaching for farm types and geographical areas, and the impact of derogations farms at the national level, 2012 data

Modelled nitrate leaching is an effect of the crop distribution, nitrogen input, soil type, and water percolation through the soil. Therefore, this section includes a presentation of all these parameters. The analyses are based on the national data sets from the single payment register and the fertilizer accounts. However, before data can be used for this purpose, a detailed data compiling of the two data sets must be undertaken (Børgesen et al., 2009). The single payment register contains information on crops at field-block level, and the fertiliser accounts contain information on use of nitrogen (inorganic fertilizer and organic manure) at the farm level. The two datasets are linked by means of the common farm identity number, and the reported amount of fertilizer and the manure from the individual accounts are divided between the fields of each farm according to the crop nitrogen standards. Hereby, we obtain a data set with coherent data for crops and nitrogen application at the field level. We have no information on grass-ley from either data set. Therefore, we estimate this parameter based on the area with rotation grass, assuming a conversion rate of 3 years. If there is not enough space in the crop rotation, the area with grass-ley is reduced accordingly. Data for 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 data set now contains all necessary information for geographically distributed computation of crops, field nitrogen balance sheets and of modelled nitrate leaching.

Farm type

The data are divided into 3 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 animal units originate from pigs and a cattle farm where more than 2/3 of the animal units originate from cattle. An arable farm is a farm with less than 2 LU but the farm may import animal manure which will figure in the fertilizer account and is therefore included in this analysis. Other farm types are not included in this analysis.

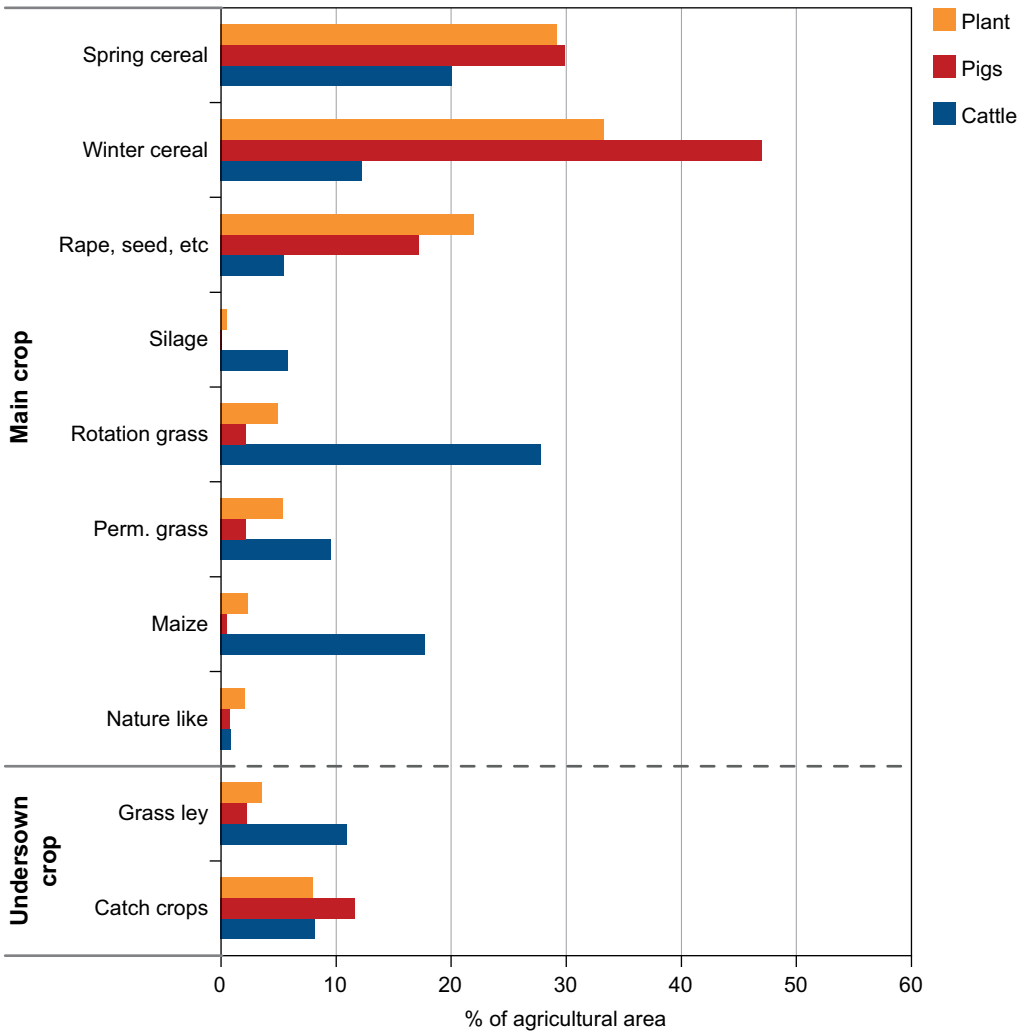


Figure 4.2. Crop distribution for three main farm types in 2013, combined data set from the single payment register and the fertilizer status accounts

Figure 4.2 shows that arable farms and pig farm grow cereals, and particularly winter wheat, on the majority of the agricultural area (62-77 %). Other cash crops, i.e. oilseed rape, peas, root crops (potatoes and sugar beet) and grass for seeds, are also major crops (17-22 %). Cereal silage, grass and maize take up a minor part of the area (5-13%). Catch crops are grown on 8-12 % and grass-ley on 2-4 % of the agricultural area.

Cattle farms have a different crop rotation. Cereals and other cash crops are grown on 32 % of the area whereas cereal silage, grass and maize are grown on 61 % of the area. Fodder beet is grown on 0.5 % of the area. In addition grass-ley is found on 11 % and catch crops on 8 % of the area.

Animal manure is applied in an amount of about 44 kg N ha^{-1}on average on arable farms, 95 kg N ha^{-1} on pig farms and 123 kg N ha^{-1} on cattle farms (table 4.6). The use of inorganic fertilizers decreases with increasing application of animal manure. Total inputs of nitrogen from inorganic fertilizer, organic manure, other organic sources, N-fixation and atmospheric deposition add up to 166, 184 and 233 kg N ha^{-1} for arable farms, pig farms and cattle farms, respectively. The N balances, calculated as the difference between total input of nitrogen and removal by harvested crops are 67, 84 and 97 kg N ha^{-1} for arable farms, pig farms and cattle farms, respectively. As expected modelled nitrate leaching is lower for arable farms (56 kg N ha^{-1} on average) than for animal husbandry farms (67 kg N ha^{-1} on average). The average leaching on pig farms and cattle farms is at the same level, despite a larger N input and N balances for cattle farms than for pig farms. This is because the cattle farms grow a high proportion of fodder crops, with a long growing season and therefore a large N uptake.

On arable farms the modelled nitrate leaching amounts to 90 % of the calculated N balance which seems rather high. It may be that leaching on these soils with low input of organic manure is affected by mineralisation of the organic pool. However, the high leaching rate may also be caused by the uncertainties associated with the two separate calculations.

The water percolation through the soils is considerably higher on cattle farms than on arable and pig farms. However, this is not due to differences in farm type, but is because the cattle farms are

Table 4.6 N-inputs, N-balances and nitrate leaching for three main farm types in 2013, combined data set

	Comm. fertiliser	Animal manure	Other org.	N-fix.	N-depos.	Total input	Har-vest	N balance	Per-col.	N-leach	NO3-conc
	---------- kg N ha^{-1} ----------								mm	kg N ha^{-1}	mgl^{-1}
Arable	94	44	4,8	7,6	13	166	99	67	336	56	74
Pigs	69	95	1,2	4,0	14	184	101	84	382	67	77
Cattle	62	123	1,2	31	15	233	137	97	414	67	71

located mainly in the western part of the country with more sandy soil and higher rainfall, and consequently higher percolation. The higher percolation on the cattle farms leads to a dilution of the nitrate concentration in the soil water. Thus, the modelled average nitrate concentrations in soil water are 74-77 mg NO_3 l^{-1}on arable and pig farms, respectively, and 71 mg NO_3 l^{-1}on cattle farms.

