Drainage filters targeting nutrient removal in agricultural drainage discharge: A new cost-effective mitigation strategy in Denmark

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SEGES, Danish Agriculture & Food Council

SEGES

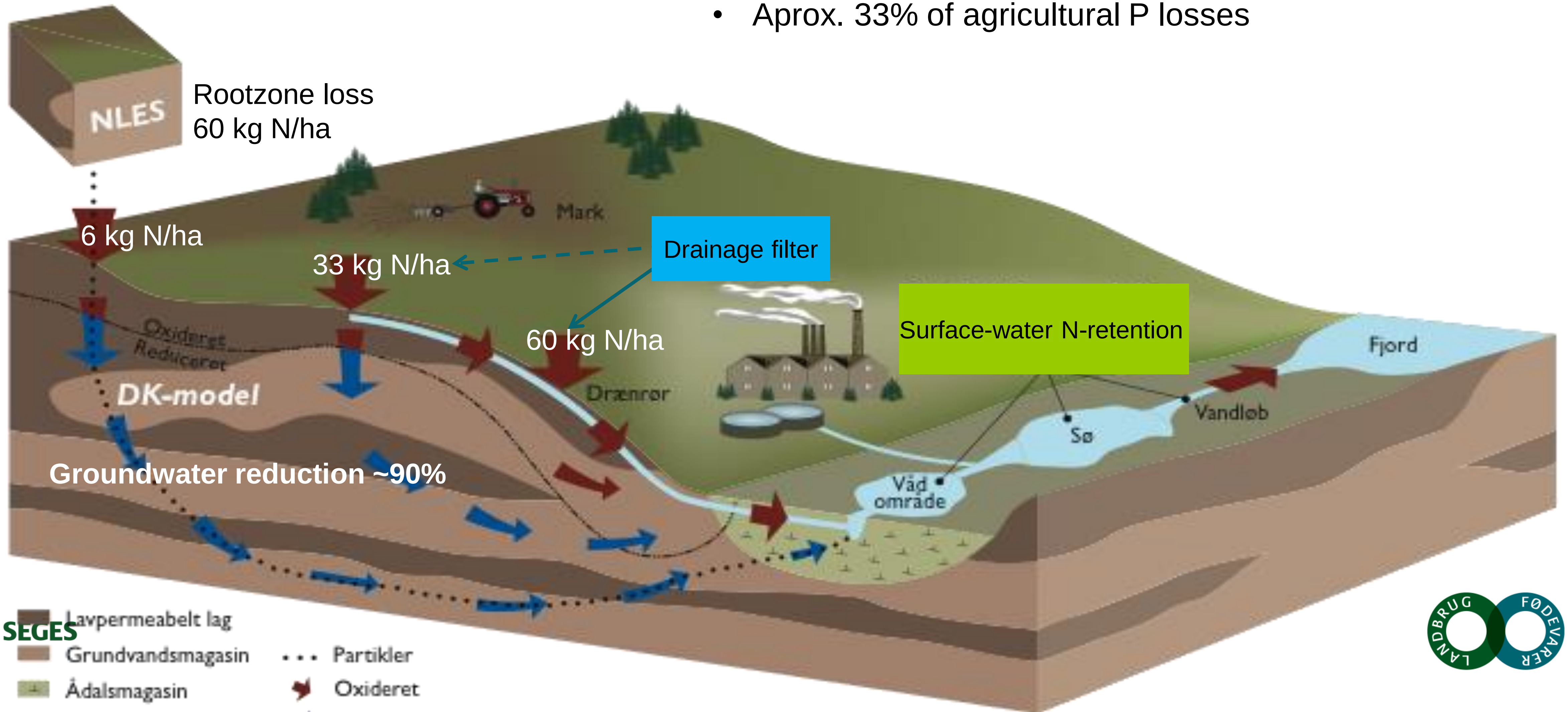
Studietur Sverige 3. september 2019

STØTTET AF
Promilleafgiftsfonden for landbrug

Drainage filters a new targeted mitigation strategy

Drainage losses of nutrients accounts nationally for:

- 50-60% of agricultural N losses -> locally up to 90%
- Aprox. 33% of agricultural P losses



