International Fertiliser Society
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Chief Adviser Leif Knudsen

UPWARD REVISION OF RESTRICTIONS ON NITROGEN APPLICATIONS IN DENMARK

STØTTET AF
promilleafgiftsfonden
for landbrug

SEGES
Crop & Environment

DISPOSITION

- Review of the Danish N-legislation for 30 years
- Problems with a fixed suboptimal N-quota
- From suboptimal to optimal N-quota 2016/2017

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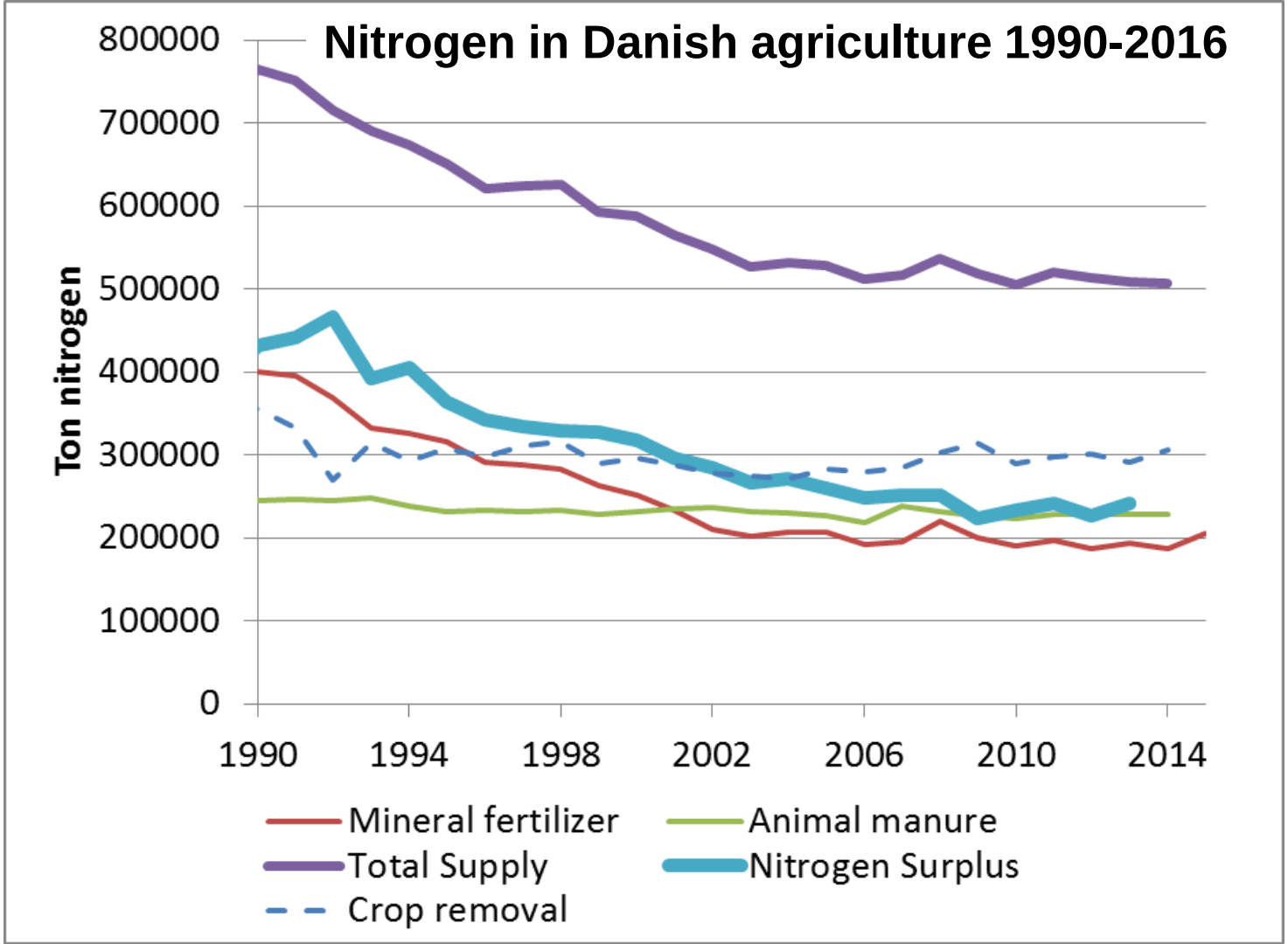
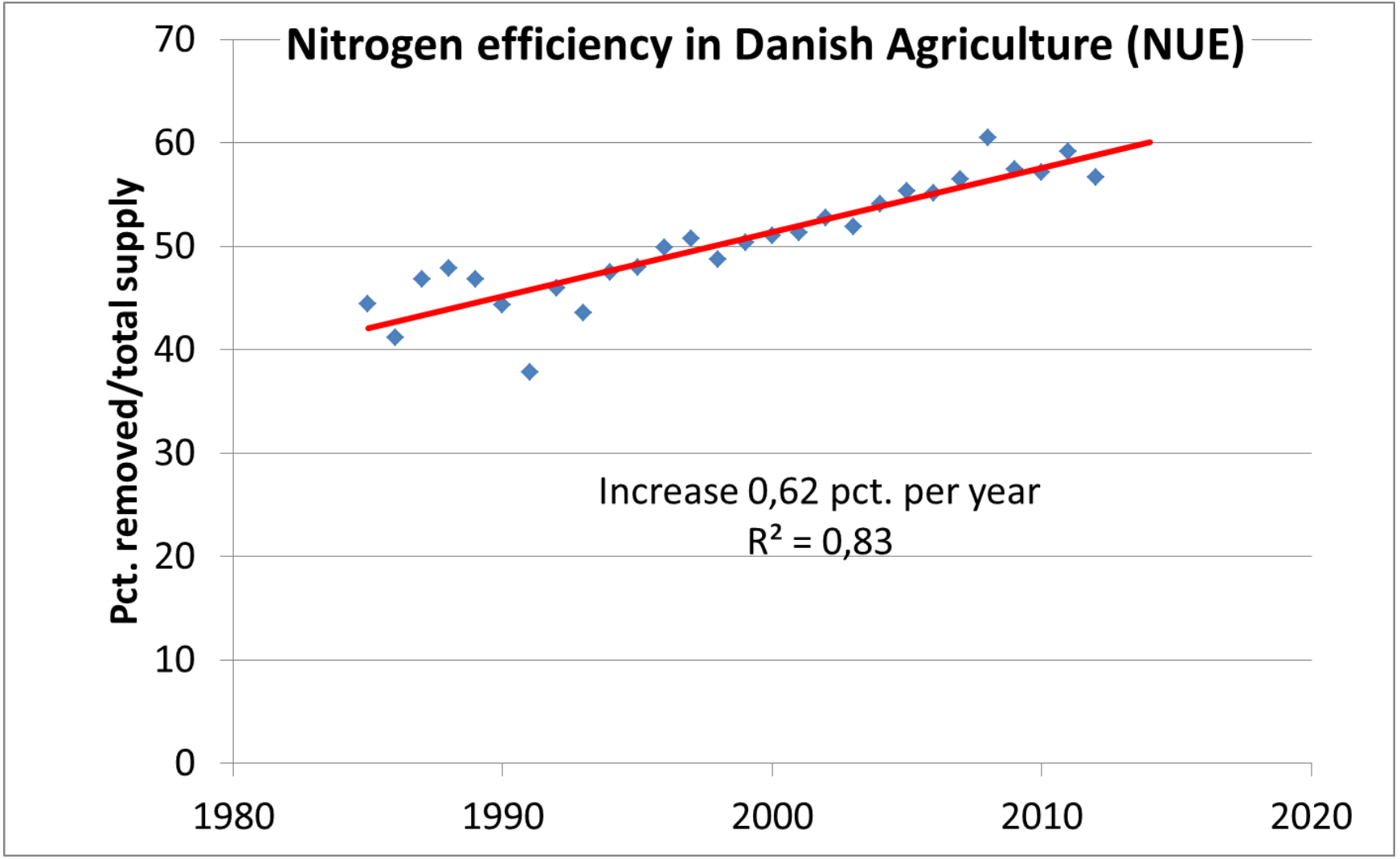
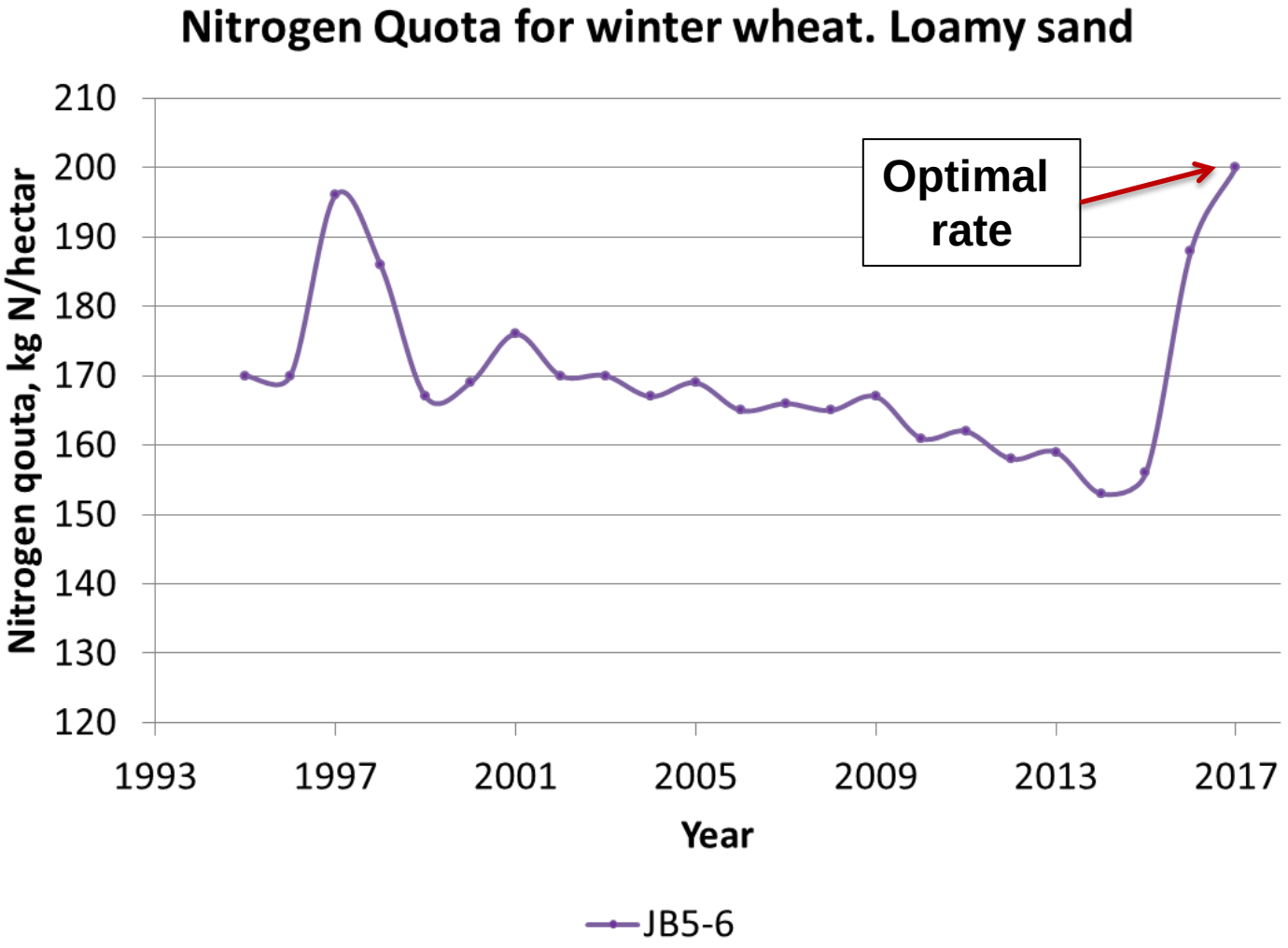
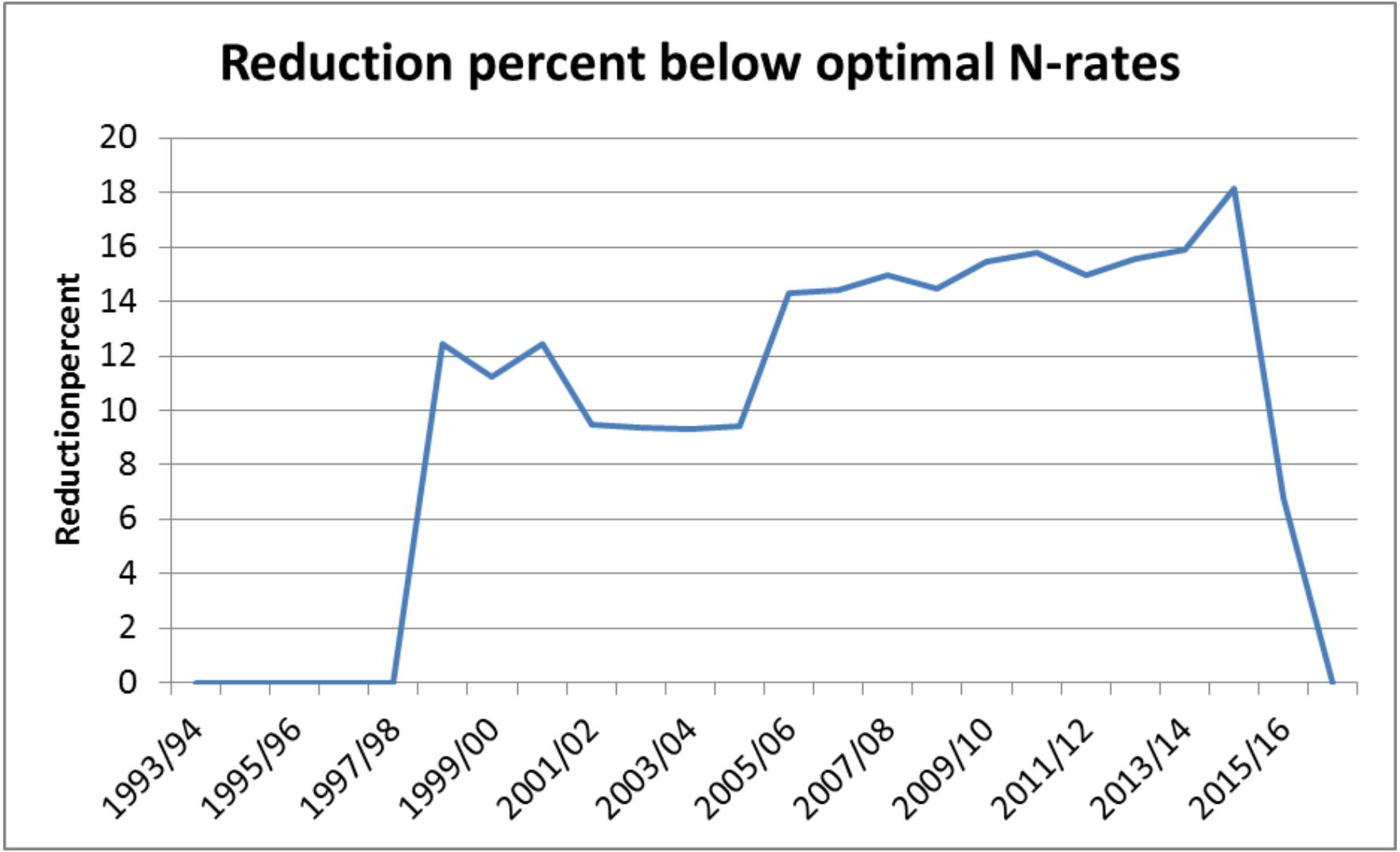
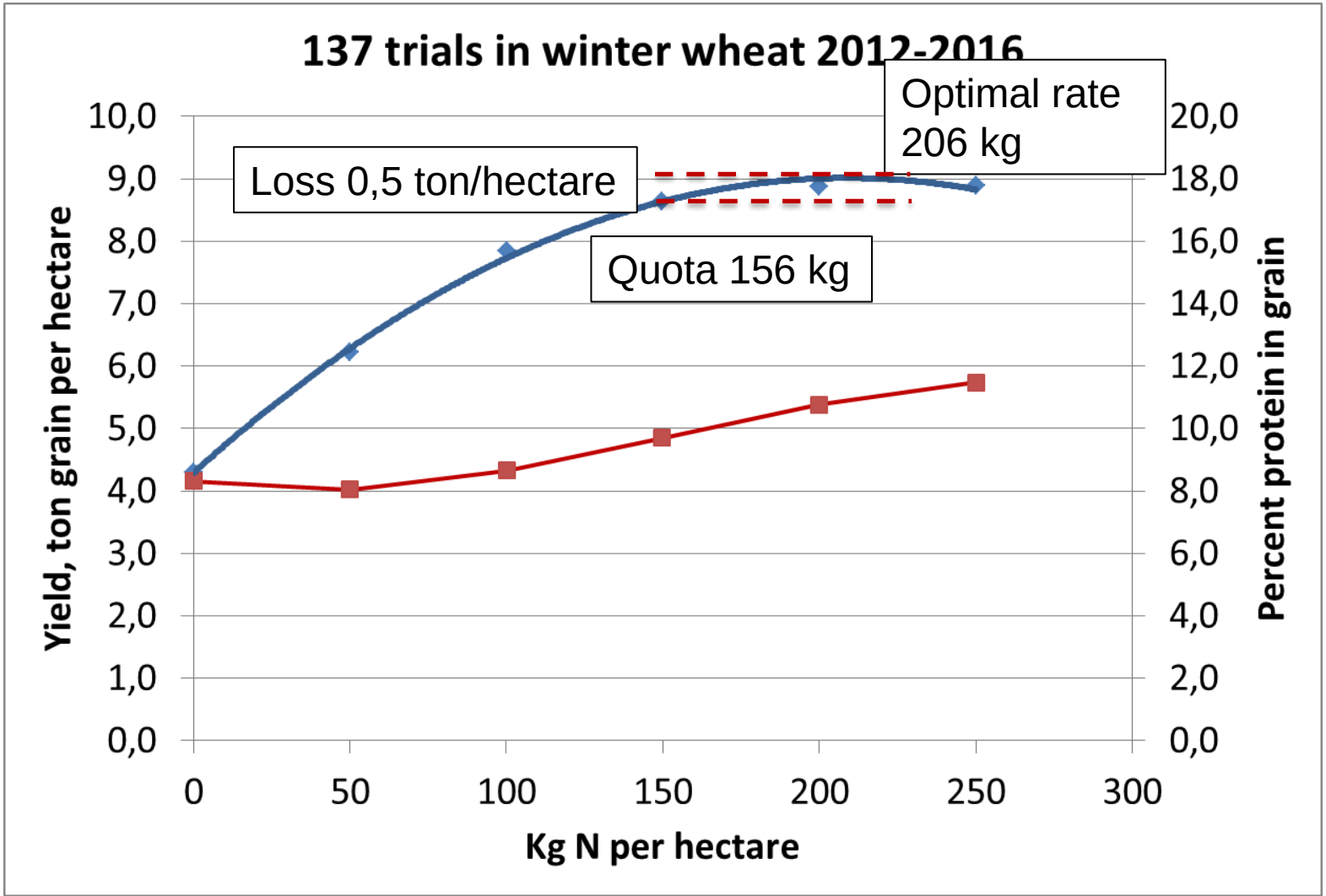
Year	Action plan	Most important elements in the plan	Target
1985	NPO - Plan	Ban of direct outlet of manure Minimum area per LU (Live stock Unit	
1987	Water Environment Plan I	Min. storage capacity for manure Min area with “winter green crops Mandatory fertiliser plans	50 pct. reduction of nitrogen leaching
1991 and 1996	Plan for sustainable agriculture	Maximum Nitrogen quotas based on optimal rates Minimum utilisation of manure Mandatory fertiliser accounts	50 pct. reduction of nitrogen leaching
1998	Water Environment Plan II	10 per cent reduction of N-quotas below optimum Minimum area with catch crops, Wetlands, afforestation.	50 pct. reduction of nitrogen leaching
2004	Water Environment Plan III	Increasing demand catch crops, Volunteer buffer strips	13 pct. reduction in nitrogen leaching
2009	Green Growth (WFD)	Restriction in soil tillage 50,000 ha mandatory buffer strips 140,000 hectare extra cover crops	Reduction of loss of nitrogen with 30 pct.
2016	Food and agricultural Plan	Increasing N-quotas from 2016 Stop for mandatory buffer strips Volunteer catch crop with subsidies	Reduction of the loss of nitrogen by 13 percent until 2021