Geographical areas

As mentioned above the farm types are not evenly distributed throughout the country because of variation in farming conditions. We have therefore divided the country into 5 parts (figure 4.3). Table 4.7 shows that Sealand 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 the loamy soils and with low rainfall, whereas cattle farms are located mainly in the northern and western parts with sandy soils, and a higher rainfall, and with the rainfall increasing from North to South.

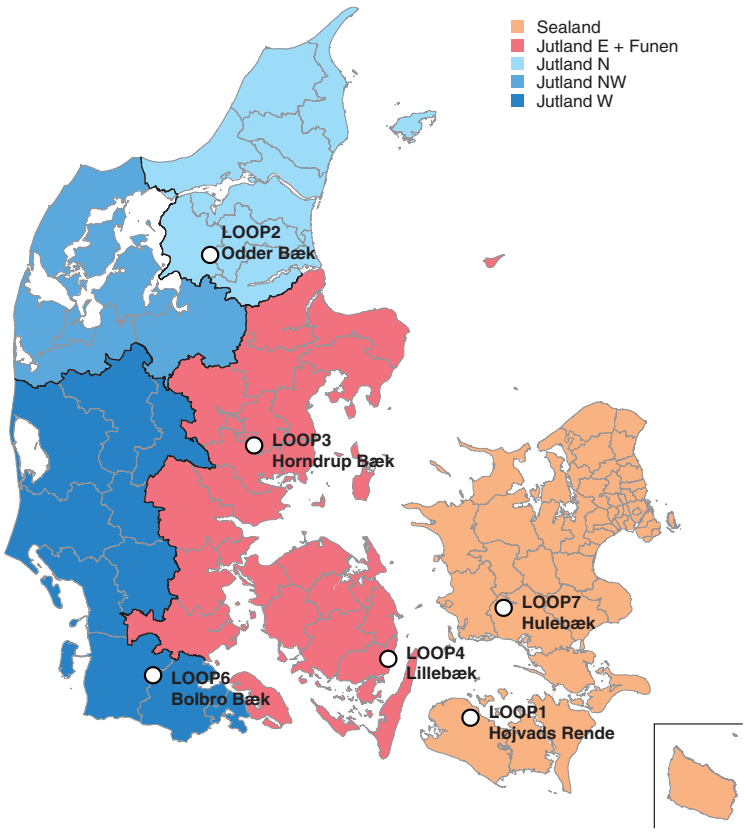


Figure 4.3. Five areas of Denmark with different soil type, farming practise and rainfall, and the position of the six monitored agricultural catchment

Table 4.7. Distribution of farm types and soil types and the water percolation through the soils in Denmark divided into five main geographical area, 2013

	Arable	Pig	Cattle	Other	Sand	Loam	Humus	Percol.
	% of agricultural area				% of agricultural area			mm/year
Sealand	60	15	15	10	5	92	3	203
Jutland E+ Funen	38	28	25	9	26	70	4	336
Jutland N	31	19	38	12	80	10	10	365
Jutland NW	23	26	42	10	62	33	5	451
Jutland W	27	17	46	10	76	18	6	542

The crop distribution within the five parts of Denmark follows the same pattern as seen for the farm types, ie. with mainly cereals and other cash crops on the Islands and Eastern Jutland and with cereals and fodder crops in West to North Jutland (figure 4.4).

The input of nitrogen in animal manure, the total nitrogen input and the field nitrogen balances are lowest on Sealand, higher in E Jutland and Funen and highest in W, NW and N Jutland (table 4.8). In the latter three areas the nitrogen inputs are almost similar. The modelled nitrate leaching generally increases from the East to the West due to increases in nitrogen input and percolation. Within the three western-northern parts of Jutland, the nitrate leaching increases from the North to the South mainly due to the increased water percolation through the root zone. Higher water percolation leads to dilution of the nitrate concentrations of the soil water, resulting in an average concentration in soil water of 83, 75-76 and 65-69 mg N/l in Sealand, Funen + E and N Jutland , and NW and W Jutland, respectively.

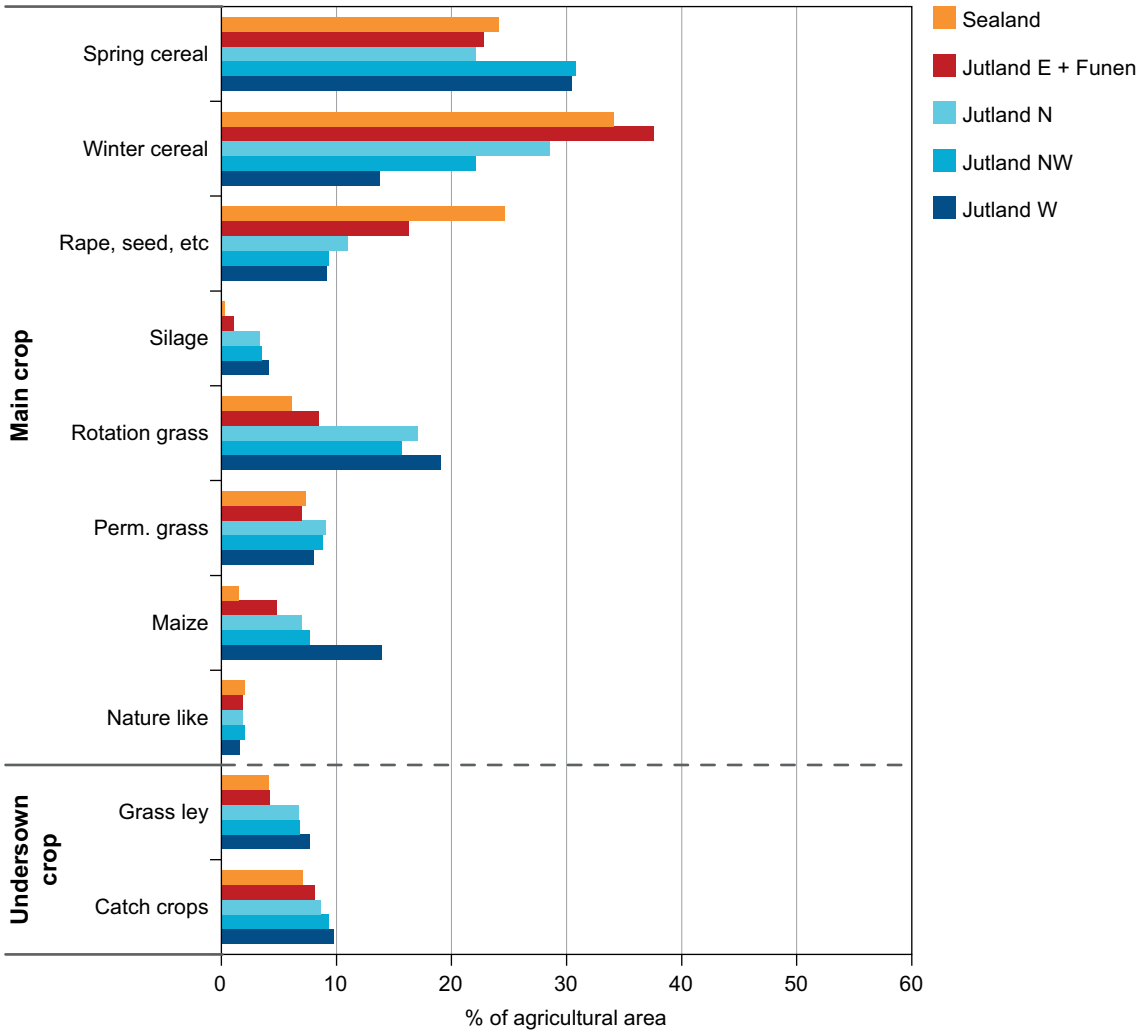


Figure 4.4. Crop distribution for five geographical areas in Denmark in 2013, combined data set from the single payment register and the fertilizer accounts