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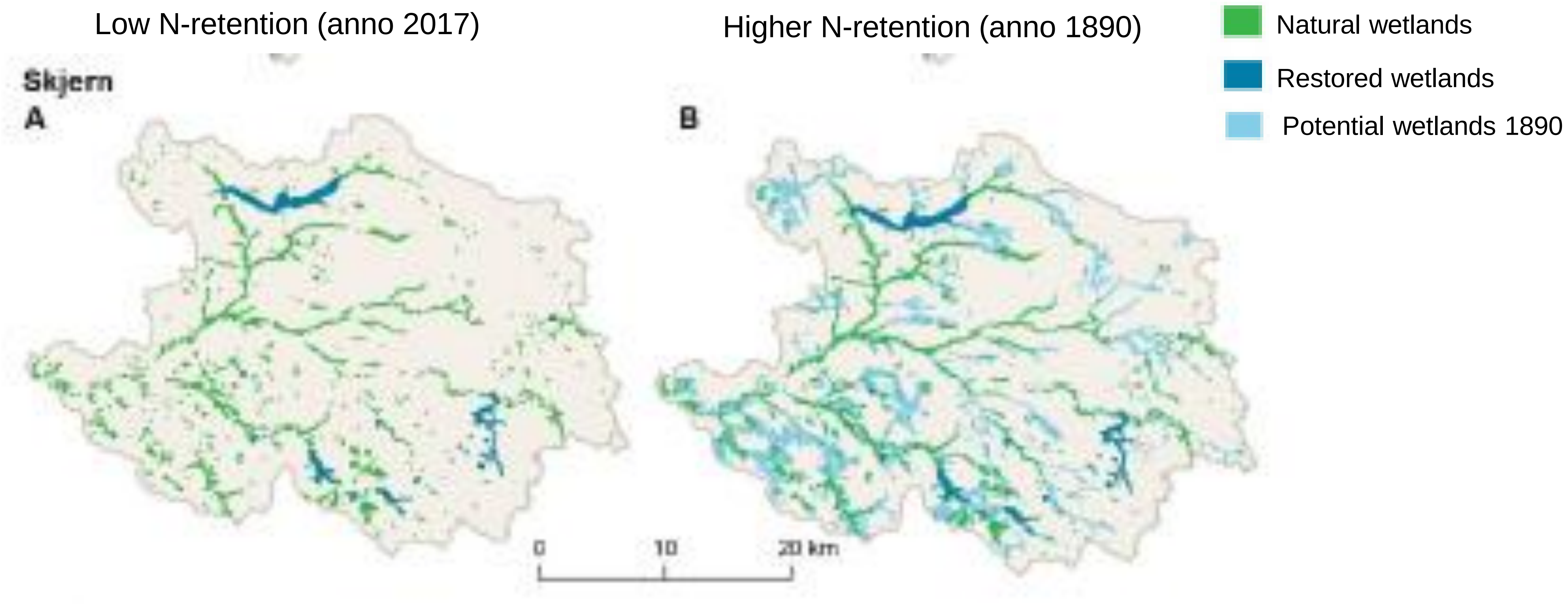
Wetlands as natural landscape filters – before and now

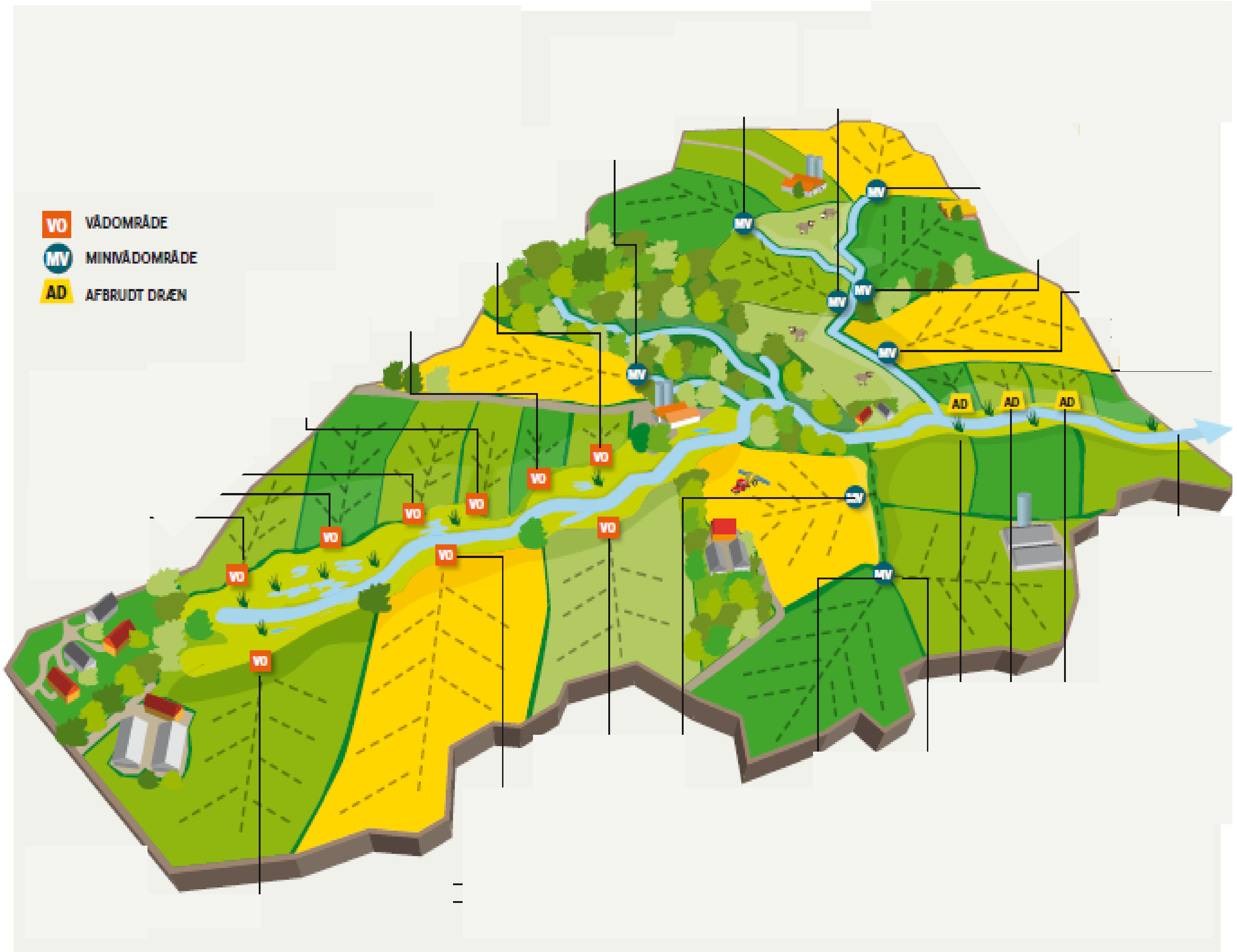
Low N-retention (anno 2017)