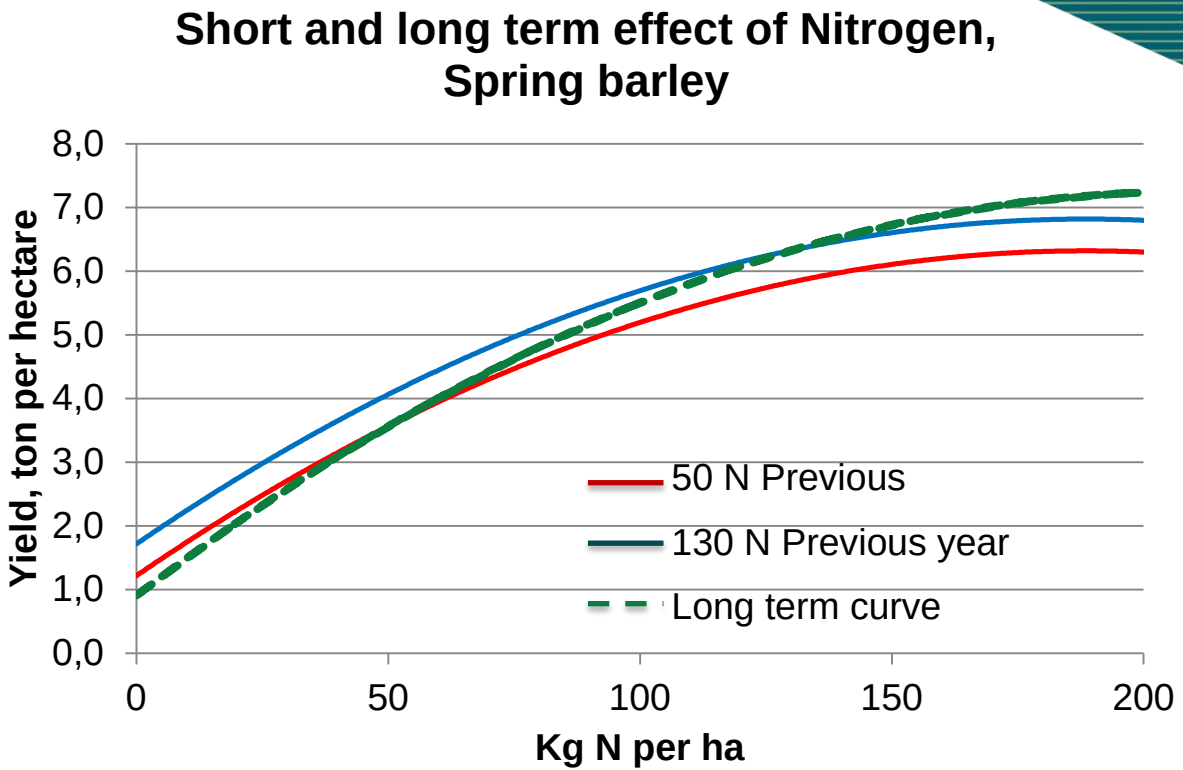

Nitrogen in Danish agriculture 1990-2016
Ton nitrogen
800000
700000
600000
500000
400000
300000
200000
100000
0
1990
1994
1998
2002
2006
2010
2014
Mineral fertilizer
Animal manure
Total Supply
Nitrogen Surplus
Crop removal