Table 4.8 N-inputs, N-balances and nitrate leaching for five geographical areas in Denmark in 2013, combined data set from the single payment register and the fertilizer accounts

	Comm. fertilizer	Animal manure	Other org. N	N-fix.	N-depos.	Total input	Harvest	N balance	Percol	N-leach	NO3-conc
	---------- kg N ha^{-1} ----------								mm	kg N ha^{-1}	mg l^{-1}
Sealand	103	34	4	9	12	163	106	57	201	38	83
Jutl. E+Funen	81	72	2	11	14	183	107	76	336	57	75
Jutland N	61	99	2	19	14	196	109	86	365	63	76
Jutland NW	54	106	1	19	14	195	111	84	452	71	69
Jutland W	58	107	3	21	16	207	119	89	543	80	65

Derogation farms

Derogation farms are mainly located in N, NW and W Jutland where also cattle farming is dominant (see chapter 2). The effect of the derogation is evaluated for these three geographical areas. The cattle farms are grouped into 4 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 are almost identical; hence the average crop distribution for 2013 is shown in figure 4.5. There is a clear trend, that the area with cereals and other cash crops decreases with increasing livestock density, and in turn that the area with fodder crops increases with increasing livestock density. The area with roughage amounts to 50, 70 and 71 % for the three groups, 0-1.0, 1.0-1.4, 1.4-1.7 LU ha^{-1}, respectively, whereas derogation farms grow roughage on an average of 81 %.

The effect of the derogation on nitrate leaching is evaluated for the three geographical areas separately. The nitrogen input as well as the field nitrogen balances increase with increasing livestock density (table 4.9). 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 4.9 shows that modelled nitrate leaching generally increases with increasing livestock density and hence with increasing nitrogen input. Thus, the modelled nitrogen leaching is 3-7 kg N/ha higher for the derogation farms than for farms using 140-170 kg N ha^{-1} of organic N. Similarly, the nitrate concentrations in the soil water of derogations farms are 5-8 mg NO_3 l^{-1} higher than for cattle farms using 140-170 kg organic N/ha.

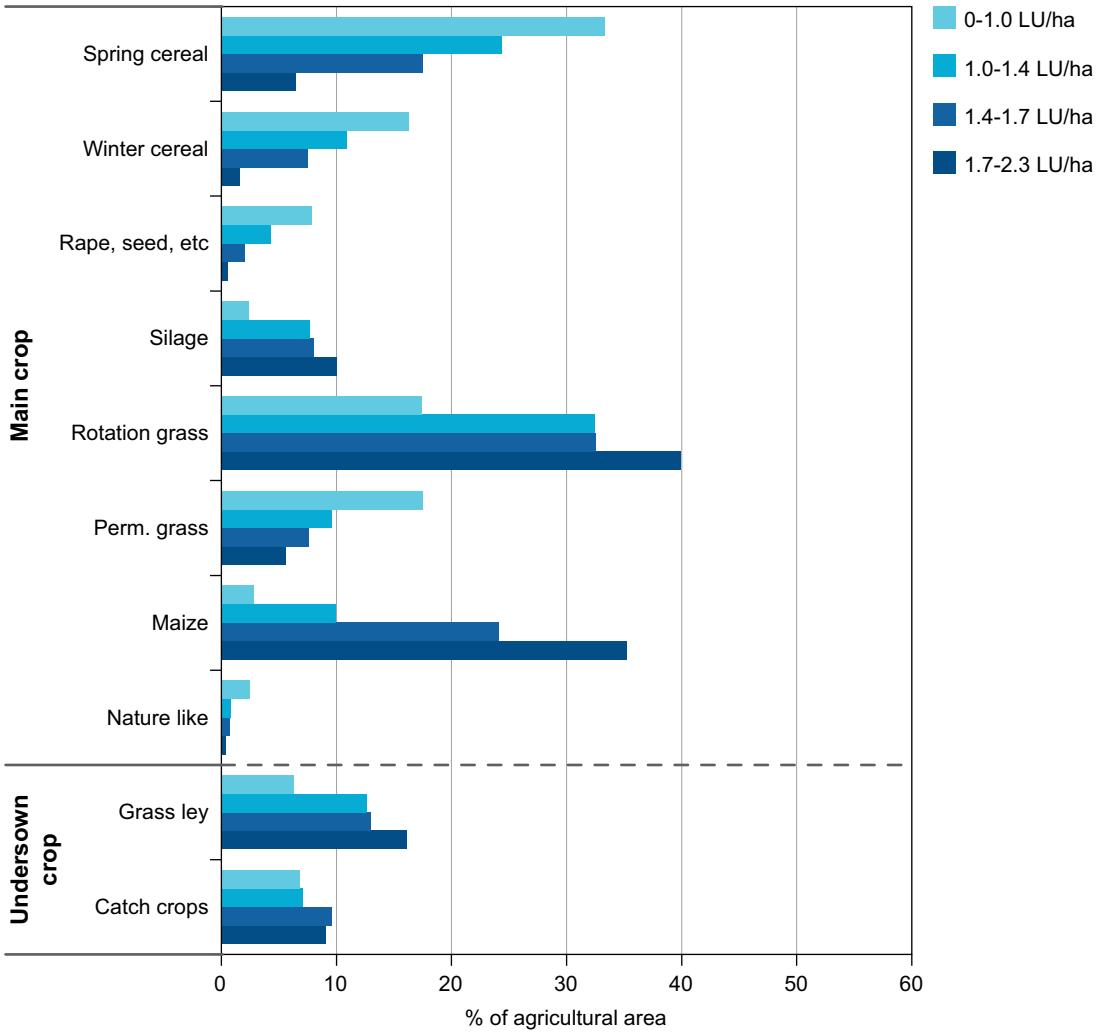


Figure 4.5. Average crop distribution for four groups of livestock density in N, NW and W Jutland in 2013, combined data set from the single payment register and the fertilizer status accounts

Table 4.9 N-inputs, N-balances and nitrate leaching for four groups of livestock density at cattle farms in three geographical areas in Denmark in 2013, combined data set from the single payment register and the fertilizer status accounts

Region	Live-Stock density	Comm. fertliser	Ani-mal manure	Other org. N	N-fix.	N-depos.	Total input	Har-vest	N balance	Percol	N-leach	NO3-conc
	LU/ha	---------- kg N ha^{-1} ----------								Mm	kg N ha^{-1}	mg l^{-1}
Jutland N	0-1.0	73	56	2	20	13	166	97	68	357	54	67
	1.0-1.4	50	121	0	39	14	225	129	96	358	58	72
	1.4-1.7	62	149	0	40	14	266	153	113	354	67	84
	1.7-2.3	53	195	0	45	14	307	173	134	348	71	90
Jutland NW	0-1.0	73	59	1	17	14	166	97	69	432	59	61
	1.0-1.4	41	122	0	40	14	218	127	91	457	66	64
	1.4-1.7	58	148	0	36	14	258	150	108	444	75	75
	1.7-2.3	48	194	0	42	14	299	168	131	421	78	83
Jutland W	0-1.0	75	59	6	20	16	176	107	70	532	68	56
	1.0-1.4	36	123	1	46	16	223	135	88	538	69	57
	1.4-1.7	65	152	2	33	16	269	157	112	547	89	72
	1.7-2.3	58	198	0	33	16	307	178	129	549	96	77

The use of legumes (clover, alfalfa, peas) in grass and cereal silage is shown in table 4.10. The general trend is that derogation farms apply legumes to a slightly less extend than non-derogation farms (table 4.10). Thus, clover or alfalfa in rotation grass is used on 75% of the grass area for derogation farms and on 76-90 % for non-derogation farms. For permanent grass the similar values are 24% for derogation farms and 34-54% for non-derogation farms. And cereal silage with peas amounts to 24% of the silage area for derogation farms and 12-29% for non-derogation farms.

