

Ten years of experience with artificial wetlands to reduce nitrogen and phosphorus emissions from drained agricultural areas in Denmark

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Outline



Background

Regulations

- Targeted national regulations
- Measures and catchment officers

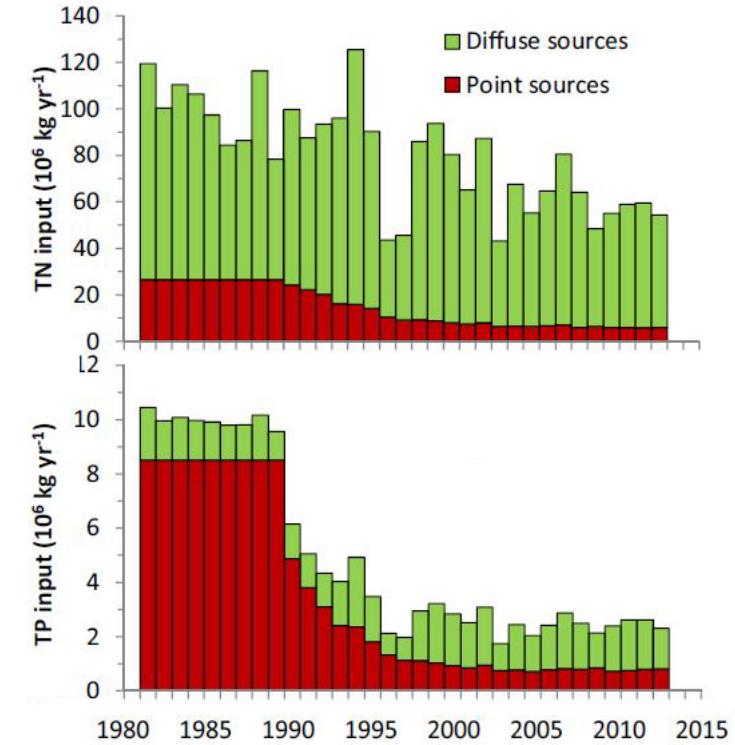
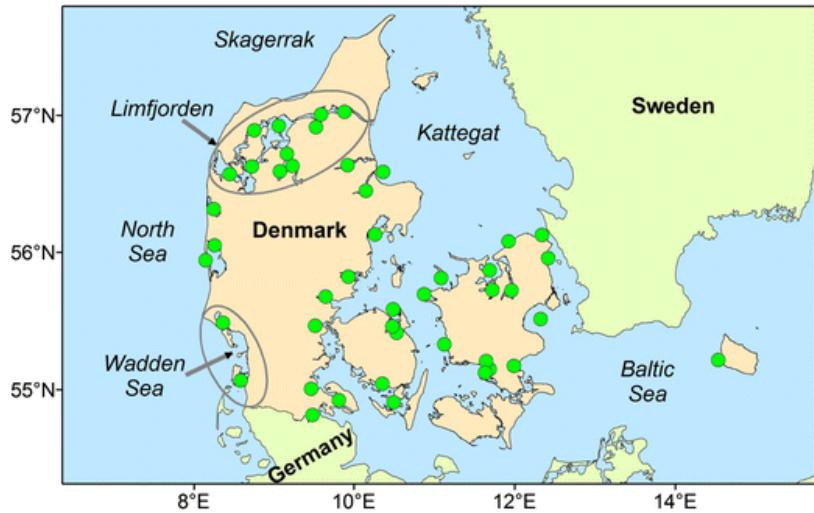
Collective measures to reduce nutrient losses

- Surface flow constructed wetlands (SF-CWs)
- SF-CWs paired with woodchip bioreactors