Higher N-retention (anno 1890)



Jensen, P.N. (Ed.) 2017. Estimation of Nitrogen Concentrations from root zone to marine areas around year 1900. Aarhus University, DCE-Danish Centre for Environment and Energy, 126 pp. Scientific Report No. 241. http://dce2.au.dk/pub/SR241.pdf

Visions for the targeted nutrient mitigation – restore landscape filters



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Kjærgaard, 2018. Kombiner virkemidlerne, og find den optimale løsning. Landbrugsavisen 21. juni 2018.

Visions for the targeted nutrient mitigation – restore landscape filters

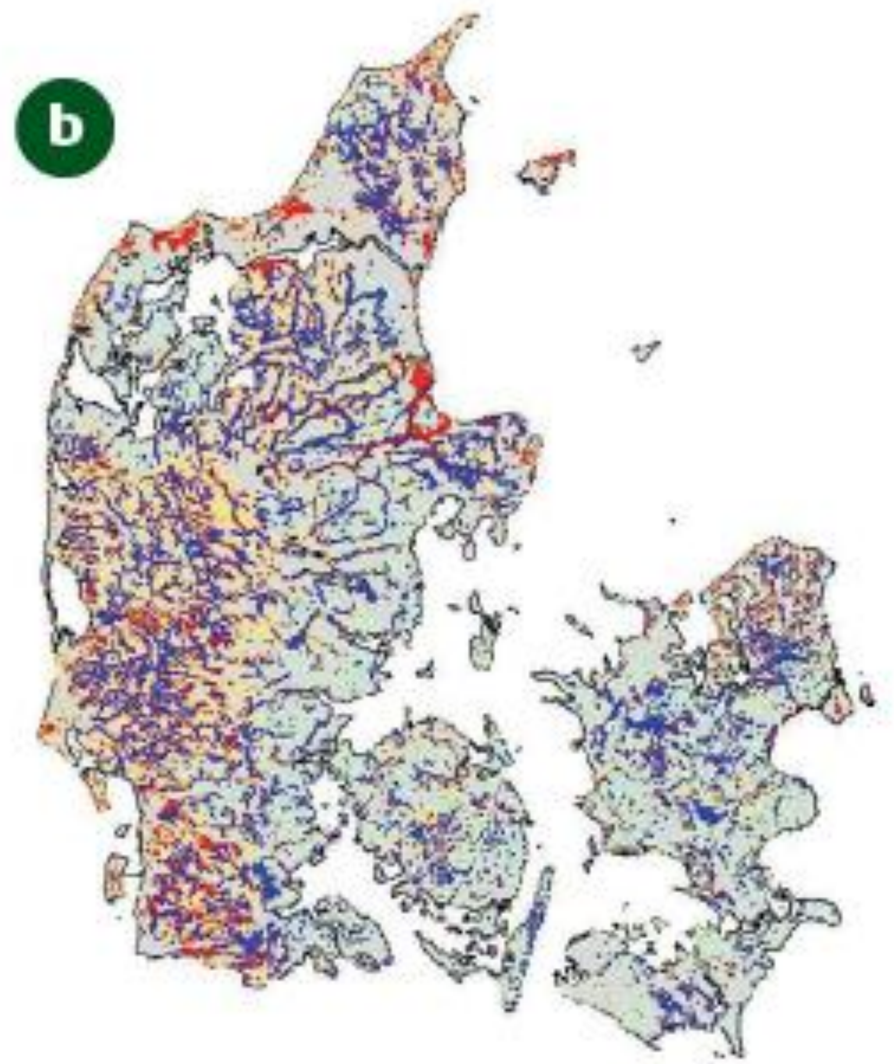
Riparian lowland

Kjærgaard, 2018. Kombiner virkemidlerne, og find den optimale løsning. Landbrugsavisen 21. juni 2018.