Nitrogen efficiency in Danish Agriculture (NUE)
Pct. removed/total supply
70
60
50
40
30
20
10
0
1980
1990
2000
2010
2020
Increase 0,62 pct. per year
R² = 0,83


Nitrogen Quota for winter wheat. Loamy sand
Nitrogen qouta, kg N/hectar
210
200
190
180
170
160
150
140
130
120
1993
1997
2001
2005
2009
2013
2017
Year
Optimal rate
JB5-6


Reduction percent below optimal N-rates
Reductionpercent
20
18
16
14
12
10
8
6
4
2
0
1993/94
1995/96
1997/98
1999/00
2001/02
2003/04
2005/06
2007/08
2009/10
2011/12
2013/14
2015/16


137 trials in winter wheat 2012-2016
Optimal rate
206 kg
Loss 0,5 ton/hectare
Quota 156 kg
Yield, ton grain per hectare
Percent protein in grain
Kg N per hectare
10,0
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
20,0
18,0
16,0
14,0
12,0
10,0
8,0
6,0
4,0
2,0
0,0
0
50
100
150
200
250
300



From Petersen et al.

Yield in Denmark and Germany (FAOSTAT)

	1999-2010	1994-98	1980-94
	Ton per hectare		
Denmark	6.0	6.0	5.0
Germany	6.7	6.2	5.0
Difference	-0.6	-0.2	-0.1

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LOSS OF YIELD BY SUBOPTIMAL N-LEVEL

	Reduction, pct. from optimal level	Short term loss	Long term loss	Total loss, cereals
		Ton grain per hectare		
Knudsen,2013[1]	20-30	0.45-0.50	0.15	0.60
Knudsen, 2015[1]	20-30	0.55	0.18	0.73
Kristensen et. al. 2014[2]	15-20	0.20-0.30	0.10-0.20	0.30-0.50

[1] SEGES

[2] Aarhus University, University of Copenhagen

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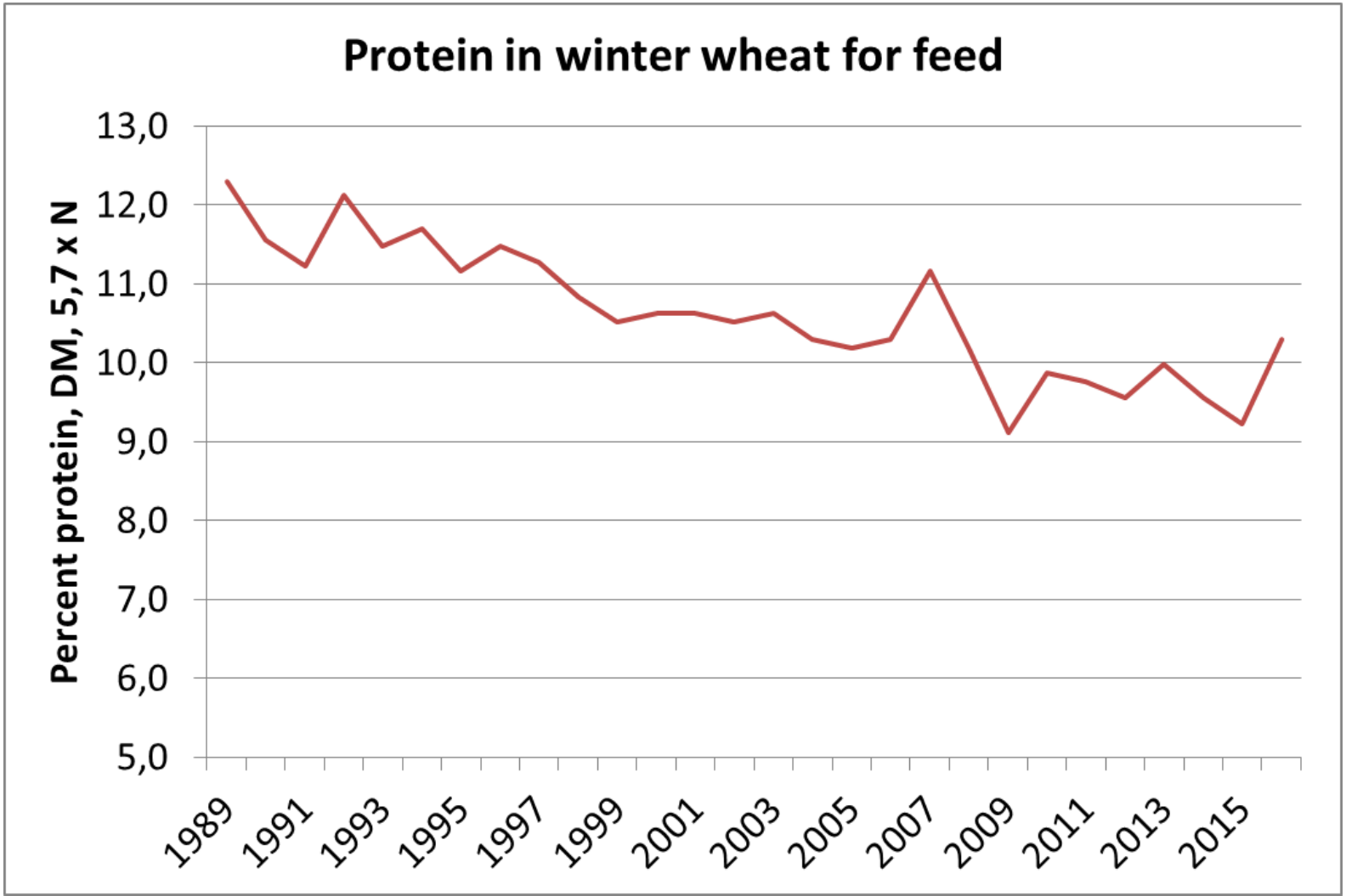
Protein in winter wheat for feed
Percent protein, DM, 5,7 x N
13,0
12,0
11,0
10,0
9,0
8,0
7,0
6,0
5,0
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

LOSS OF INCOME IN AGRICULTURE CAUSED BY REDUCED N-QUOTA

	Loss related to quality (protein), Mill. Euro DK	Loss related to reduced yield, Mill. Euro DK	Total loss for Danish agriculture, Mill. Euro	Total loss, Euro per hectare
Knudsen, 2015[1]	119	278	300	120
Kristensen et. al. 2014[2]	21	98-164	70-130	28-52
Jacobsen et al., 2016[3]	38	206	175-250	70
Troelsen[4]			450	180

[1] SEGES
[2] Aarhus University, Copenhagen University
[3]Copenhagen University
[4]Copenhagen Buisness School