Perspectives

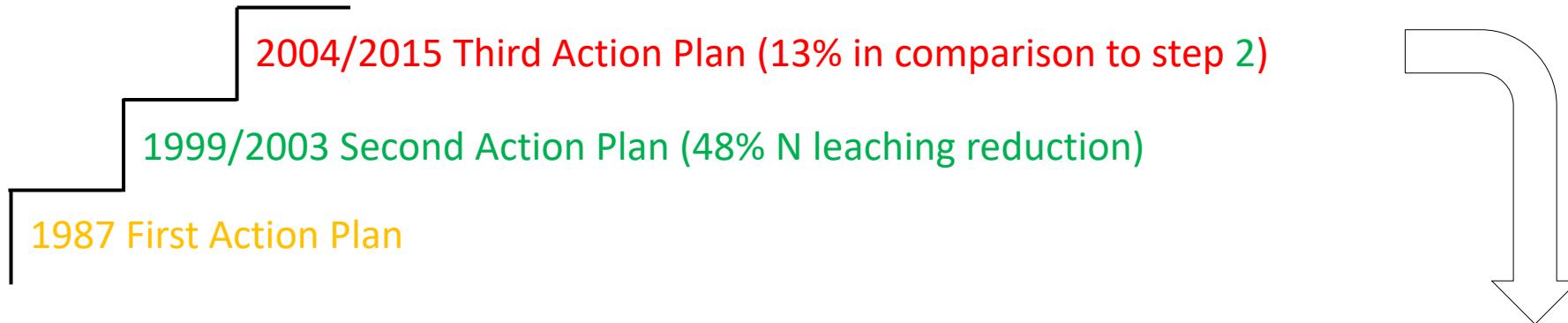


N and P inputs to coastal waters in Denmark



Riemann et al. (2016)

National regulations



Green Growth Agreement (2009)
From leaching to nutrient load reduction

- River Basin Management Plan – 2009/2015
- River Basin Management Plan – 2015/2021

Food and Agricultural Package Legislation (2015)



1. Remove historical mitigation measures
 - The mandatory reduction of nitrogen application standards
 - Mandatory buffer stripes
2. Collective measures – Catchment basis
 - Voluntary
 - Financially compensated
 - Primarily off-field
3. Targeted regulations (2019) – Farm basis
 - Mandatory
 - No compensation
 - Mostly on-field (catch crops, buffer strips, etc.)

Measures

Measures	N reduction (tons N/a)
Establishment of wetlands	1,253
Establishment of mini-wetlands	900
Afforestation (new forests)	150
Set-aside of farmland on organogenic soils in river valleys	150
Improved Wastewater treatment	44
Acquisition of fishfarms	84
Limitation on use of Ecological Focus Area (EFA) as alternatives to area with mandatory catch crops plus effect from replacing EFA buffer strips with other EFA elements after annulment of regulation on statutory buffer strips. (the EFA area can be established by buffer strips, catch crops, fallow land, coppice and GAEC landscape elements*)	867
A targeted regulation of nitrogen leaching at farm level	3,513
Total N reduction effect of new measures in 2021	6,961

*Supported by EU
Rural Development Programme*

Ministry for Food, Agriculture and Fisheries 2017

Catchment officers

- Part of agricultural advisory service
- Preparation of tender material
- Obtaining offers from contractor
- Obtain permits from the authorities
- Preparation of grant application
- Coordination of project implementation
- Reporting and withdrawal request



<https://oplandskonsulenterne.dk>

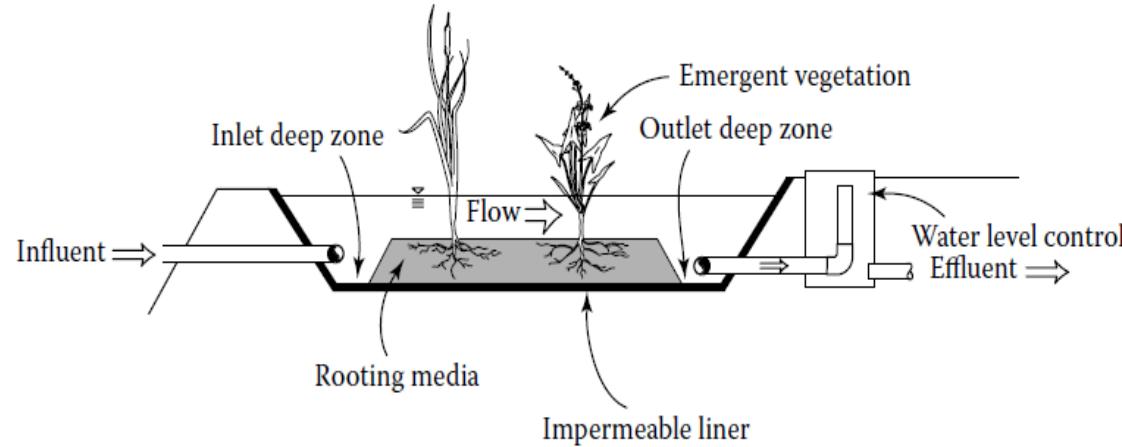
Potential map for mini-wetlands

- The potential map from 2019 can be used as the first designation criterion in the 2020 application round.
- If the local inspection shows that the area has a carbon content > 6% , the area must be excluded
- "Not suitable" areas from the 2017 map and low-lying area are not suitable.
- In borderline cases an external expert may be involved in the local inspection.
- **The area can be used if it is suitable according to the 2019 map that the carbon content is < 6% and there is no real lowland soil.**