Riparian lowland

- Wetland restoration
- Disconnected tile drains

Significance of the N-reduction potential using riparian lowland



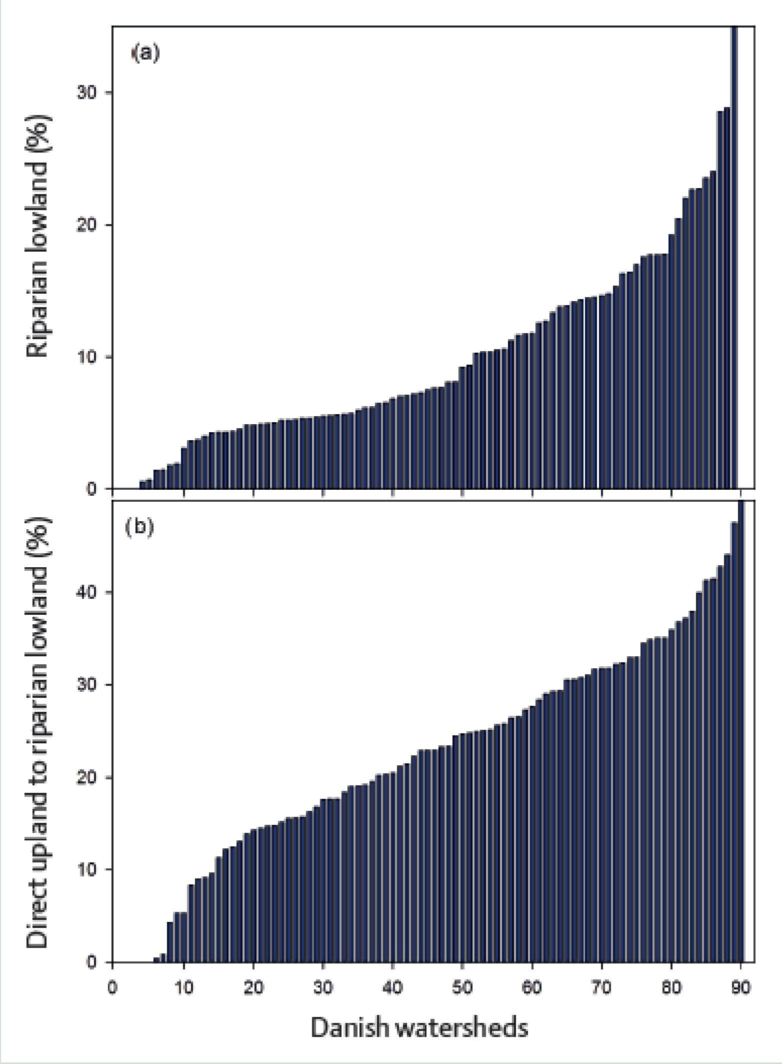


FIGURE 2. (a) Riparian lowland area, and (b) agricultural upland intercepted by riparian lowland in the Danish watersheds.

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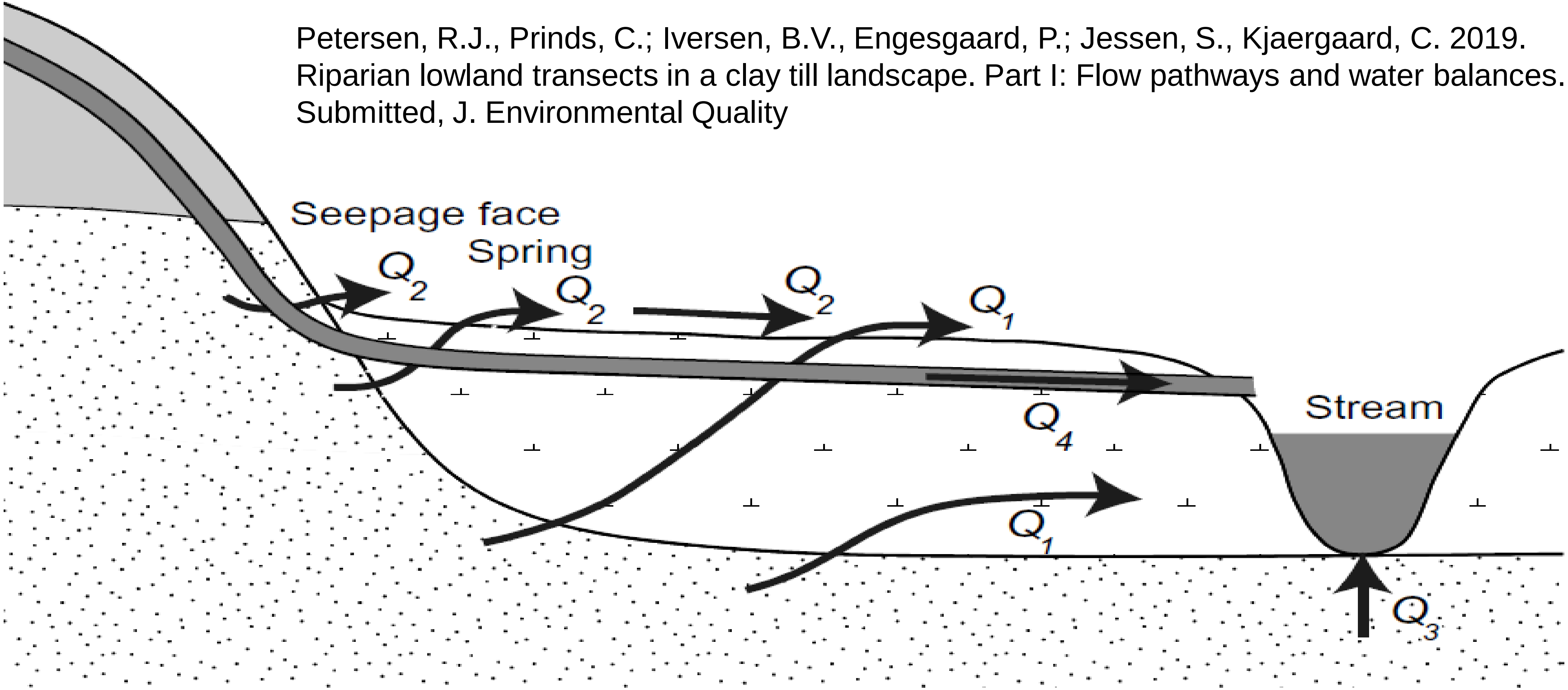
Kjærgaard, C. & Hørfarter R. 2018. Potential significance of of riparian lowlands on nitrogen fluxes from agricultural drainage in Danish watersheds. Presentation BONUS, Gdansk, Polen 14-16, March 2018.