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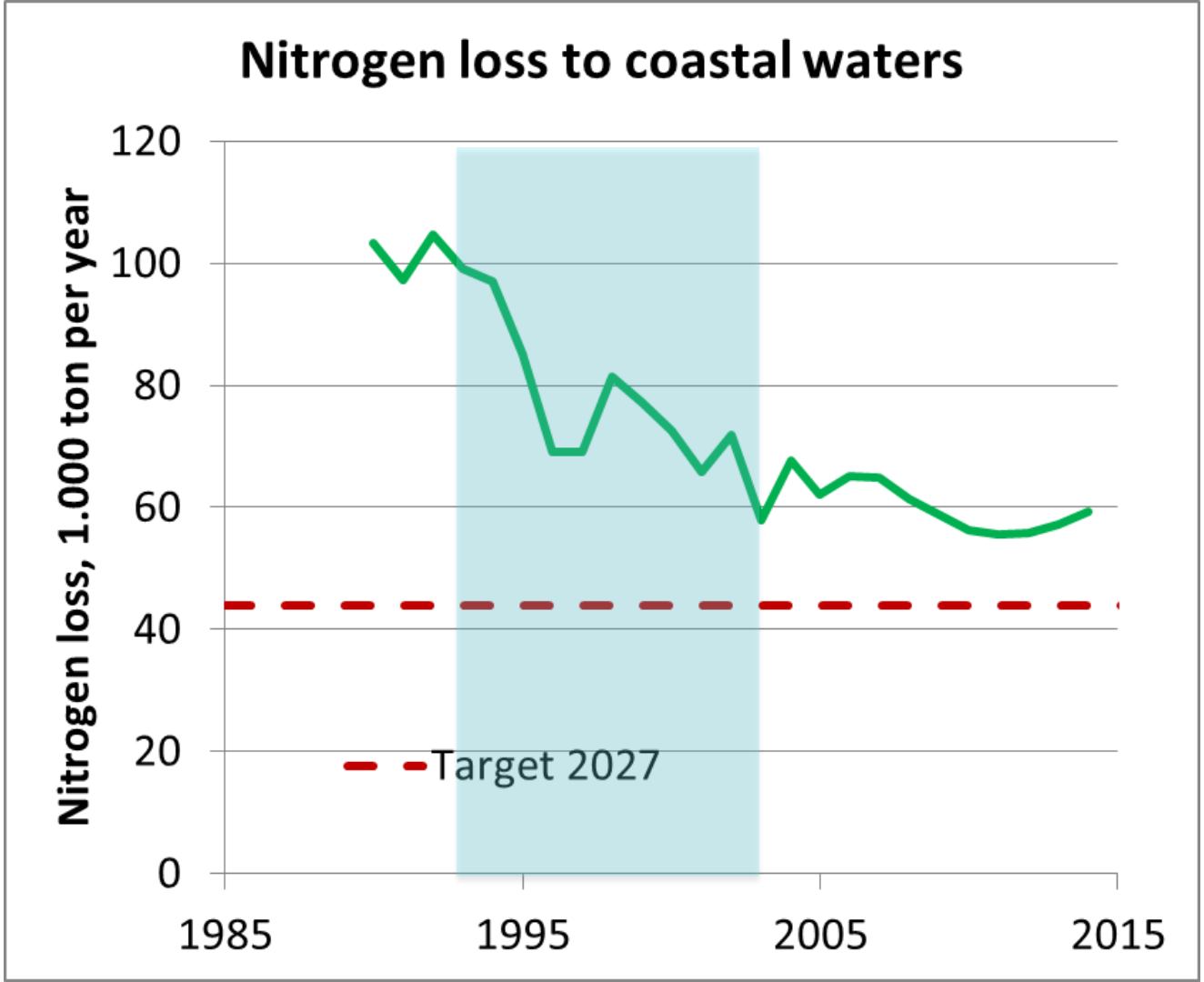
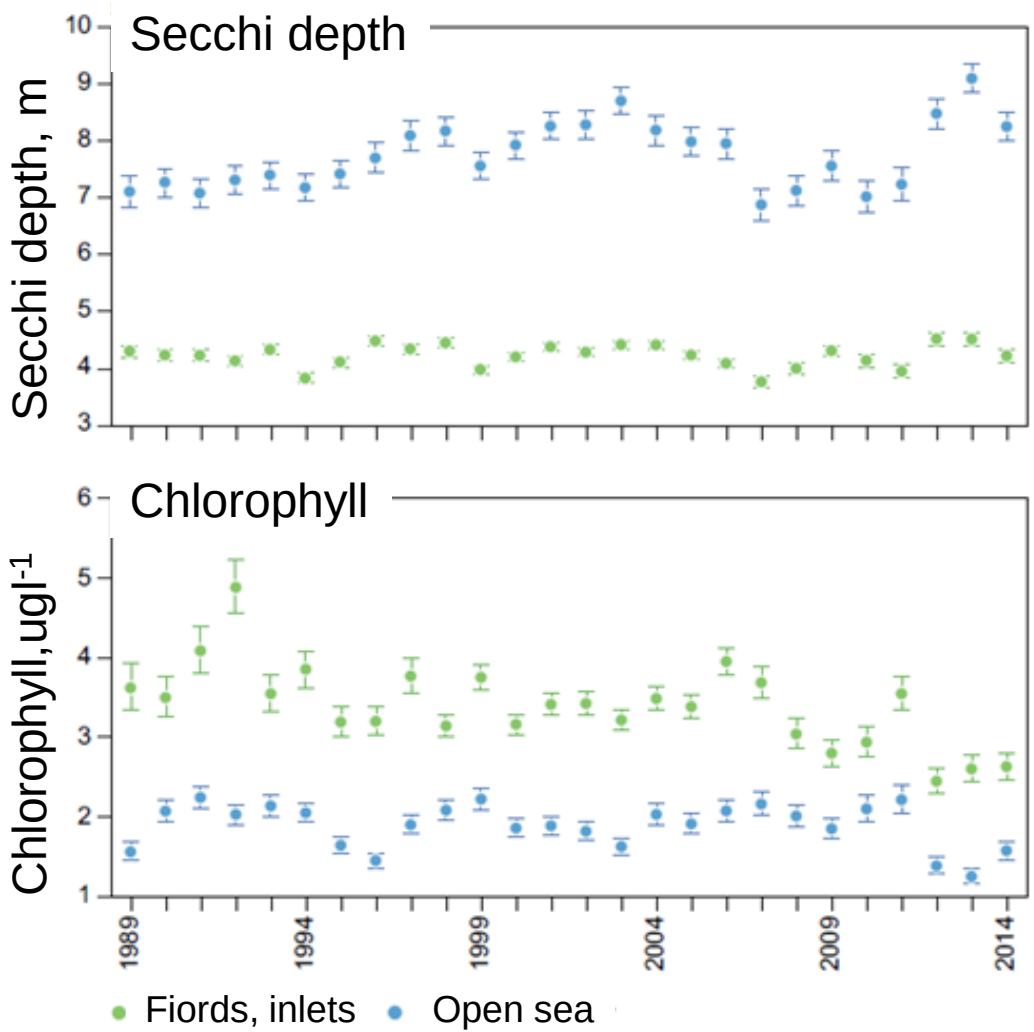
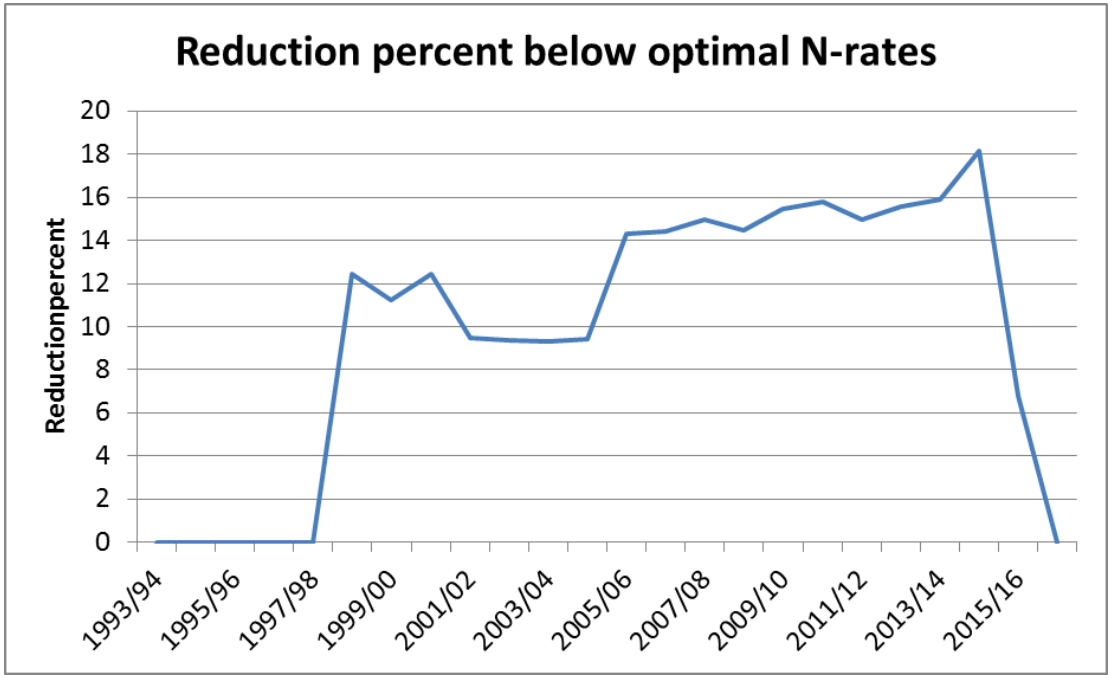


Data from Aarhus University



Jensen et. al., 2014

Why has the underfertilisation increased over the years?