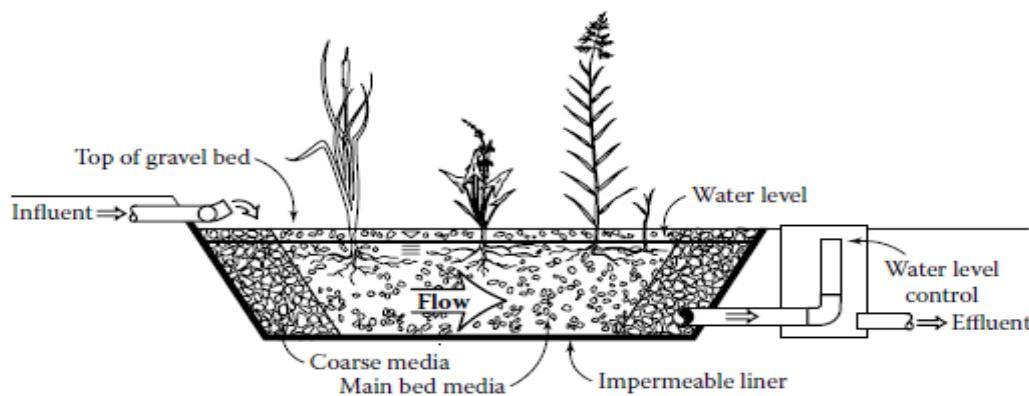
Børgesen et al. 2019

Types of constructed wetlands



Surface flow (SF-CW)

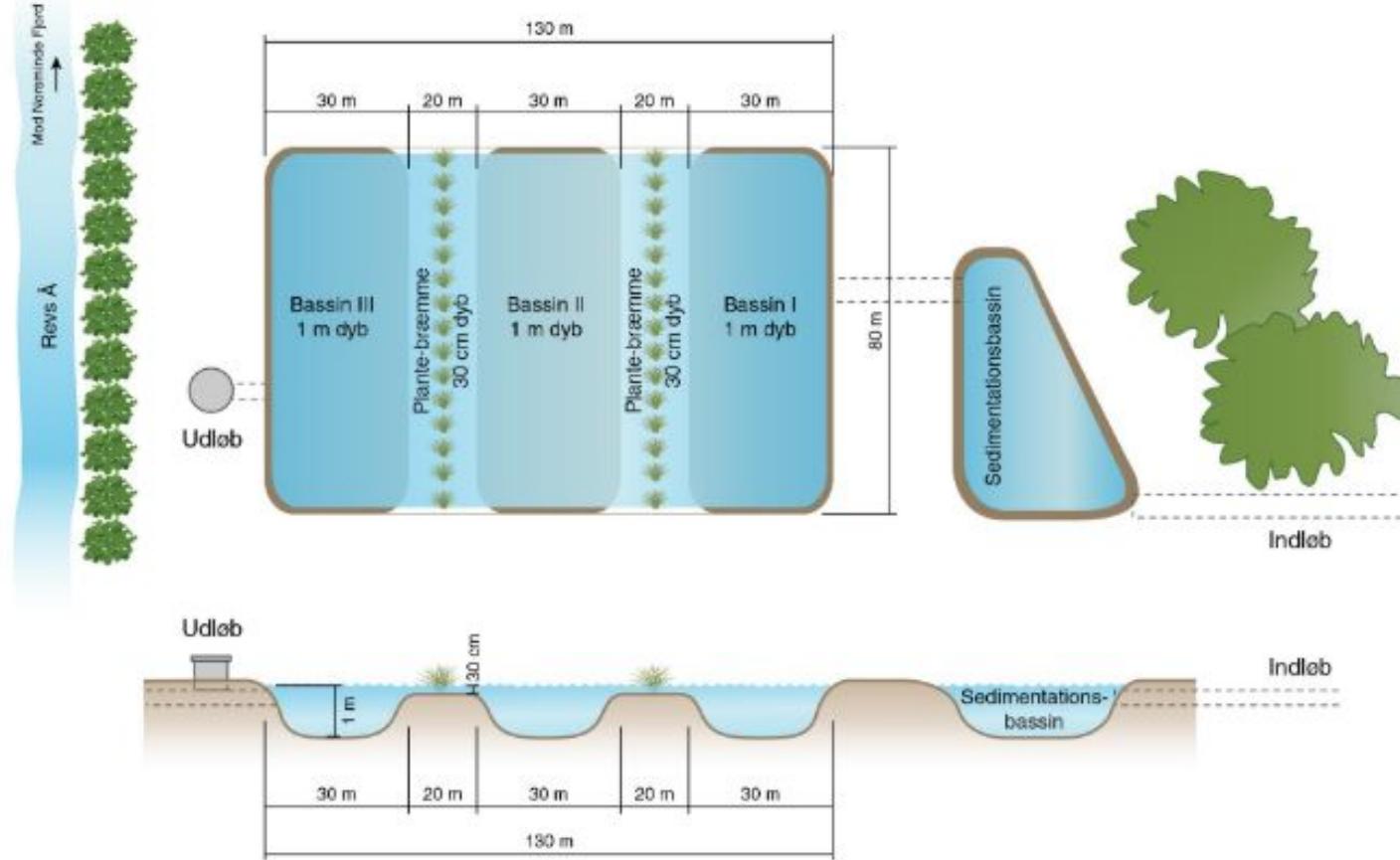
- + Higher flow rates
- Higher surface occupied