Challenges in predicting N-reduction in riparian lowlands

Innovation Fund project TReNDS:

Water-balance model to distribute flow-pathways in riarian lowlands

Petersen, R.J., Prinds, C.; Iversen, B.V., Engesgaard, P.; Jessen, S., Kjaergaard, C. 2019. Riparian lowland transects in a clay till landscape. Part I: Flow pathways and water balances. Submitted, J. Environmental Quality



Visions for the targeted nutrient mitigation – restore landscape filters

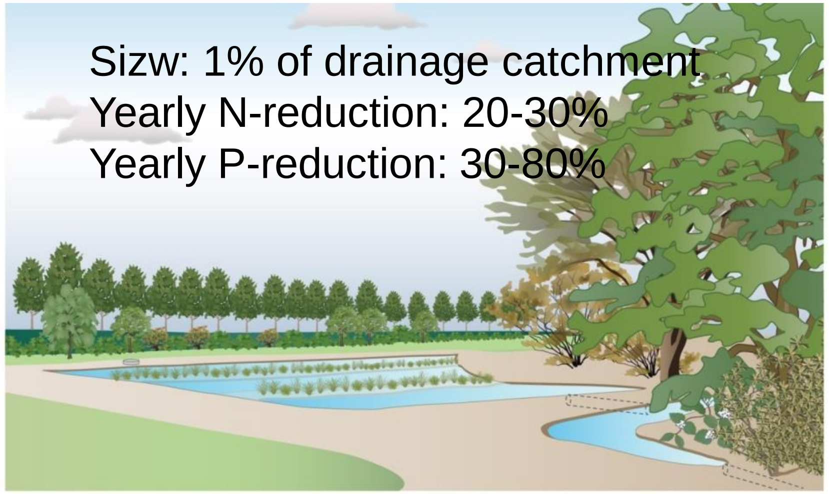
Riparian lowland

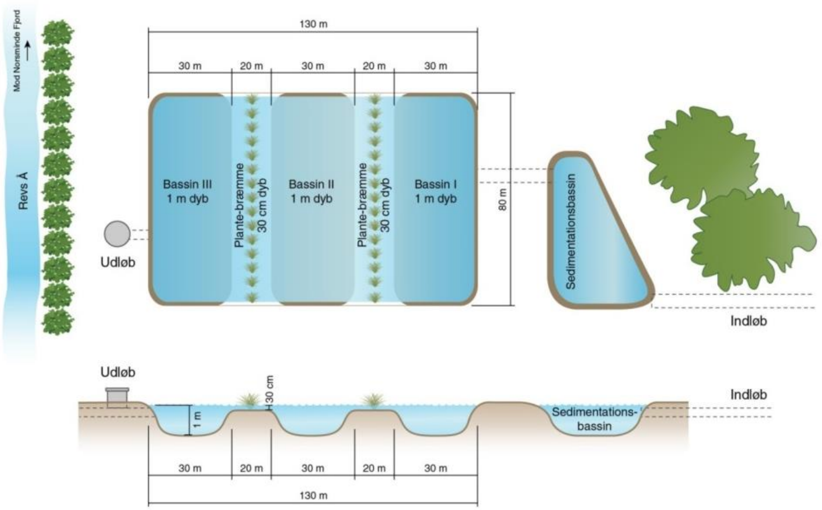
Constructed wetlands

Kjærgaard, 2018. Kombiner virkemidlerne, og find den optimale løsning. Landbrugsavisen 21. juni 2018.