4.4 Development in modelled nitrate leaching in the Agricultural Catchment Monitoring Programme, 1990-2013

This section deals with the general development in nitrate leaching from 1990 to 2013. Information on agricultural practises is supplied from the Agricultural Catchment Monitoring Programme. This programme is carried out in 6 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 fertilisation and cultivation practises. Nitrate leaching is modelled for every field in the catchments based on the information on agricultural practises and standard percolation values calculated on basis of the average climate for 1990-2010.

Table 4.10 The use of legumes in grass and cereal silage at cattle farms for derogation and non-derogation farms, 2013.

	LU/ha			
	0-1.0	1.0-1.4	1.4-1.7	1.7-2.3
		% of agric area		
Rotation grass	13.9	30.0	29.7	38.4
		% of rotatoin grass		
No clover/alfalfa	21	9	17	25
< 50% clover/alfalfa	77	90	83	75
> 50% clover/alfalfa	2	1	1	0
		% of agric area		
Permanent grass	14.9	9.5	6.9	5.1
		% of permanent grass		
No clover/alfalfa	45	58	66	74
< 50% clover/alfalfa	55	42	34	26
> 50% clover/alfalfa	0	0	0	0
		% of agric area		
Cereal silage	1.6	6.8	6.7	5.1
		% of cereal silage		
No legumes	81	56	68	74
< 50% legumes	12	27	26	26
100% legumes	7	17	7	0

In 2013 114 farmers participated in the investigation. 17 farms were cattle holdings, and of these 3 were registered as derogation farms. These farms covered 5.8 % of the total area in 2012/13 which is equivalent to the national level at 6.1 % of the total derogation area for 2012/13.

The development in modelled nitrogen leaching from the agricultural area in the catchments from 1990 to 2013 (representing the hydrological years 1990/91 to 2013/14) is shown in figure 4.6 as an average for sandy and loamy catchments, respectively. If weighted in accordance with the distribution of the main soil types in Denmark it was found that modelled nitrate leaching was reduced by 43 % during the period 1991 to 2003 due to the general improvement in agriculture and fertilisation practise (Action Plan I+II). After 2008 there was a small increase in nitrate leaching, particularly on the sandy soils, probably caused by the cease 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 fertiliser application. After 2011 the modelled nitrate leaching for the sandy soils reached the same level as before 2008. For the loamy soils modelled nitrate leaching was less affected during the years 2008-2013.

For 2013 the nitrate leaching was estimated to be 51 and 83 kg N ha^{-1} for loamy and sandy soils, respectively.

The purpose of this modelling is to show the effect of measures introduced in agriculture. The modelling is therefore carried out for normalised growth conditions, i.e. for climatic data representing measurement in 1990-2010 and for average crop yields. Actual measurements may show annual variations from this trend depending on the actual climate.

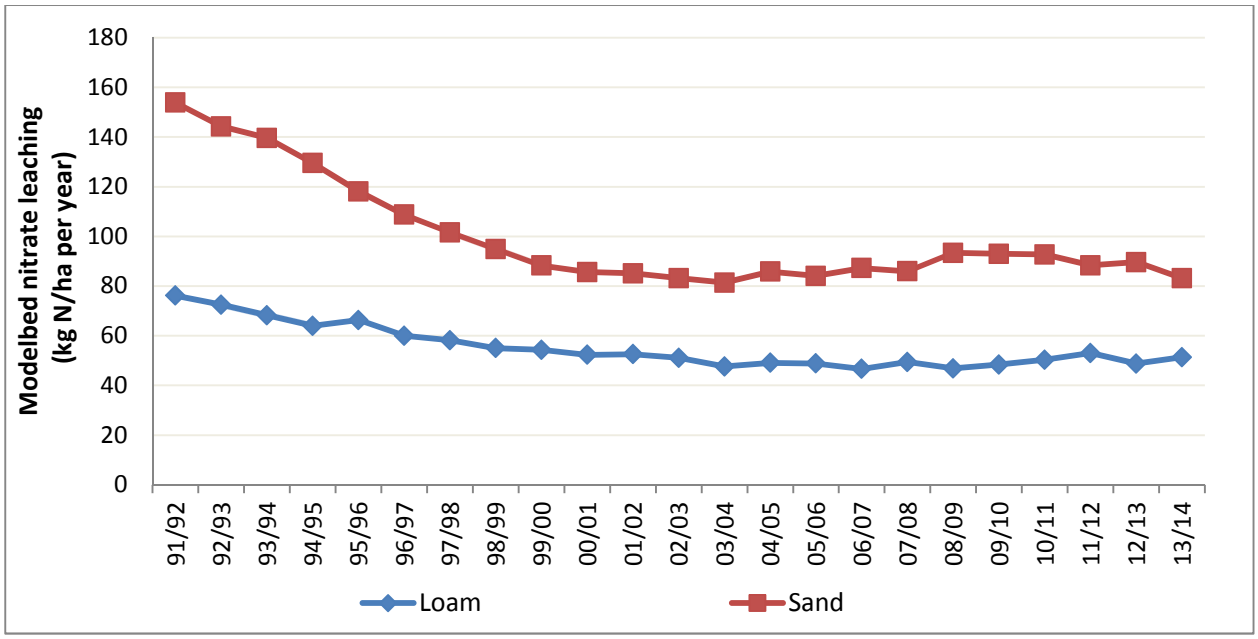


Figure 4.6. Modelled nitrate leaching at a standard climate for the fields of the Agricultural Catchment Monitoring Programme, 1990/91-2013/14

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. The samples represent the root zone water (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 1990/91-2012/13 (figure 4.7).

Generally, measured data for nitrate leaching from the root zone cannot be used directly for estimating the effect of a single variable because of the variability between monitoring fields and years as seen in figure 4.7. However, the data are used for development and testing of the nitrate leaching model, N-LES4. This model is then used for calculating the leaching from all the fields in the catchment based on the agricultural practises (figure 4.6) and for scenario analyses. The measurements are also used for statistical trend analysis as shown below.