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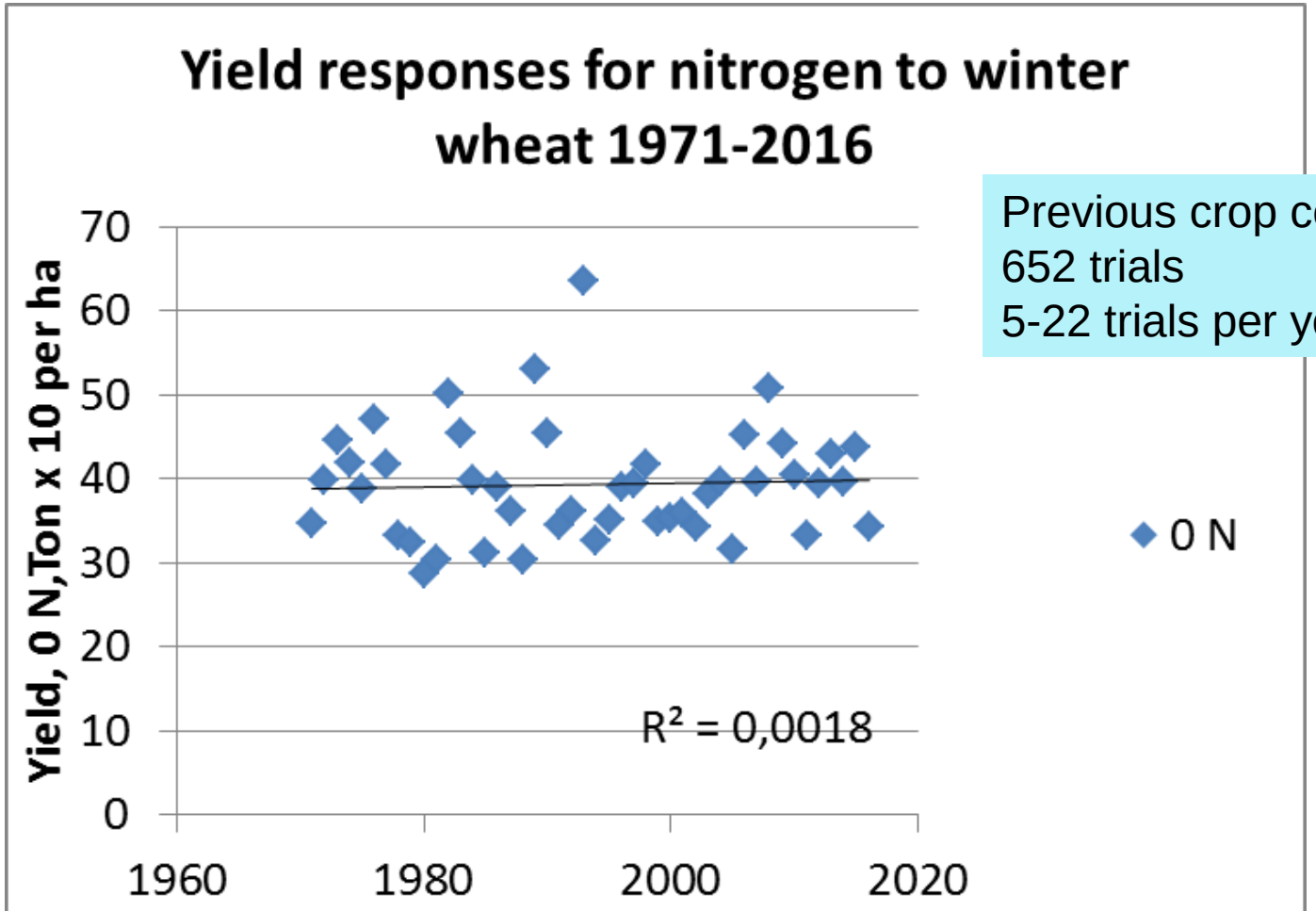
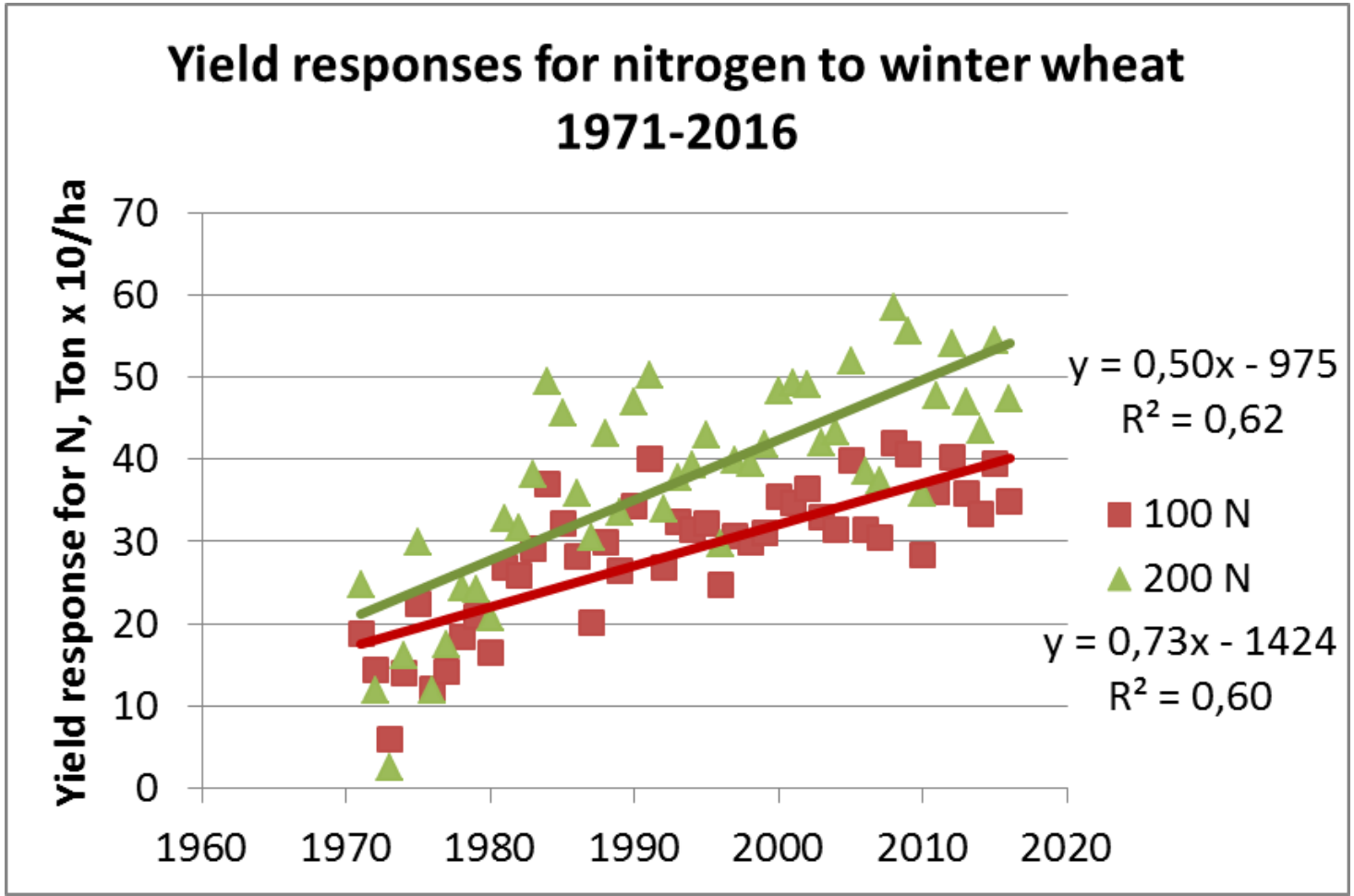
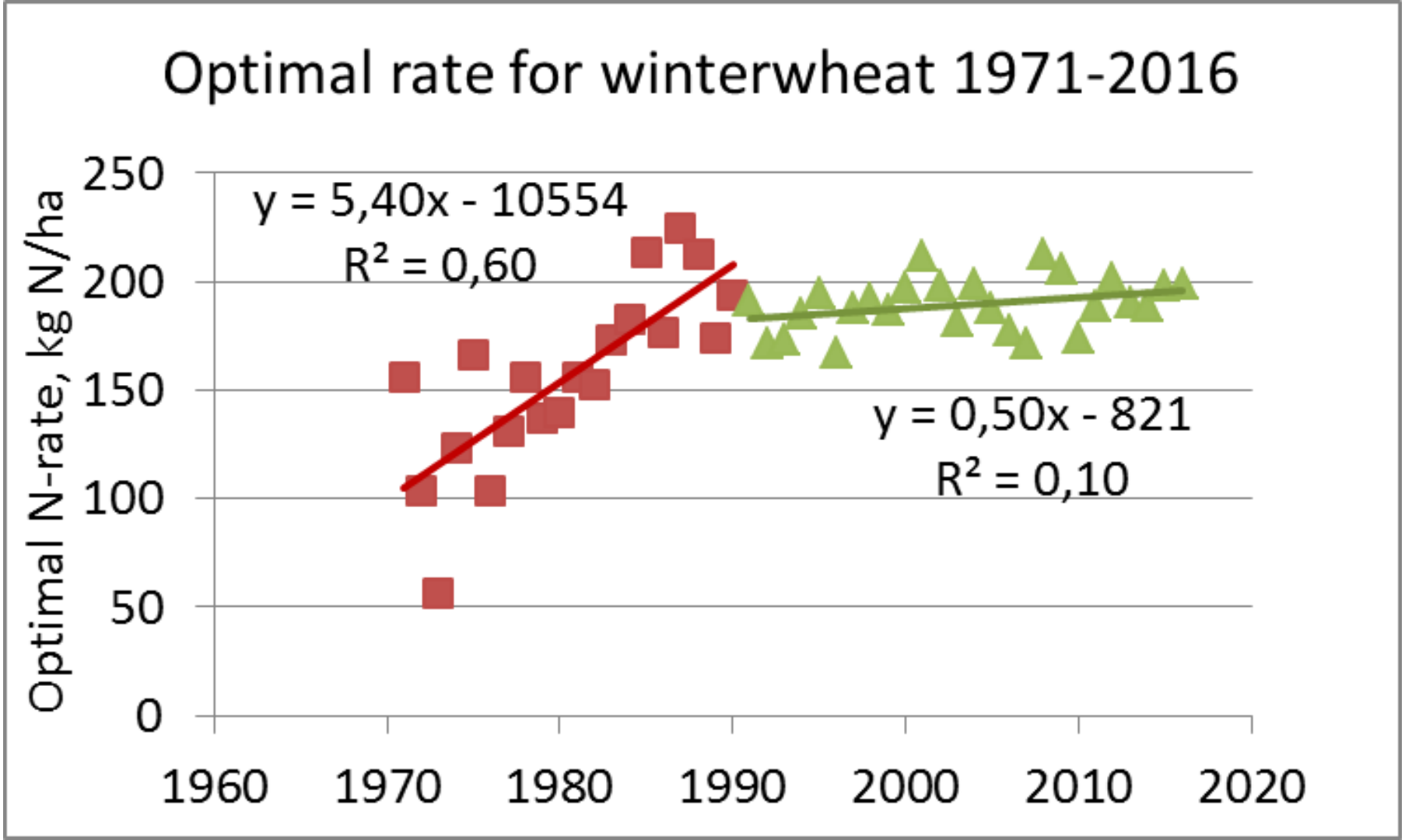


Previous crop cereal
652 trials
5-22 trials per year


Yield responses for nitrogen to winter wheat 1971-2016
Yield response for N, Ton x 10/ha
70
60
50
40
30
20
10
0
1960
1970
1980
1990
2000
2010
2020
y = 0,50x - 975
R² = 0,62
100 N
200 N
y = 0,73x - 1424
R² = 0,60


Optimal rate for winterwheat 1971-2016
Optimal N-rate, kg N/ha
250
200
150
100
50
0
1960
1970
1980
1990
2000
2010
2020
y = 5,40x - 10554
R² = 0,60
y = 0,50x - 821
R² = 0,10

FACTORS INFLUENCING THE N-DEMAND OVER TIME

Result of analysis of 635 trials with N to winter wheat 1993-2016

Factor	N-demand	Change over time (1992-2016)	Signifi-cance
Higher yield	Higher	0.069 ton year^{-1}ha^{-1}	***
Better N-utilisation[a]	Lower	0.43 pct. uptake kg N^{-1}	***
Reduced mineralisation of N from soil[b]	Higher	-1.17 kg N year^{-1}	*
Optimal N-rate,kg ha^{-1}[c]	-	1.4 kg N year^{-1}ha^{-1}	***

a. N-utilisation: pct. additional N-uptake from application of 0-150 kg N/ha
b. Mineralisation: (N-uptake at 0 N)/N-utilisation – (N-min – 20)
c. Without protein correction

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YIELD, PROTEIN AND N-UPTAKE 1994 AND 2016

Factor	1994	2016
Yield, ton ha^{-1}	7.66	9.17
Protein in grain. DM	10.2	10.3
Optimal N-rate, kg N ha^{-1}	143	173
Marginal uptake of N, pct. kg N^{-1}	40.9	50.3
Uptake of nitrogen at optimum, kg N ha^{-1}	116	141
Nitrogen surplus, kg N ha^{-1}	27	32
Calculated N-mineralisation, kg N ha^{-1}	130	105