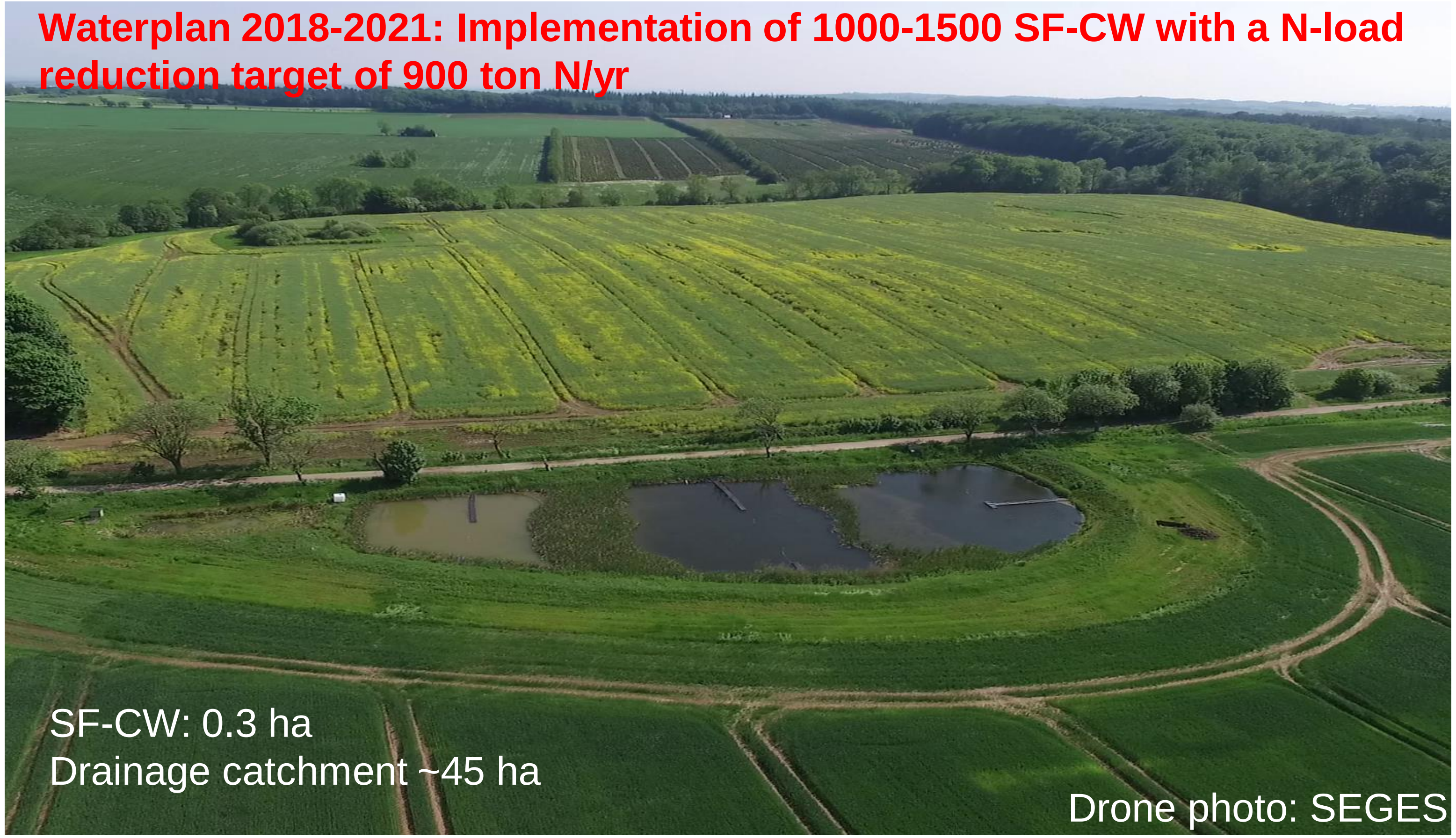
The first Danish surface-flow constucted wetland – Fillerup

Constructed in 2010 in the Norsminde Fjord Catchment, Odder, Denmark by DLMO, SEGES, AU