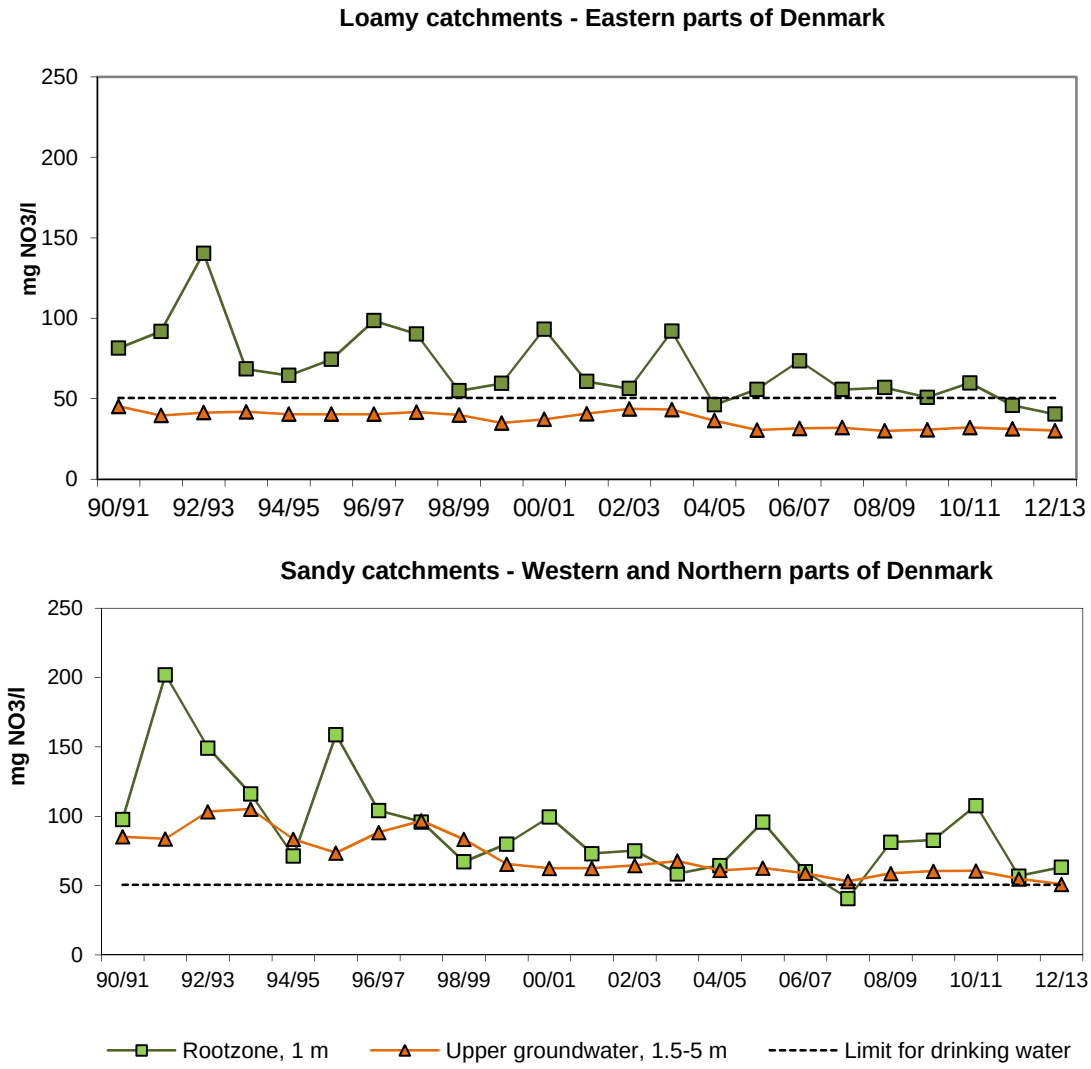


Figure 4.7. Annual flow weighted nitrate concentrations measured in root zone water and annual average nitrate concentrations measured in upper oxic groundwater, the Agricultural Catchment Monitoring Programme 1990/91-2012/13.

General trend for nitrate concentrations in water leaving the root zone

There is a high annual variation in measured nitrate concentrations due to variations 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 showed that the nitrate concentrations in water leaving the root zone with 95% probability have decreased with 17 and 89 mg NO_3 l^{-1} for loamy and sandy soils, respectively, during the years 1990/91-2003/04 (Action Plan I+II), corresponding to a relative reduction of about 17 % (25-81%) and 62 % (18-100%), respectively.

After 2003/04 (Action Plan III + Green Growth) there has been no statistical significant change in measured nitrate concentrations in soil water. However, within the past five years high concentrations have been observed temporarily for sandy soils. This is most likely a coincidence of crops with high leaching potential on those particular sites for those 2-3 years, such as conversion of grassland, turning over of well-established catch crops and 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 samplings stations (30 stations) and these do not include any set-aside fields which have been cultivated during 2008 and 2009. Furthermore the measurements are affected by high crop yields in particularly in 2009. These conditions contribute to a trend that differs from the modelled nitrate leaching in 2008-2010, as shown in figure 4.6.

In the upper ground water (1.5-5.0 m), nitrate concentrations are lower than in the root zone water, indicating that nitrate reduction and denitrification take place in the uppermost layer of the soils. The variations in oxic groundwater concentrations between the years follow the same pattern as for root zone water but with a time lag of about one year. During the years 2003/04-2012/13 the annual mean concentrations in upper oxic groundwater varied from 30-43 and 51-68 mg NO_3 l^{-1} for the loamy and sandy sites, respectively.

The general conclusion to be drawn from the Agricultural Catchment Monitoring Programme is that:

- Nitrate concentrations in soil water (1.0 m below soil surface) have decreased steadily from 1990 to 2004, approaching the limit of 50 mg nitrate l^{-1}. Since 2004 this trend has levelled out.
- Nitrate concentrations in the upper oxic groundwater (1.5-5.0 m below soil surface) are reduced to a level below the limit of 50 mg nitrate l^{-1} for both loamy and sandy.

Nitrate concentrations in water leaving the root zone for cattle holdings

Three of the monitoring sites belong to cattle holdings using less than about 170 kg organic manure N ha^{-1} and 5 belong to holdings using more than about 170 kg organic manure N ha^{-1} on the measuring site. Measurements of nitrate in water leaving the root zone are shown in figure 4.8 for each of the sites during the years 2000/01-2012/13. There is a high annual variation in measured concentrations, partly caused by the crop rotation and by the variations in climate.

During the years 2000/01-2005/06 the average concentrations on soils receiving 166-263 kg organic manure N ha^{-1} were markedly higher than the concentrations on soils receiving 107-123 kg organic manure N ha^{-1} (106 mg NO_3 l^{-1} and 62 mg NO_3 l^{-1}, respectively). However, for the group with low input of organic manure the concentrations have increased within the last few years resulting in

almost similar average concentrations during the period (2006/07-2012/13) (86 and 83 mg NO_3 l^{-1} respectively for the sites low and high input of organic manure). The increase in concentrations on the sites with low input of organic N is likely to be an effect of the crop rotation on these particular fields as mentioned above.