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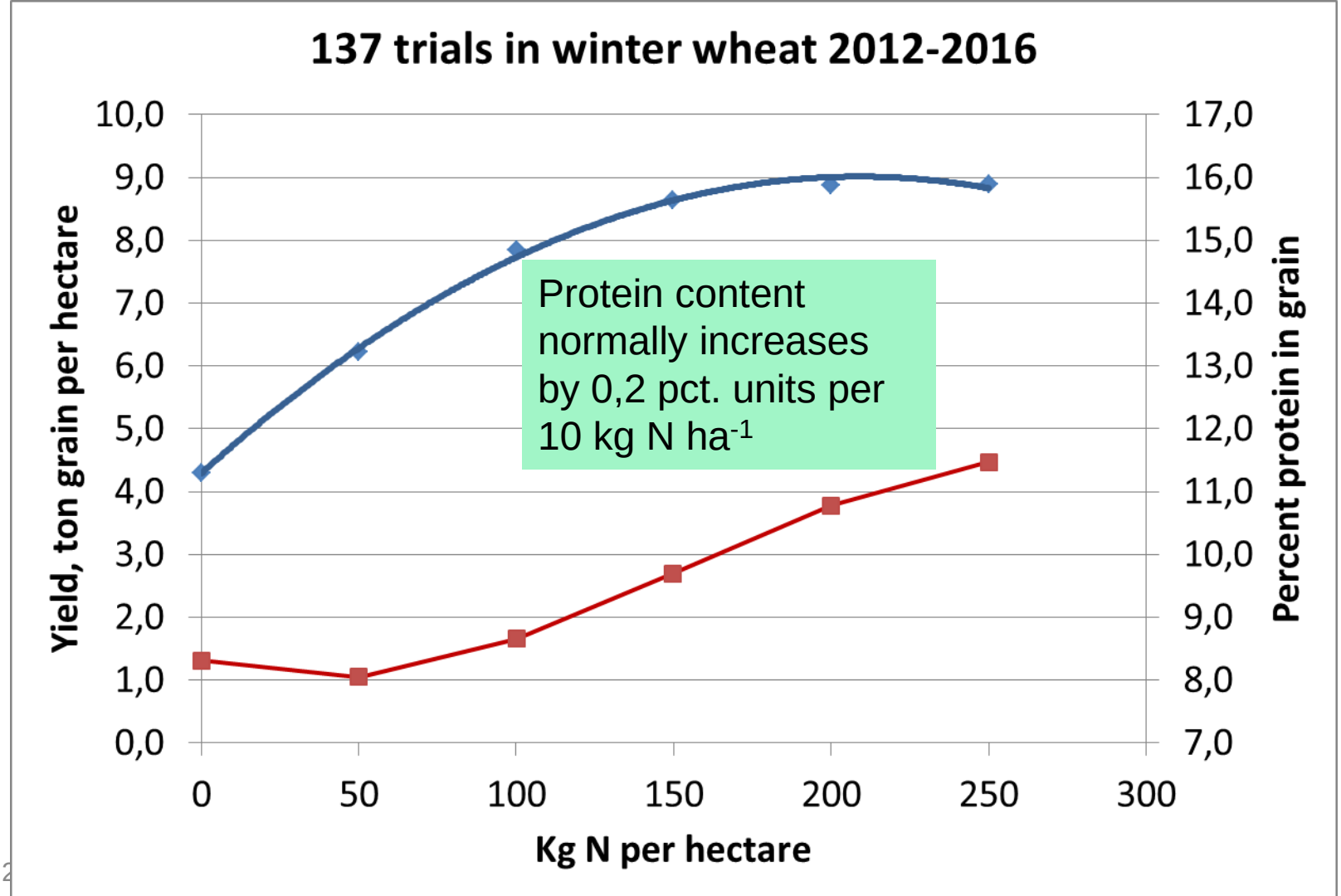
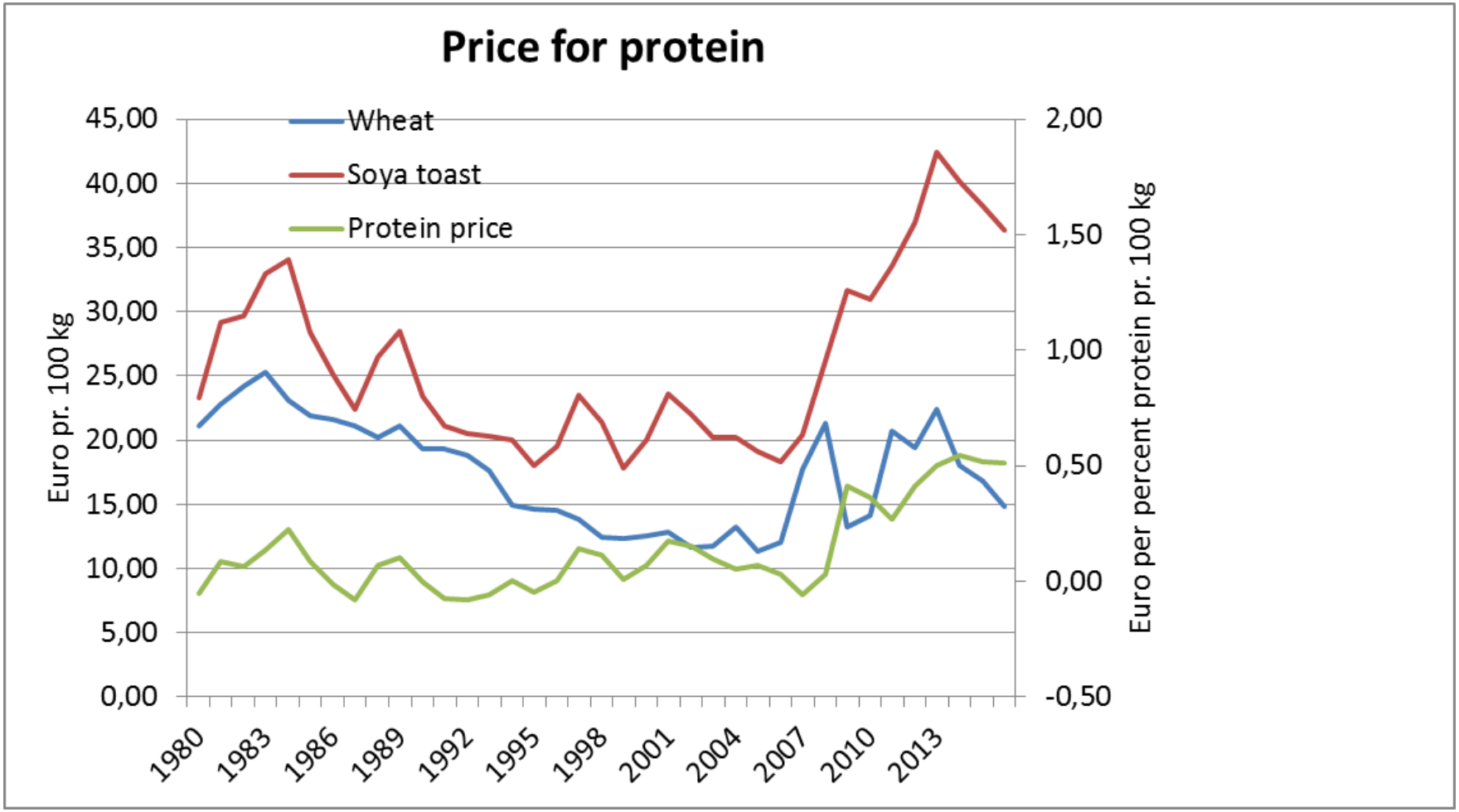
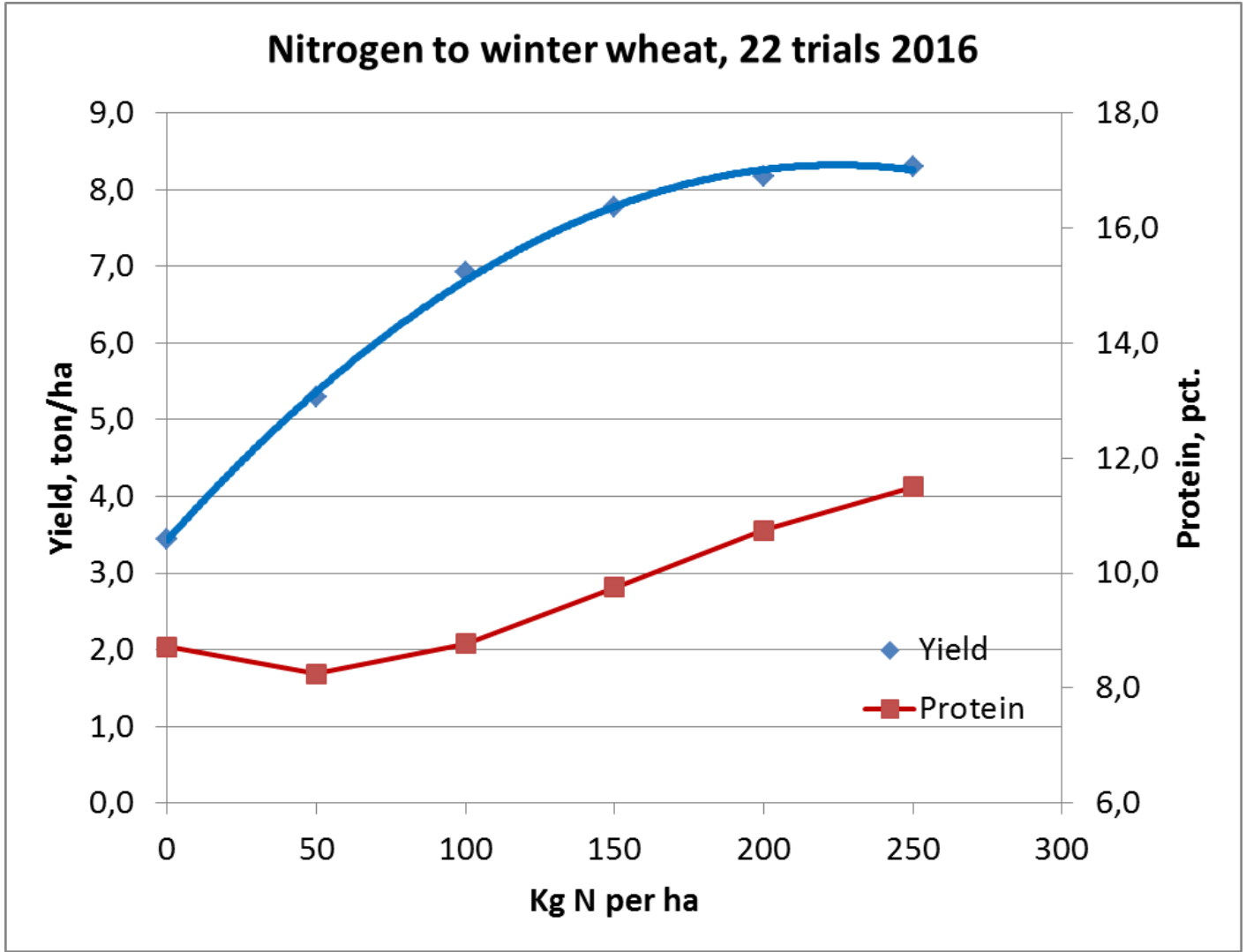
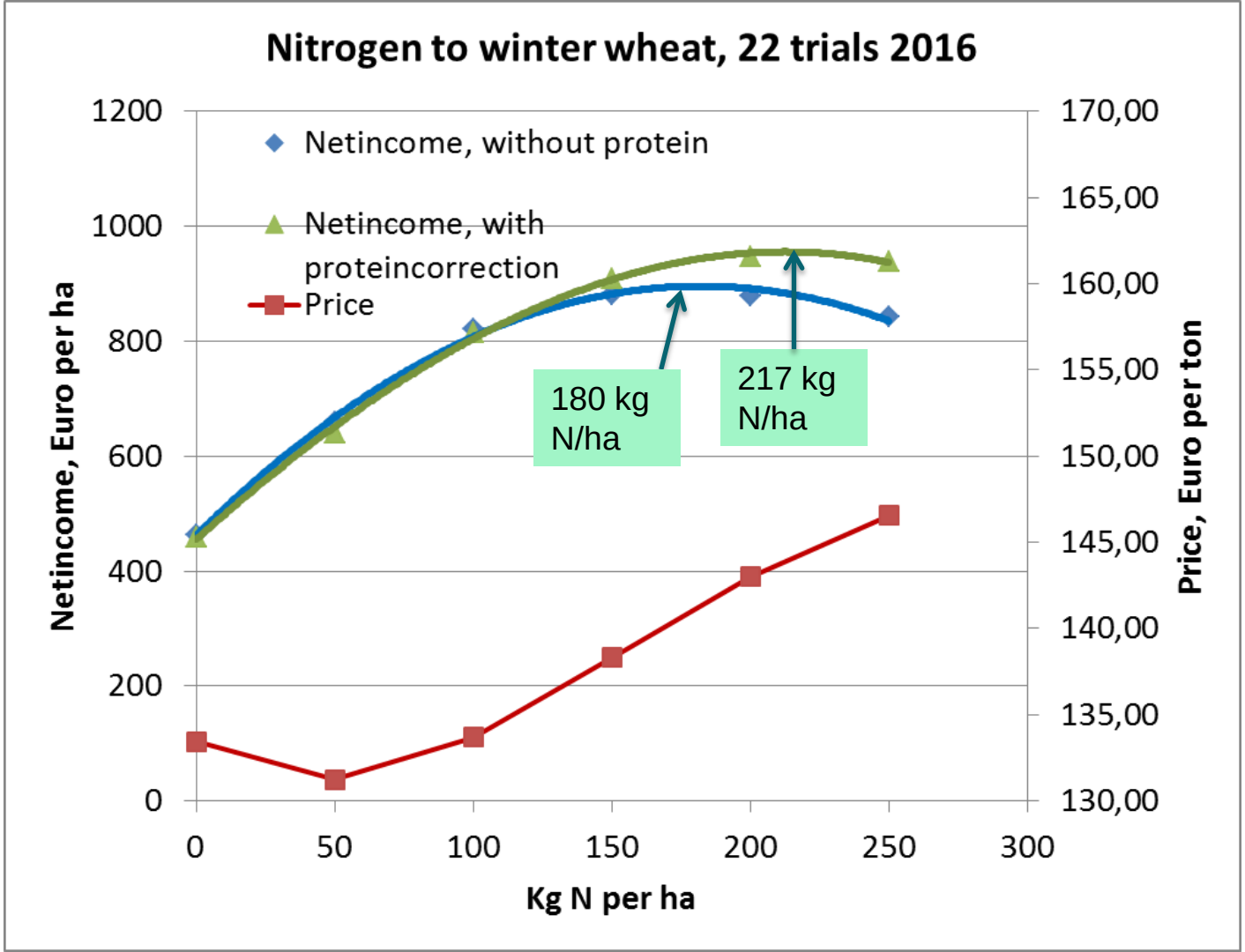