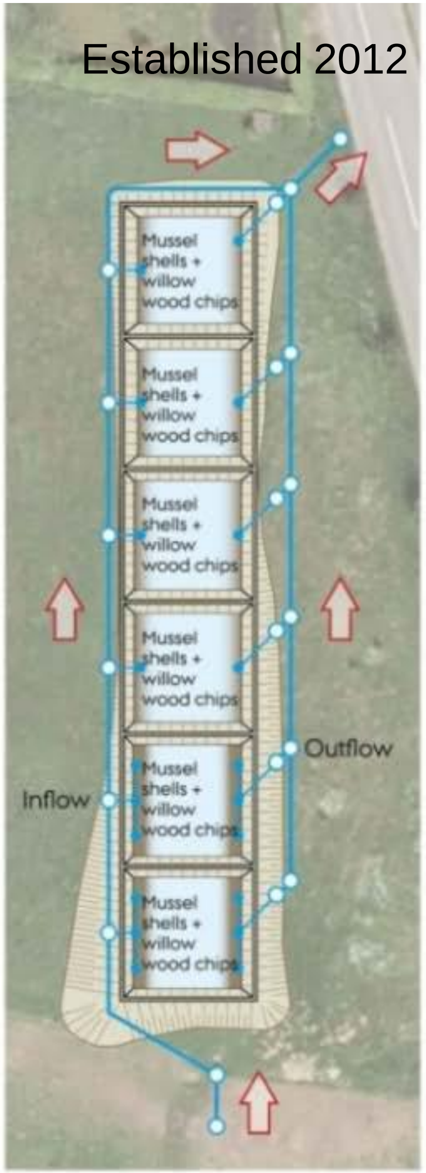


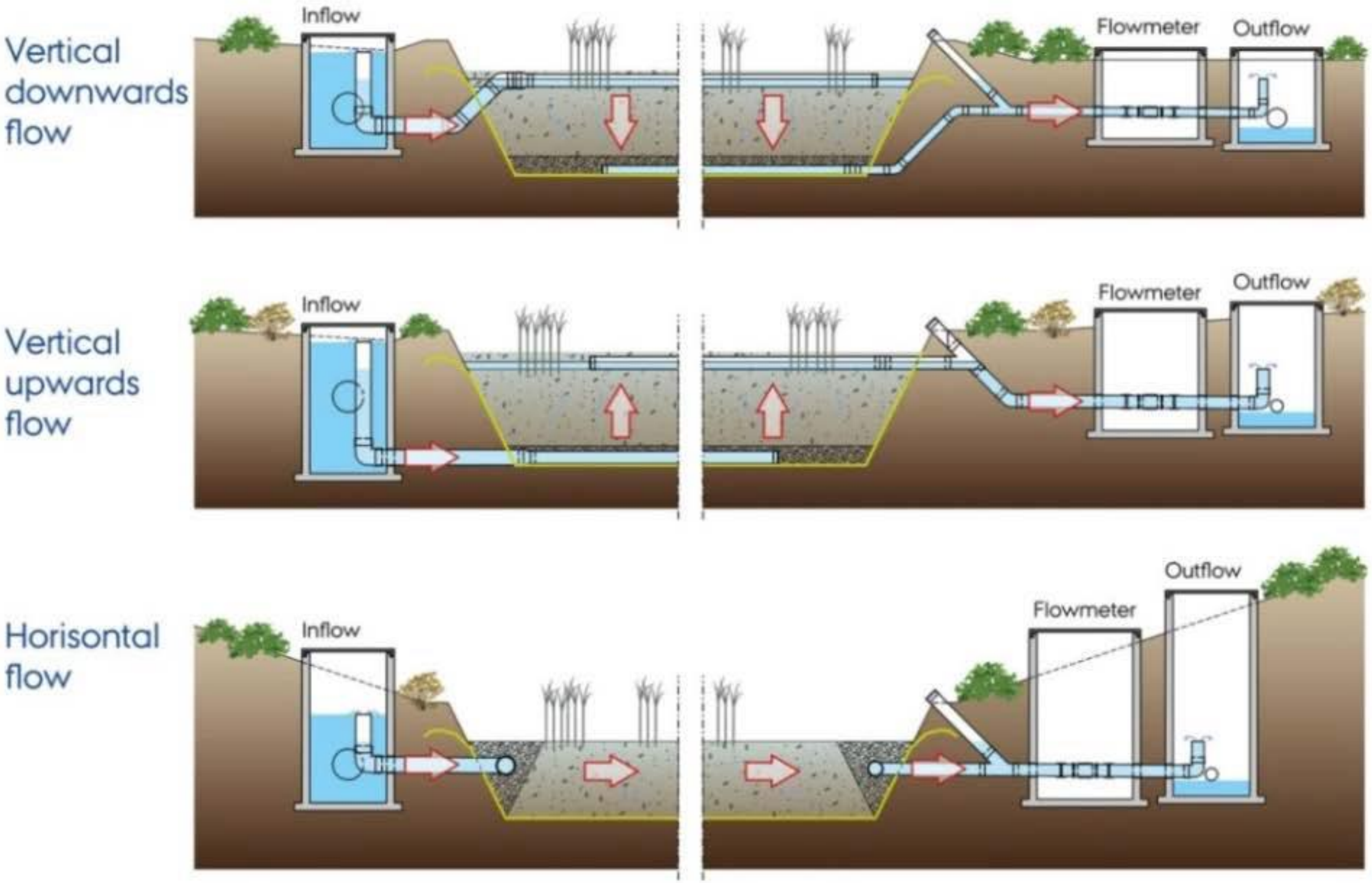
www.supremetech.dk



25 SF-CW constructed in DK in 2010-2015
Kjaergaard et al., (2014; 2017; 2019)

Subface-flow constucted wetlands (woodchips based bioreactors)





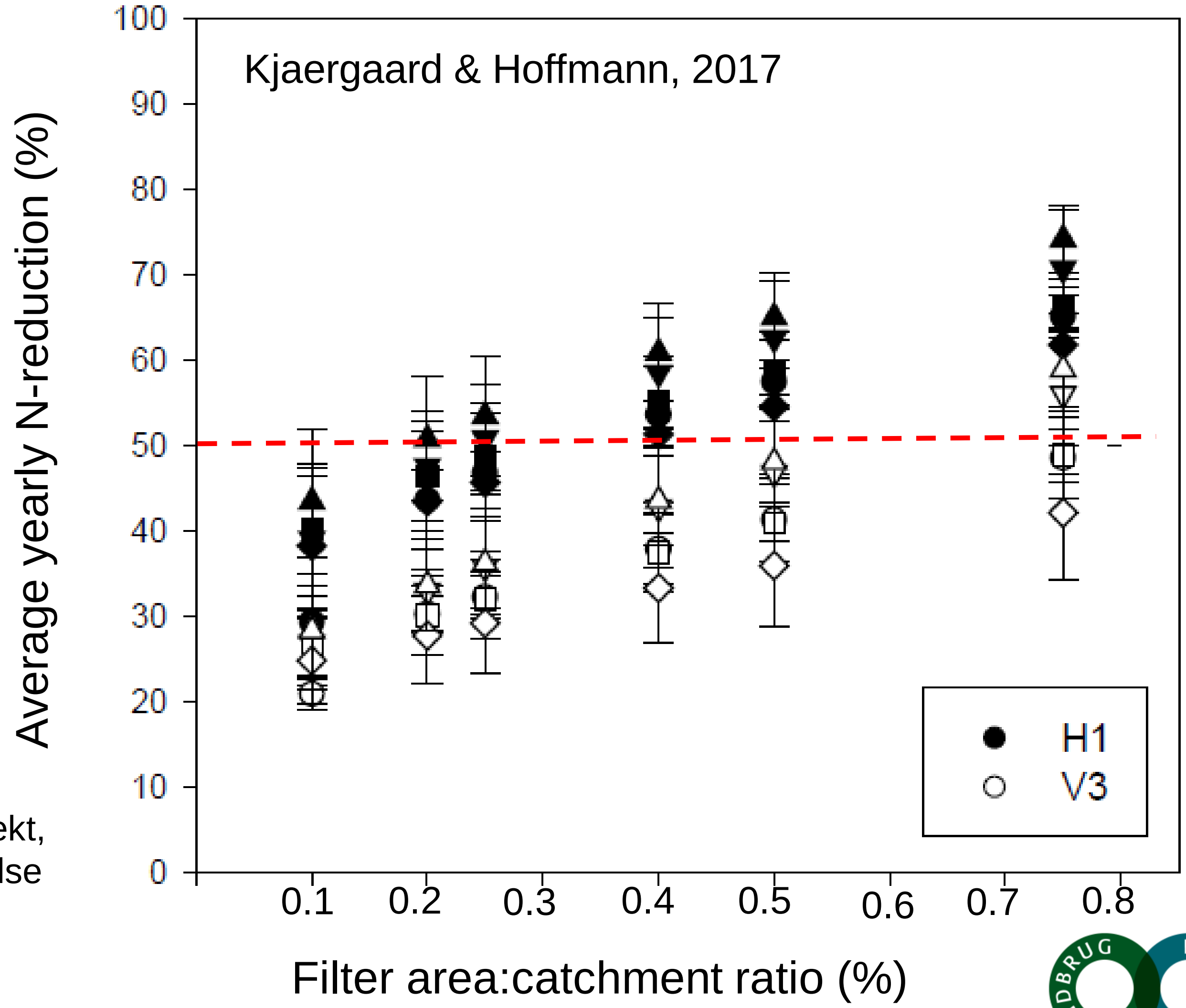
Hoffmann, C.C.; Larsen, S.E.; Kjaergaard, C. 2019. Nitrogen Removal in Woodchip-based Biofilters of Variable Designs Treating Agricultural Drainage Discharges. J. Environ. Qual. doi:10.2134/jeq2018.12.0442