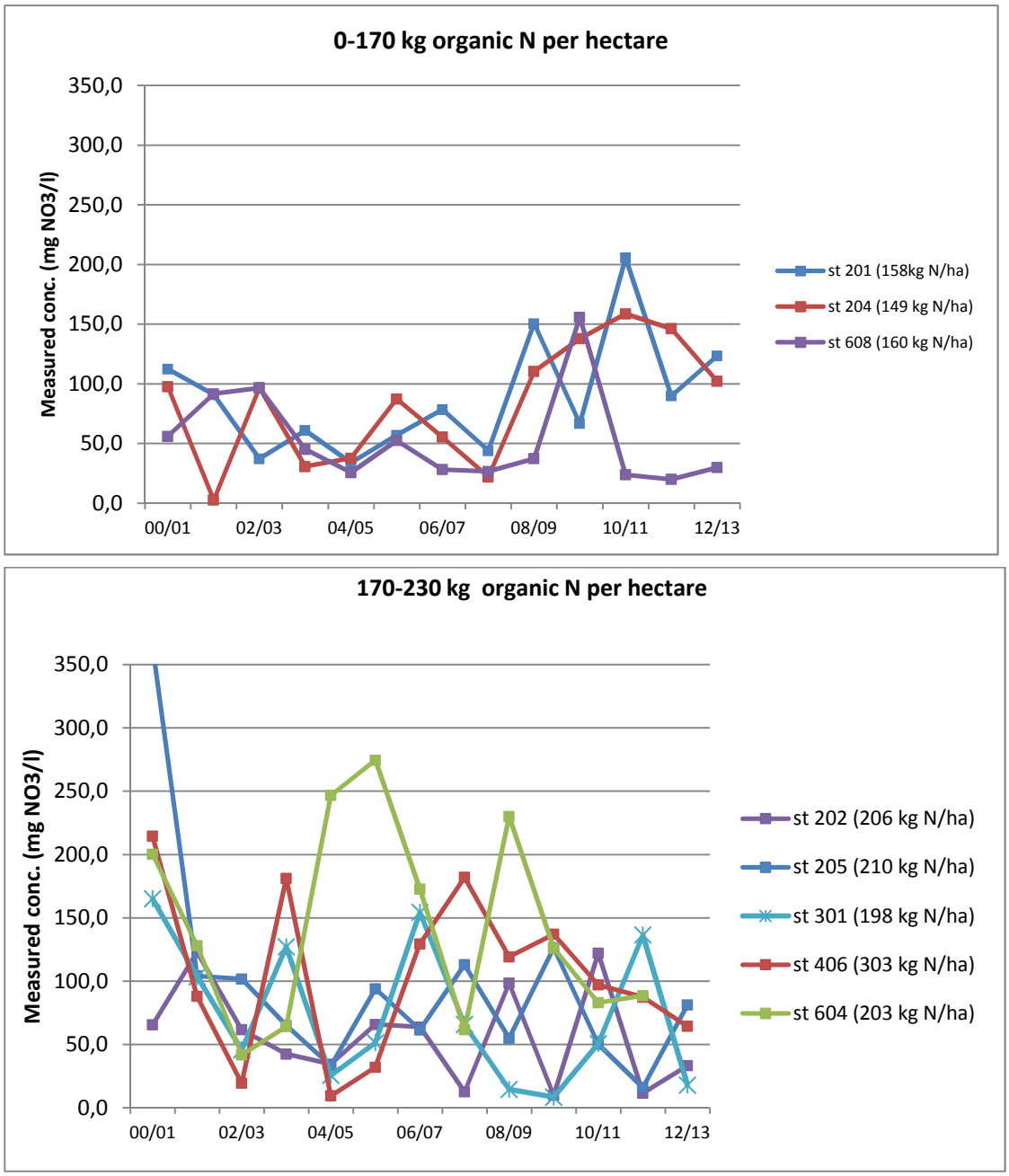


Figure 4.8. Measured nitrate concentrations at soil water stations (depth of 1 m) with average application of 0-170 and more than 170 kg organic N per hectare at the sites (average application of organic manure N is shown in brackets)

Phosphorus concentrations in the water leaving the root zone are shown in figure 4.9. Generally, the concentrations vary between 0.005-0.050 mg PO4-P/l, irrespective of the use of organic manure.

However, on one soil receiving an average of 160 kg organic N/ha (station 608), the P-concentrations are much more variable. This field consists of coarse sand and is located in an area with high rainfall. It may be concluded that P concentrations in soil water are largely dependent on the soil texture, the soil structure (fingering flow, macroporus flow), the rainfall magnitude and events, in combination with P application.

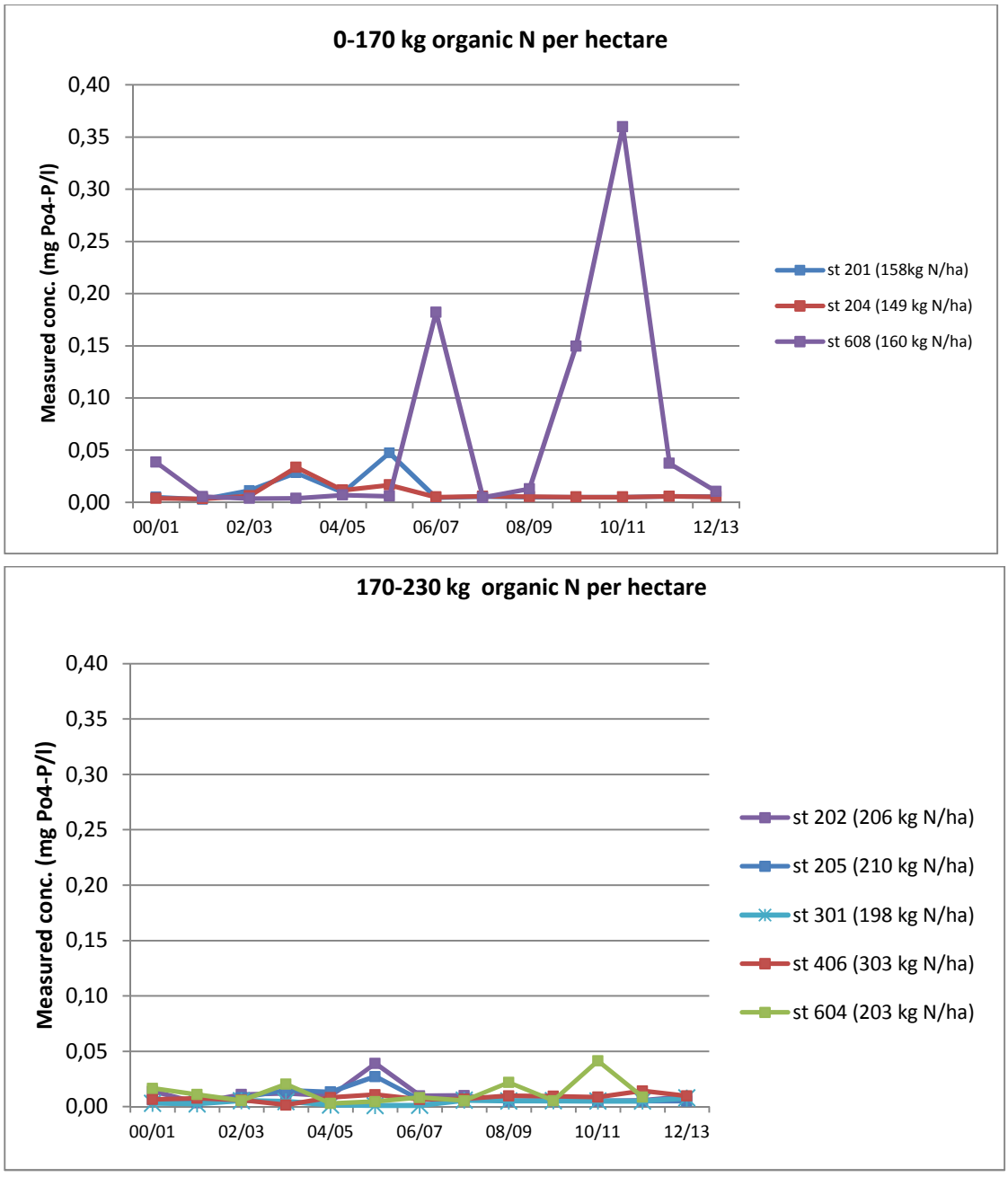


Figure 4.9. Measured concentrations of dissolved ortho phosphate (Po4-P) at soil water stations (depth of 1 m) with average application of 0-170 and more than 170 kg organic N per hectare at the sites (average application of organic manure N is shown in brackets)

4.6. The nitrogen flow to surface water in agricultural catchments

When percolating water leaves the root zone it will divide into a component which discharges to the surface water, and a component which discharges to the ground water from where it will eventually - often many 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, drainage water (on loamy soils), upper oxic groundwater and stream water. The monitoring programme includes three loamy catchments and two sandy catchments.

It is not possible from the monitoring programme to evaluate the effect of derogation farms specifically, on the nitrate transport in the stream, as this measure is a combined effect 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 pathway in the hydrological cycle and describes the trends for nitrate in water for the period 1990-2013. Continued monitoring of the Agricultural Catchment Programme and the Stream Programme will provide indicators for the future development.

The hydrological pathway

An analysis of the water flow in the streams of the 5 agricultural catchments has shown that the flow-path can be divided into three arbitrary components with a rapid, intermediate and slow response to precipitation, respectively (table 4.11). These components may be regarded as flow from the upper soil layers (including drainage), from the upper oxic groundwater and from deep groundwater.

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

Table 4.11. Partitioning of water discharge in streams into three flow components – rapid, intermediate and slow responding water. The analysis is for 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 %

This flow pattern is outlined in figure 4.11. Measurements of nitrate concentrations in soil water (1 m), upper oxic groundwater (1.5-5 m) and the streams are also shown. 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 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 drainage systems where less nitrate reduction takes place. 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 derogation farms are mainly located in the western and northern parts of Jutland, that is areas dominated by sandy soils and deep groundwater flow. Therefore those catchments do have higher denitrification and nitrate reduction processes in the aquifer and low nitrogen concentrations in the streams.