Subsurface flow (SSF-CW)

- + Operation under colder conditions
- Clogging of the media

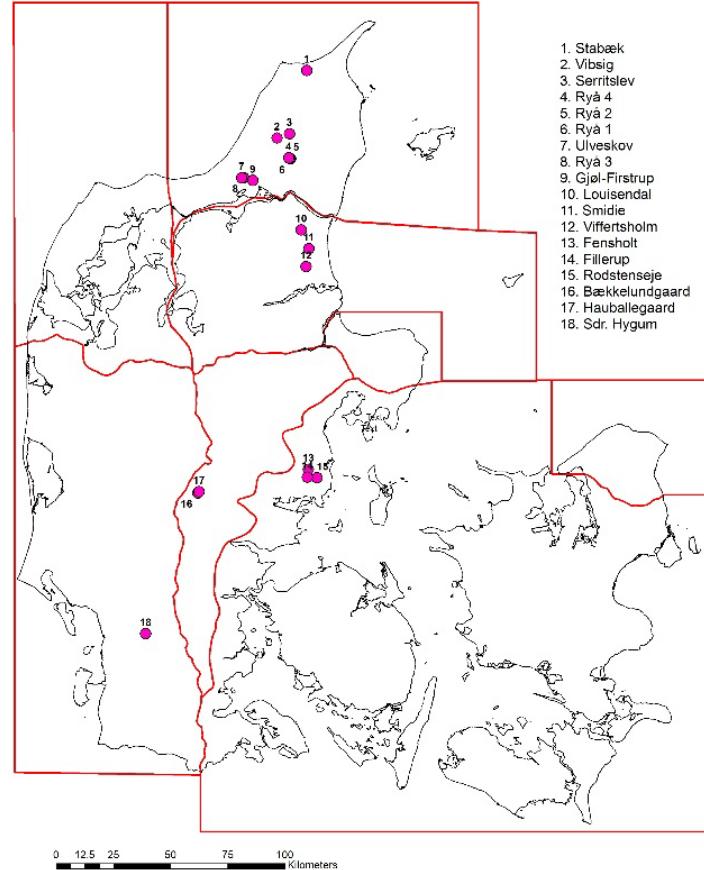
SF-CWs design



Monitoring program for SF-CWs

CW	Construction year	A _c ha	A _{CW} m ²	V _{CW} m ³	A _{CW:A_C} ratio (%)	
14	Fillerup	2010	38	2984	2.053	0.79
15	Odder	2010	100	8450	7.121	
13	Fensholt	2015	33	2453	1.478	0.74
6	Ryå 1	2013	230	21354	14.103	0.93
5	Ryå 2	2013	110	7960	4.881	0.72
8	Ryå 3	2013	78	8484	6.659	1.09
4	Ryå 4	2014	130	15157	10.675	1.17
2	Vibsig	2014	100	4443	2.459	0.44
7	Ulveskov	2014	130	15267	10.324	1.17
3	Serritslev	2015	50	6283	4.134	1.26
9	Gjøl-Fistrup	2015		8152	6.725	
12	Wiffertsholm	2014	58	6.865	3.877	1.18
11	Smidie	2015	55	6408	3.990	1.17
18	S. Hygum	2016		3014	2.053	