137 trials in winter wheat 2012-2016
Yield, ton grain per hectare
Percent protein in grain
Kg N per hectare
Protein content normally increases by 0,2 pct. units per 10 kg N ha-1
10,0
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
17,0
16,0
15,0
14,0
13,0
12,0
11,0
10,0
9,0
8,0
7,0
0
50
100
150
200
250
300

Quality of protein with increasing nitrogen application

Amino acids	Change in percent with a 10 percent increase of total protein		Price for amino acid, Euro per 100 Feeding Unit, pig
	Barley	Winter wheat	
Lysine, g digestilbe pr. kg	8	5	0,13
Methionine, g digestilbe pr. kg	9	8	0,11
Treonine, g digestilbe pr. kg	9	7	0,09
Tryptofane, g digestilbe pr. kg	8	8	0,13
Valine, g digestilbe pr. kg	11	10	0,43
Leucine, g digestilbe pr. kg	12	10	Not available
Isoleucine, g digestilbe pr. kg	12	11	Not available
Histidine, g digestilbe pr. kg	11	10	Not available


Price for protein
Wheat
Soya toast
Protein price
Euro pr. 100 kg
Euro per percent protein pr. 100 kg
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
2,00
1,50
1,00
0,50
0,00
-0,50
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013


Nitrogen to winter wheat, 22 trials 2016
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
Yield, ton/ha
18,0
16,0
14,0
12,0
10,0
8,0
6,0
Protein, pct.
0
50
100
150
200
250
300
Kg N per ha
Yield
Protein


Nitrogen to winter wheat, 22 trials 2016
Netincome, without protein
Netincome, with proteincorrection
Price
180 kg N/ha
217 kg N/ha
Netincome, Euro per ha
Price, Euro per ton
Kg N per ha
1200
1000
800
600
400
200
0
170,00
165,00
160,00
155,00
150,00
145,00
140,00
135,00
130,00
0
50
100
150
200
250
300

BACK TO OPTIMAL N-QUOTAS

Headlines of the political agreement in 2015:

- Stop for suboptimal N-quotas (17 pct. increase of quotas in 2016 and 25 pct. in 2017 = optimal rates)
- No mandatory bufferstrips (earlier 50,000 hectares)

- New more targeted regulation from 2019
- New phosphorous regulation
- Volunteer catch crops with subsidy 2017 and 2018

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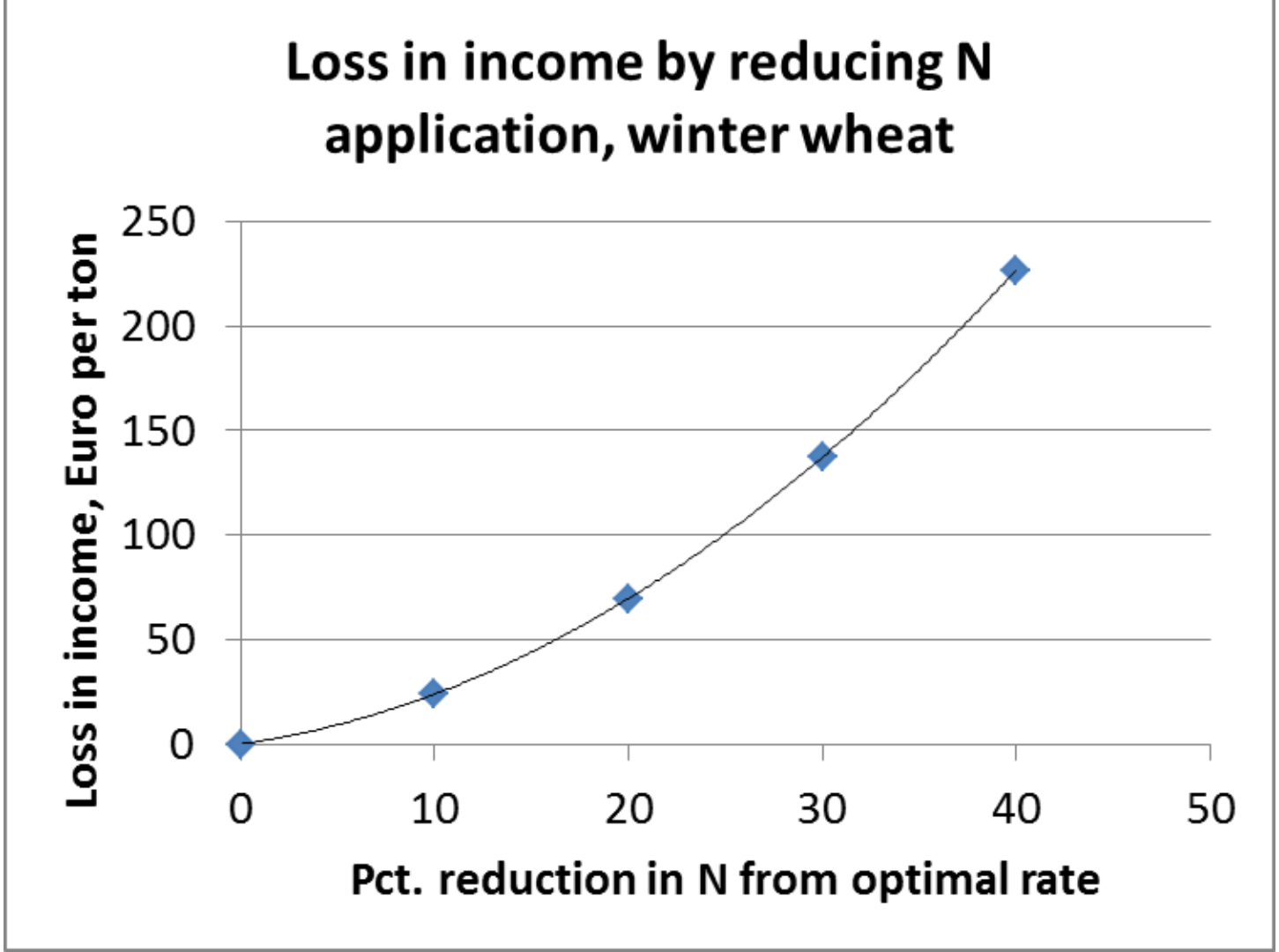
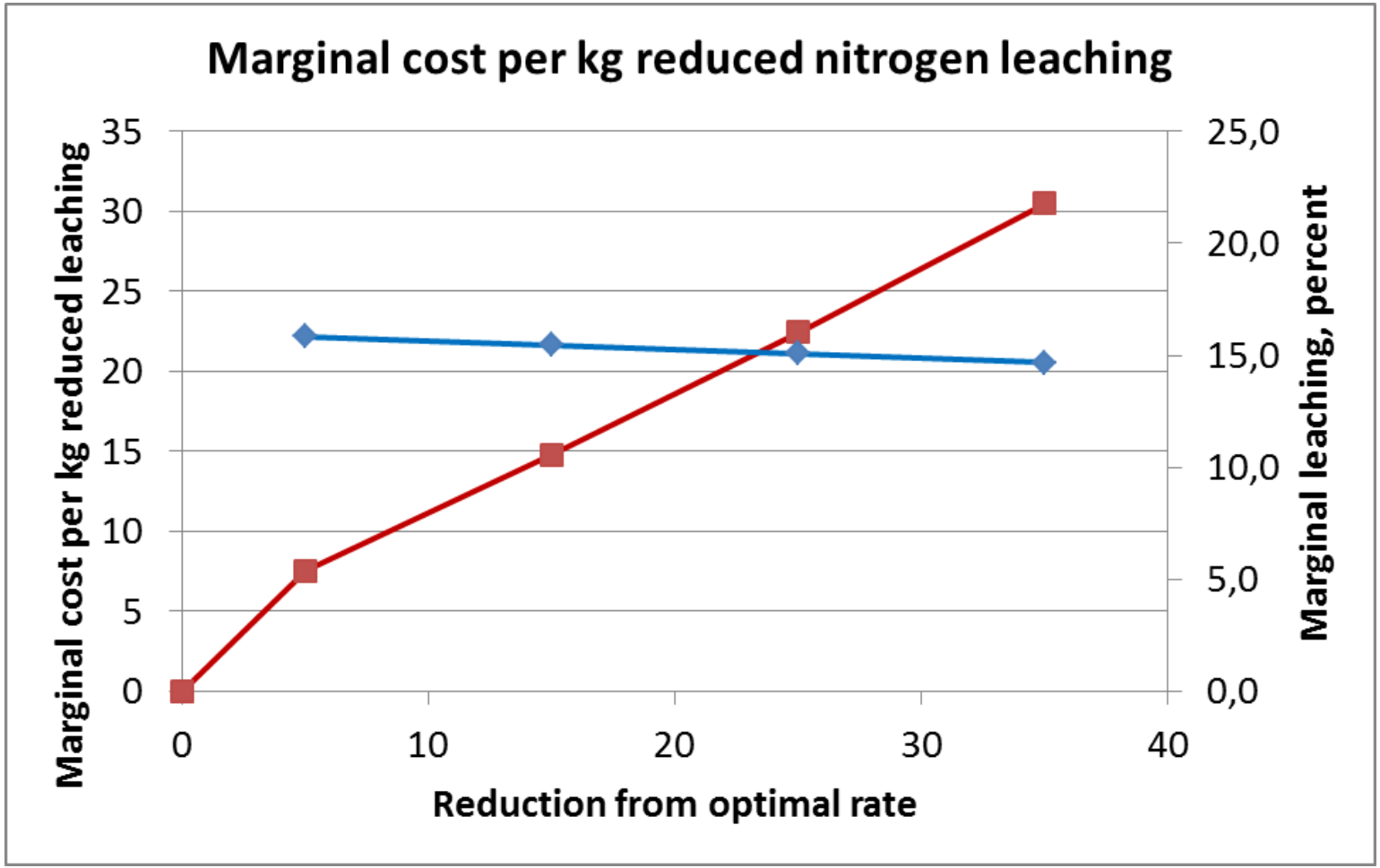
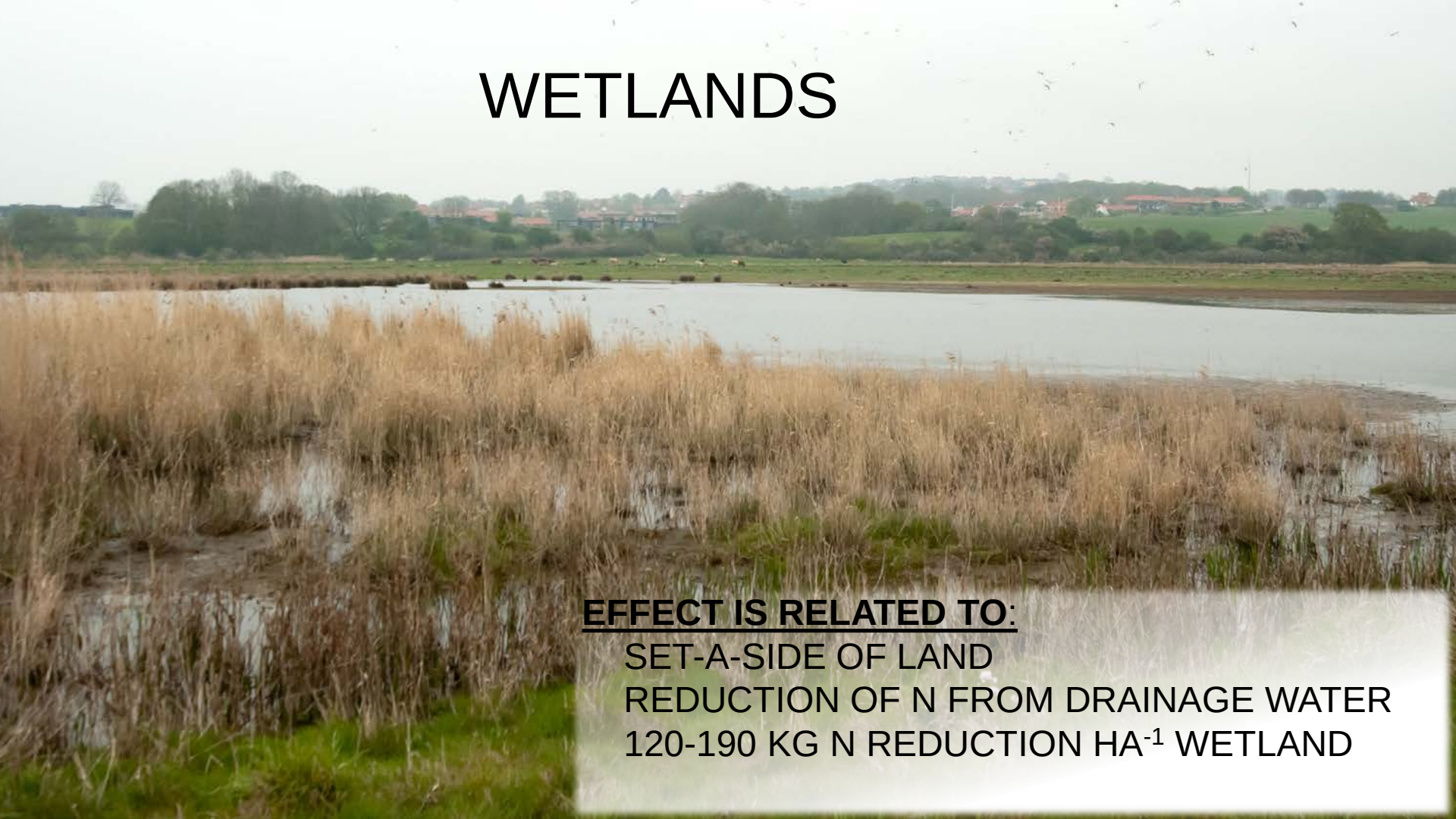