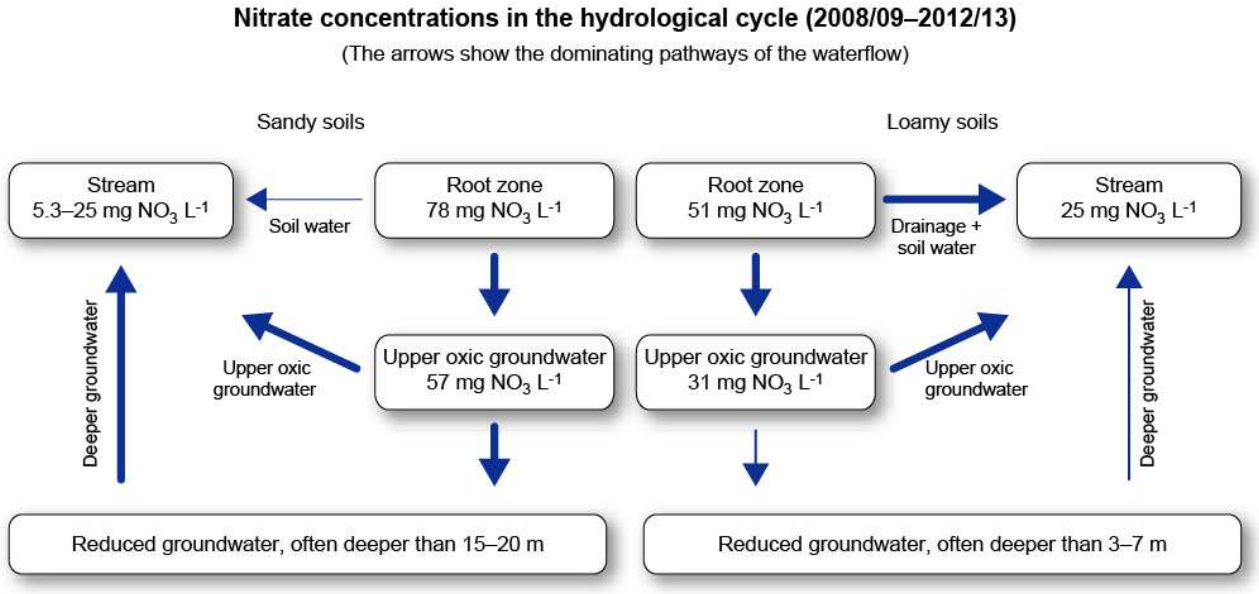
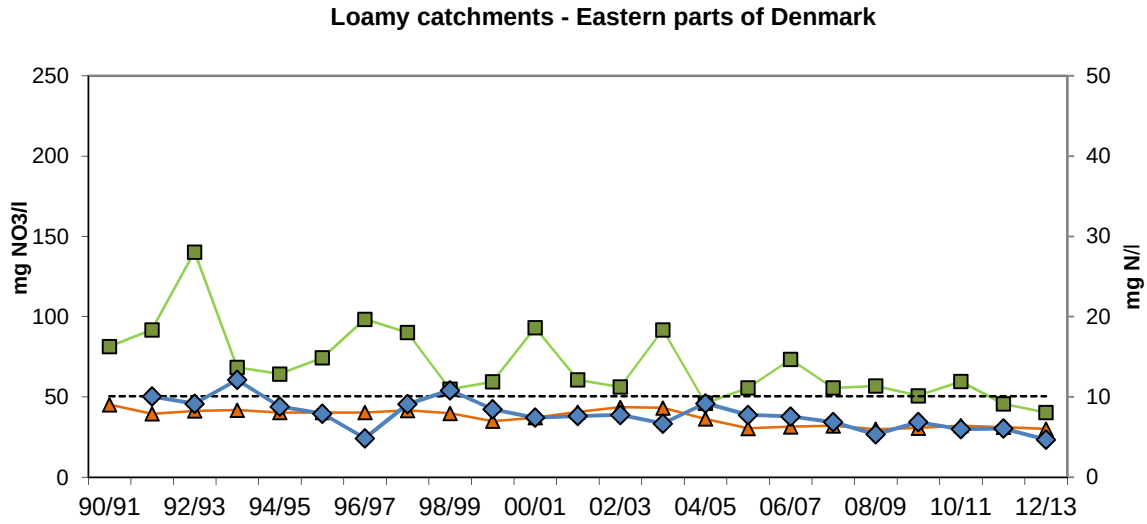


Figure 4.10.Measured nitrate concentration in the hydrological pathway in 3 loamy catchment and 2 sandy catchments, the Agricultural Catchment Monitoring Programme calculated as an annual mean for the period 2008/09-2012/13. Data is for mg nitrate in root zone and upper oxic groundwater but measured total N concentration in streams converted to mg nitrate for comparison in the hydrological pathway.

Trends in nitrate concentrations in the hydrological cycle

The development in concentration level for root zone water, upper oxic groundwater and stream water is shown in figure 4.11. For loamy soils the nitrate concentrations in the upper oxic groundwater are at the same order of magnitude as the concentrations in the stream. Statistical analyses allowing for annual variations in climate showed that nitrate concentration in rootzone water had decreased by 17 % and 62 % fo1990/91-2003/04 from loamy and sandy soils respectively, followed by no further decrease up until 2012/13 (see section 4.5). In the Stream Monitoring Programme the development is analysed for a larger number of streams. This programme showed during the years 1989-2013 an average reduction of 48% in nitrate concentration for 54 agricultural catchments representing both loamy and sandy soils. The Agricultural Catchment Monitoring Programme enables detailed studies of the hydrological pathways whereas the Stream Monitoring Programme provides nationwide estimates for the trends in surface water.



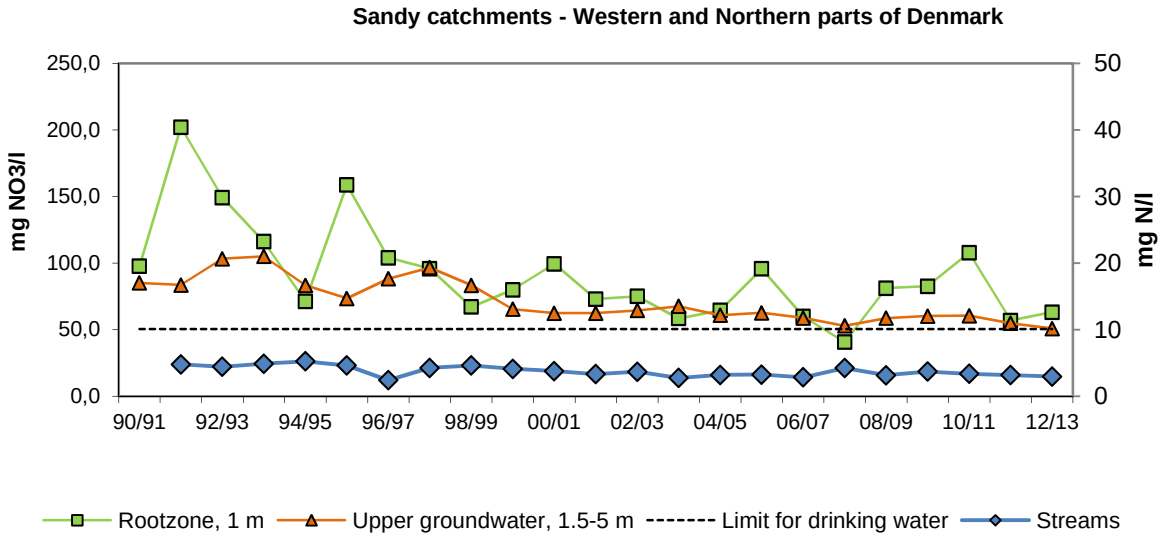


Figure 4.11. Trends in nitrate concentration in root zone water, upper ground water and in total nitrogen in streams for three loamy catchments and two sandy catchments, the Agricultural catchment Monitoring programme, 1990/91-2012/13.

5. Conclusions

In 1998 the Action Plan for the Aquatic Environment (APAE) II was accepted by the EU Commission as the Danish Nitrate Actions 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 1985. The following APAE III was submitted as the next Nitrate Action Programme and did run from 2004-2015 with planned midterm evaluations in 2008 and 2011 following article 5 in the Nitrates Directive.