Kjærgaard et al. 2021, in preparation

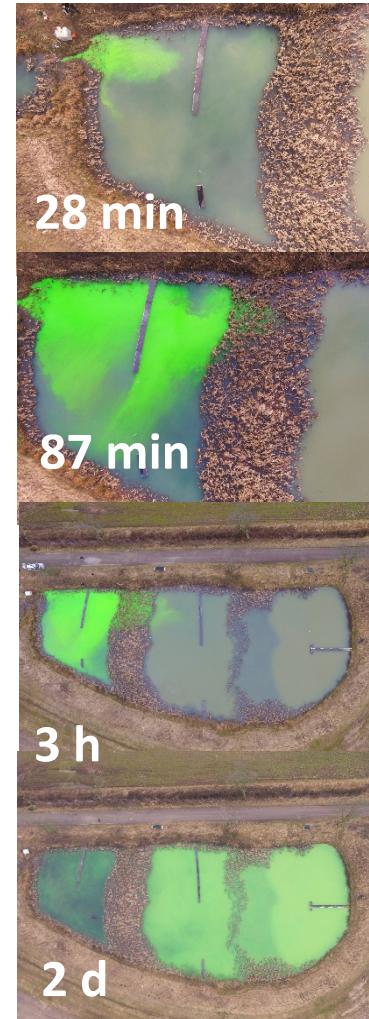


Results

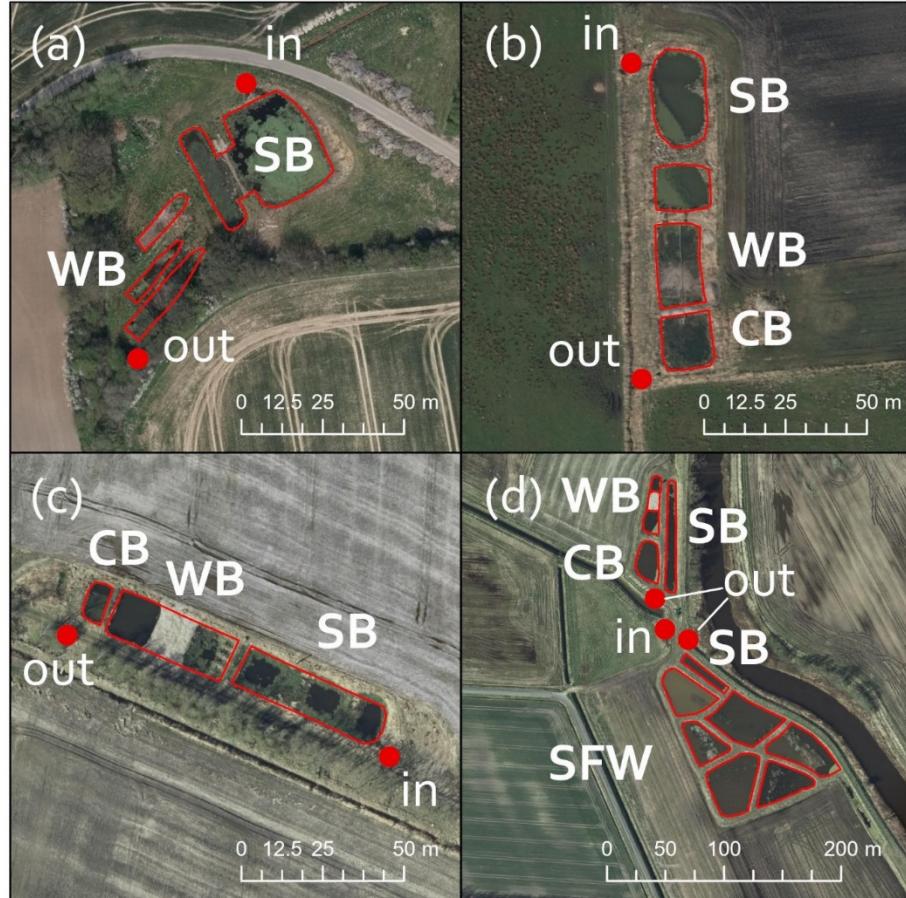
SF-CW	Year	HLR m/yr	Total Nitrogen			Total Phosphorus		
			Field loss kg/ha/yr	Concentration mg/l	Retention %	Field loss kg/ha/yr	Concentration mg/l	Retention %
Vibsig	2014/15	42	24.6	10.7	18	0.455	0.198	14
	2015/16		21	9.14		0.462	0.201	
	2016/17		14.4	6.26	18	0.382	0.166	32
	2017/18		29	12.6	18	0.476	0.207	32
Serritslev	2015/16	25	15.4	6.1	18	0.222	0.088	29
	2016/17		12.8	5.08	32	0.683	0.271	37
	2017/18		16.2	6.44	23	0.883	0.351	27
Ryå-4	2014/15	18	16.3	7.4	11	0.303	0.138	48
	2015/16		15	7.21	17	0.546	0.262	67
	2016/17		12.2	7.59	13	0.394	0.244	70
	2017/18		19.9	8.1	11	0.7	0.284	52
Ryå-2	2013/14	78	24.6	4.7	29	0.31	0.059	26
	2014/15		27.4	4.42	21	0.409	0.066	49
	2015/16		28.5	4.82	24	1,019	0.173	49
	2016/17		22.9	4.48	24	0.852	0.167	51
Ryå-3	2013/14	30	12	3.84	18	0.796	0.255	59
	2014/15		11.4	3.26	16	0.859	0.246	25
	2015/16		9.4	2.34	6	1,861	0.462	45
	2016/17		10.4	4.11	16	0.479	0.189	11