Loss in income by reducing N application, winter wheat
Loss in income, Euro per ton
250
200
150
100
50
0
0
10
20
30
40
50
Pct. reduction in N from optimal rate


Marginal cost per kg reduced nitrogen leaching
Marginal cost per kg reduced leaching
35
30
25
20
15
10
5
0
25,0
20,0
15,0
10,0
5,0
0,0
Marginal leaching, percent
0
10
20
30
40
Reduction from optimal rate

Headlines of the nitrogen budget from the Food and agricultural package.

	Ton nitrogen loss to the coastal waters
Average loss of nitrogen 2010-2014	56.760
Target for loss in 2021	44.700
Total demand for reducing the loss	13.460
Effect of already decided legislation and general trend in agriculture (baseline)	-5.600
Effect of the political agreement in 2015	5.200
Demand for reducing the loss after the political decision 2015	13.100
Postponing of the reduction to third period (2021-2027)	-6.200
Total target for reduction in 2021	-6.900
- Collective initiatives (wetlands, constructed wetlands..)	-3.400
- Regulation in vulnerable areas	-3.500

WETLANDS



EFFECT IS RELATED TO:

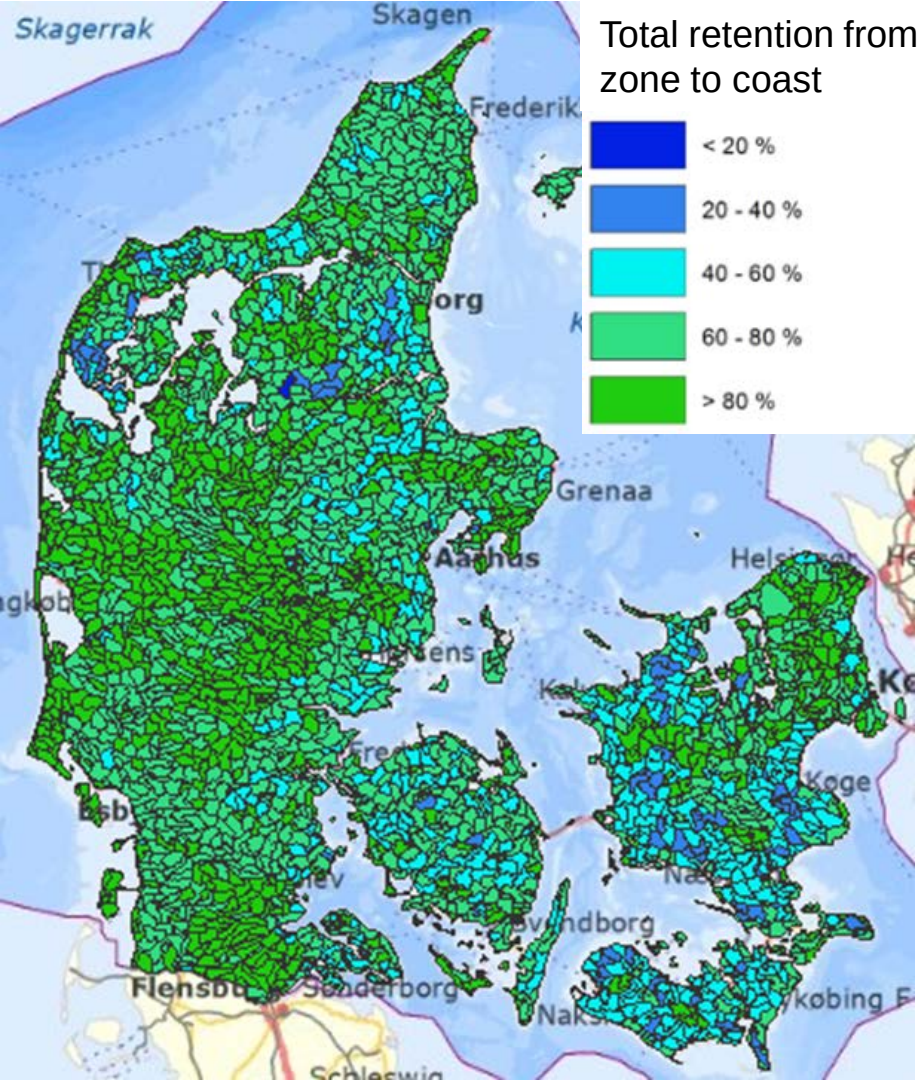
SET-A-SIDE OF LAND

REDUCTION OF N FROM DRAINAGE WATER

120-190 KG N REDUCTION HA^{-1} WETLAND

CONSTRUCTED WETLANDS

DRAINAGE WATER GO THROUGH THE CONSTRUCTED WETLAND
CA. 1 PCT. WATER SURFACE PER 100 HA CATCHMENT
20-30 PCT. N-REMOVAL



Retention: How much of the leaching from the root zone is removed before it goes to the coastal waters by denitrification in soil or in eg lakes…

Leaching from root zone, kg N	Retention, pct.	Kg N to coastal waters ha $^{-1}$
40	30	28
80	90	8

THE ACCEPTABLE N-LOSS FROM ROOT ZONE DEPENDS ON

- The sensitivity of the actual coastal water
- The actual retention in the catchment or in the actual subcatchment
- The plan/possibilities for increasing the retention by eg
  - Establishing more wetlands
  - Establishing constructed wetlands

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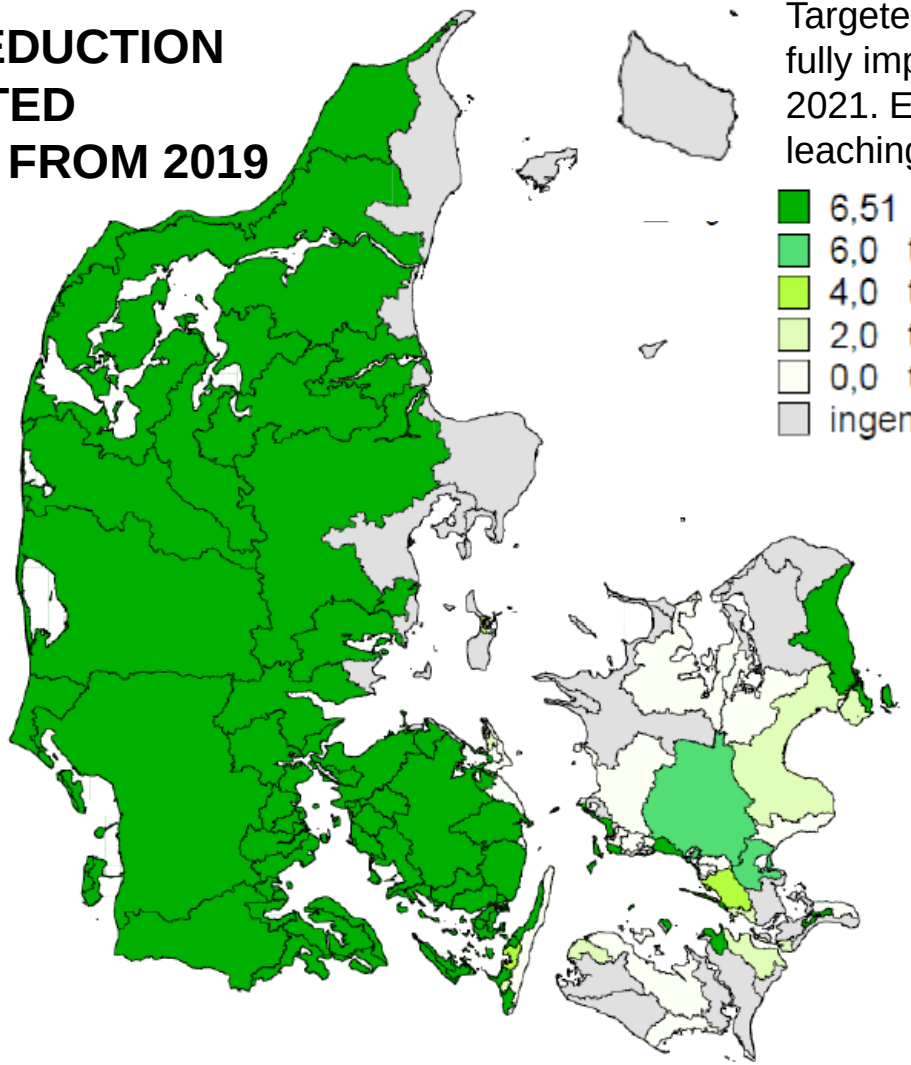
PLAN FOR REDUCTION WITH TARGETED REGULATION FROM 2019



Targeted regulation must give a reduction at 3,500 ton.

<u>Instruments:</u>

Cover crops?

Reduced quotas?

Crop rotations?

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THE PROBLEMS WITH REGULATION DO NOT STOP WITH ENDING SUBOPTIMAL N-QUOTAS

- Target for loss of N to coastal water at 44,000 ton still exists
- In 2017 and 2018 145,000 ha more catch crops
- From 2019 regulation of 75 pct. of the area with a minimum reduction of 6.5 kg N ha^{-1} from root zone (More catch crops, N-reduction?)
- From 2021-2027 the postponed N-reduction might be required

THANK YOU FOR YOUR ATTENTION!

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