In the APAE III the aim was a further reduction in nitrate leaching of 13% compared to the N-leaching in 2003. The target must be attained by 2015. An evaluation was carried out in 2008 and showed that there was not yet any significant decrease in modelled nitrate leaching during 2003-2007. In 2008 the obligation of set-a-side was abolished and as a consequence a Danish Set-aside Action Plan was implemented to compensate for the negative environmental effects. In June 2009 the government launched The Green Growth Agreement, which also deals with the problems formerly encountered in achieving expected goals in Action Plan III. As the Green Growth Agreement is much broader than the previous Action Plans a Danish Nitrate Actions Programme 2008-2015 has been composed specifying the elements that implement the Nitrate Directive.

Modelling of the nitrate leaching from the root zone at the national level showed an average - concentration of 77-90 mg NO_3 l^{-1} for cattle holdings using 170-230 kg organic manure N in 2013.

Measured average flow weighted nitrate concentrations in root zone water at four specific sites receiving 166-263 kg organic manure N per hectare were 83 mg NO_3 l^{-1} for the period 2006/07-2012/13.

In the upper oxic groundwater (1.5-5.0 m), nitrate concentrations are lower than in the root zone water, indicating that nitrate reduction and denitrification take place in the uppermost layer of the soils. The variations in oxic groundwater concentrations between the years follow the same pattern as for root zone water but with a time lag of about one year. During the five-year period 2008/09-2012/13 the upper groundwater concentrations were 31 and 57 mg NO_3 l^{-1} for the loamy and sandy sites, respectively.

The general conclusion to be drawn from the Agricultural Catchment Monitoring Programme is that:

- Nitrate concentrations in soil water (1.0 m below soil surface) have decreased steadily from 1990 to 2004, approaching the limit of 50 mg nitrate l^{-1}. Since 2004 this trend has levelled out.
- Nitrate concentrations in the upper oxic groundwater (1.5-5.0 m below soil surface) are reduced to a level below the limit of 50 mg nitrate l^{-1} for loamy and at the limit for sandy soils.

In 2012/13 a total of 1,481 cattle holdings made use of the derogation corresponding to 4 per cent of the total number of agricultural holdings in Denmark. The number of livestock units on these cattle holdings was 334,508 LU corresponding to 14.5 per cent of the total number of livestock units. The arable land encompassed by the derogation in year 2012/13 was 162,176 hectares corresponding to around 6.7 per cent of the total arable area. This is a decrease in number of holdings and a minor decrease in total arable area and livestock units compared to the previous year. The general trend in Denmark is the average size of holdings is still getting bigger.

In January 2014 49 inspections of compliance with the derogation management conditions were carried out and all 49 inspections were closed without remarks.

For the year 2011/2012 439 inspections (1.1 %) that took place at the farm were made concerning compliance with the harmony rules (amount of livestock manure applied per hectare), 52 of the inspected farms use the derogation. 50 of these inspections were closed without remarks, 2 farms are still under investigation.

856 (2.1 %) of the submitted fertilizer accounts were subject to administrative control. 40 of the controlled holdings used the derogation. All inspections were closed without remarks.

In total 52+40/1481 = about 6% of the derogations were subject to control.

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Annex 1. Implementation of Commission Decision 2012/659/EU into Danish legislation

Commission Decision 2012/659/EU	**Implementation in national legislation** Ministry of Environment Ministry of Food, Agriculture and Fisheries	**Control and inspection** Danish AgriFish Agency
Article 2 (a) 'Cattle farms' means holdings, where at least two-thirds of livestock are cattle.	*Article 31 (3)* of Order 2014/853 [i]	*On the spot inspection:* The size and composition of the farms livestock.
Article 4 (1) Cattle farmers shall submit an application for derogation to the competent authorities annually.	*Annex 3 (8)* of Order 2014/853	*Administrative inspection:* The farmer shall when applying for the single payment apply for the use of the derogation
Article 5 The amount of livestock manure applied to the land each year on cattle farms including by the livestock themselves, shall not exceed the amount of manure containing 230 kg nitrogen.	*Article 31 (4)* of Order 2014/853 *Article 15-21* of Order 2014/903 [ii]	*On the spot inspection:* On the basis of information on the size of livestock, amount of manure, and the crop rotation plan the amount of livestock manure applied per hectare is inspected. *Administrative inspection:* On the basis of the submitted fertiliser account the manure applied to the land each year is inspected (limit of 230 kg N/ha).
Article 5 (1) The total nitrogen input must comply with the nutrient uptake of the considered crop and the supply from the soil; the nitrogen maximum application standards shall be fixed at least 10 % below economic optimum.	*Article 5 and 6* of Act 2013/500[iii] *Article 7-14 and 22-23* of Order 2014/903	*On the spot inspection:* Information from the signed fertiliser account and the field plan *Administrative inspection:* On the basis of the submitted fertiliser account the farm's nitrogen quota and the total use of nitrogen is inspected.
Article 5 (2) The derogation farm must	*Annex 3 (9)*of Order 2014/853	*On the spot inspection:* The crop rotation and fertiliser

prepare a fertilisation plan to be kept on farm.	*Article 21 and 22* of Act 2013/500	plan is inspected. The capacity of manure storage facilities (This is controlled by the municipality) *Administrative inspection:* The fertilizer plan must be submitted in the spring when applying for the use of the derogation.
Article 5 (3) Each farm shall submit the fertilisation account including amounts of manure and nitrogen fertilisers by the end of March each year.	*Article 22* of Act 2013/500	*On the spot inspection:* Information from the signed fertiliser account and the field plan *Administrative control:* All fertilizer accounts are subject to an administrative control.
Article 5 (4) Periodic nitrogen and phosphorous analyses in the plough layer shall be done by each farmer who is granted derogation (at least every fourth years per 5 ha of land) for accurate fertilisation.	*Annex 3 (7)* of Order 2014/853	*On the spot inspection:* Only soil analysis for farms using the derogation for the fourth consecutive year is inspected. The soil analysis must show phosphorous and nitrogen levels. One sample per five hectares must be provided. A map and the crop rotation plan are inspected.
Article 5 (5) Livestock manure shall not be spread in the autumn before grass cultivation.	*Annex 3 (3)* of Order 2014/853	*On the spot inspection:* The farmer's written commitment on manure application is inspected.
Article 6 (1) 70 % or more of the acreage available for manure application on the derogation farm shall be cultivated with grass, grass catch crops or beet	*Annex 3 (1) and (2)* of Order 2014/853	*On the spot inspection:* On the basis of the crop rotation and fertiliser plan the share of grass, grass catch crops and beet are inspected.
Article 6 (2) Grass catch crops shall not be ploughed before 1 March in order to ensure permanent	*Annex 3 (5)* of Order 2014/853	*On the spot inspection:* Fields for possible ploughing are inspected.

vegetal cover of arable area for recovering subsoil autumn losses of nitrates and limit winter losses.		The crop rotation and fertiliser plan are inspected concerning the planning of ploughing of fields with grass catch crops.
Article 6 (3) Temporary grasslands shall be ploughed in spring and be followed by a crop with high nitrogen uptake	*Annex 3 (4)* of Order 2014/853	*On the spot inspection:* Fields for possible ploughing are inspected. The crop rotation and fertiliser plan are inspected concerning the planning of ploughing of fields with grass.
Article 6 (4) Crop rotation shall not include leguminous or other plants fixing atmospheric nitrogen. This will however not apply to clover or alfafa in grassland with less than 50% clover or alfafa and to barley/pea under sown with grass.	*Annex 3(6)* of Order 2014/853	The crop rotation and fertiliser plan are inspected concerning the planning of cropping leguminous or other plants fixing atmospheric nitrogen.

[i] Order on Commercial Livestock, Livestock Manure, Silage etc. No. 853 of 30/06/2014 (The Ministry of Environment).

[ii] Order on Farms' use of Fertiliser and on Plant cover, no. 903 of 29/07/2014 (The Ministry of Food, Agriculture and Fisheries)

[iii] Consolidated Act on Farms' use of Fertiliser and on Plant cover, no. 500 of 12/05/2013 (The Ministry of Food, Agriculture and Fisheries)