Kjærgaard et al. 2021, in preparation

Solute transport in CWs



SSF-CWs paired with woodchip bioreactors



Clarification basin (CB)
Sedimentation basin (SB)
Woodchip bioreactor (WB)

Establishment year	A_c ha	SB m^3	WB m^3	CB m^3	A_{SFW+WB} m^2	$A_{SFW+WB}:A_c$ ratio	
					%		
Aakaer	2011	75	840	110	Absent	1194	0.16
Ondrup	2010	110	776	110	220	1150	0.13
Ryaa	2011	85	624	140	500	955	0.19
Gjol	2015	164	623	110	574	1055	0.11

Pugliese et al. 2020b

SSF-CWs paired with woodchip bioreactors

SF-CW + woodchip bioreactors	Year	Q m ³	Total Nitrogen			Total Phosphorus		
			Field loss kg/ha/yr	Concentration mg/l	Retention %	Field loss kg/ha/yr	Concentration mg/l	Retention %
Aakaer	2012/13	361638	30	6	14	1.01	0.21	39
	2013/14	380031	31	6	39	0.73	0.14	64
	2016/17	324249	29	7	16	0.63	0.14	51
	2017/18	452567	51	8	9	0.46	0.08	41
	2018/19	188137	28	11	16	0.53	0.21	79
Ondrup	2010/11	131382	6	5	50	0.24	0.2	69
	2011/12	175508	9	6	42	0.65	0.41	80
	2012/13	225513	11	5	34	0.35	0.17	56
	2013/14	165828	8	5	51	0.21	0.14	71
	2016/17	235571	10	5	26	0.25	0.12	17
	2017/18	271644	13	5	32	0.64	0.26	39
	2018/19	155345	10	7	16	0.27	0.19	-23
Ryaa	2016/17	124670	4	3	32	0.06	0.04	0
	2017/18	194155	16	7	18	0.14	0.06	67
	2018/19	108647	13	10	8	0.06	0.05	44
Gjol	Dec 18/Nov19	101777	5	8	27	0.45	0.72	-24
Gjol SFW	Dec 18/Nov19	230732	12	8	26	0.82	0.58	6

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Challenges

Interreg
North Sea Region
NuReDrain

European Regional Development Fund



EUROPEAN UNION

- Decrease negative effects due to nutrient losses while maintaining or increasing food production
- Apply a holistic policy approach, not only considering the direct mitigating effect and costs but also other benefits and effects of the actual measure
- Precise farming with modern technology should be highlighted to obtain higher yields and lower nitrogen losses
- More effort is needed to meet the good ecological status for surface waters under the EU Water Framework Directives
- Future monitoring should include evaluation of greenhouse gas emissions and biodiversity
- Improved designs to mitigate greenhouse gas emissions and maximize carbon sequestration
- Evaluation of pesticide retention under Danish conditions



Thank you for your attention

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