Operational model for estimating bioreactor efficiency

www.supremetech.dk

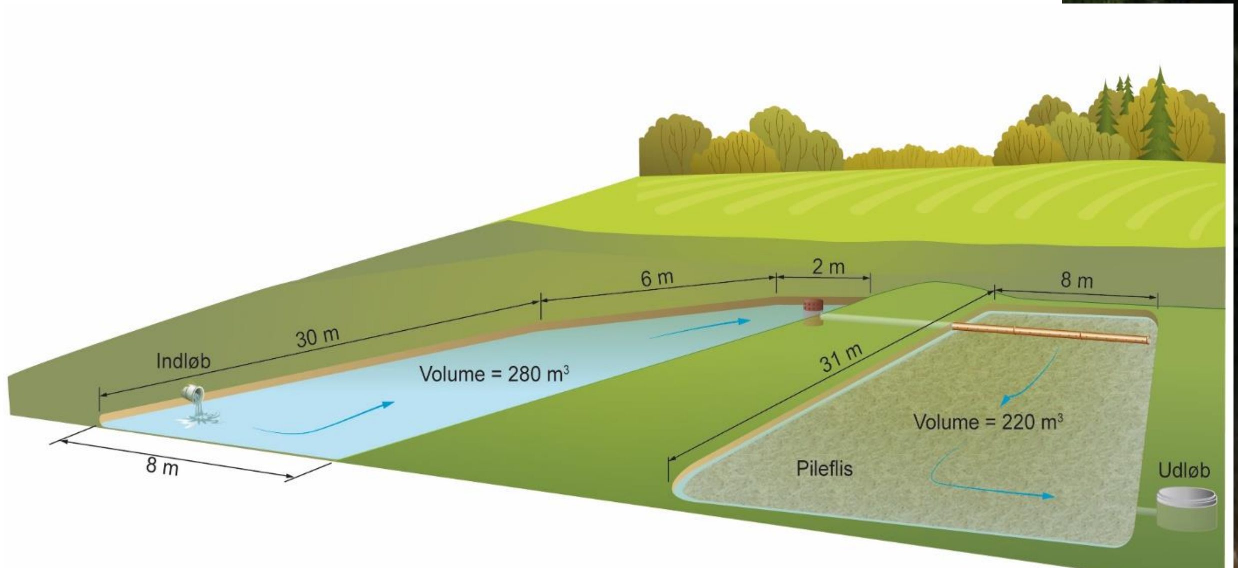
Model NO_3–N removal†	R^2
%	
$NO_3\text{–}N^{1.5} = -162.8 + 60.14WT + 132.9HRT$	0.876
$NO_3\text{–}N^{2} = -2236 + 655.7WT + 974.8HRT$	0.859
$NO_3\text{–}N = -6.946 + 4.325WT + 11.07HRT$	0.895
$NO_3\text{–}N = -1.491 + 4.332WT + 8.693HRT$	0.867
$NO_3\text{–}N^{1.5} = -173.8 + 56.72WT + 157.7HRT$	0.882
$NO_3\text{–}N^{2} = -1268 + 796.3WT + 15.23HRT$	0.835

Hoffmann, C.C.; Larsen, S.E.; Kjaergaard, C. 2019. Nitrogen Removal in Woodchip-based Biofilters of Variable Designs Treating Agricultural Drainage Discharges. J. Environ. Qual. doi:10.2134/jeq2018.12.0442



Kjærgaard, C., Hoffmann, C.C. 2017. Vurdering af kvælstofeffekt, virkemiddels-scenarier og omkostningseffektivitet ved anvendelse af minivådområder med filtermatrice. SupremeTech rapport www.supremetech.dk

Full-scale bioreactor prototype including storage pond



iDRÆN – matrice vådområde (www.idraen.dk)

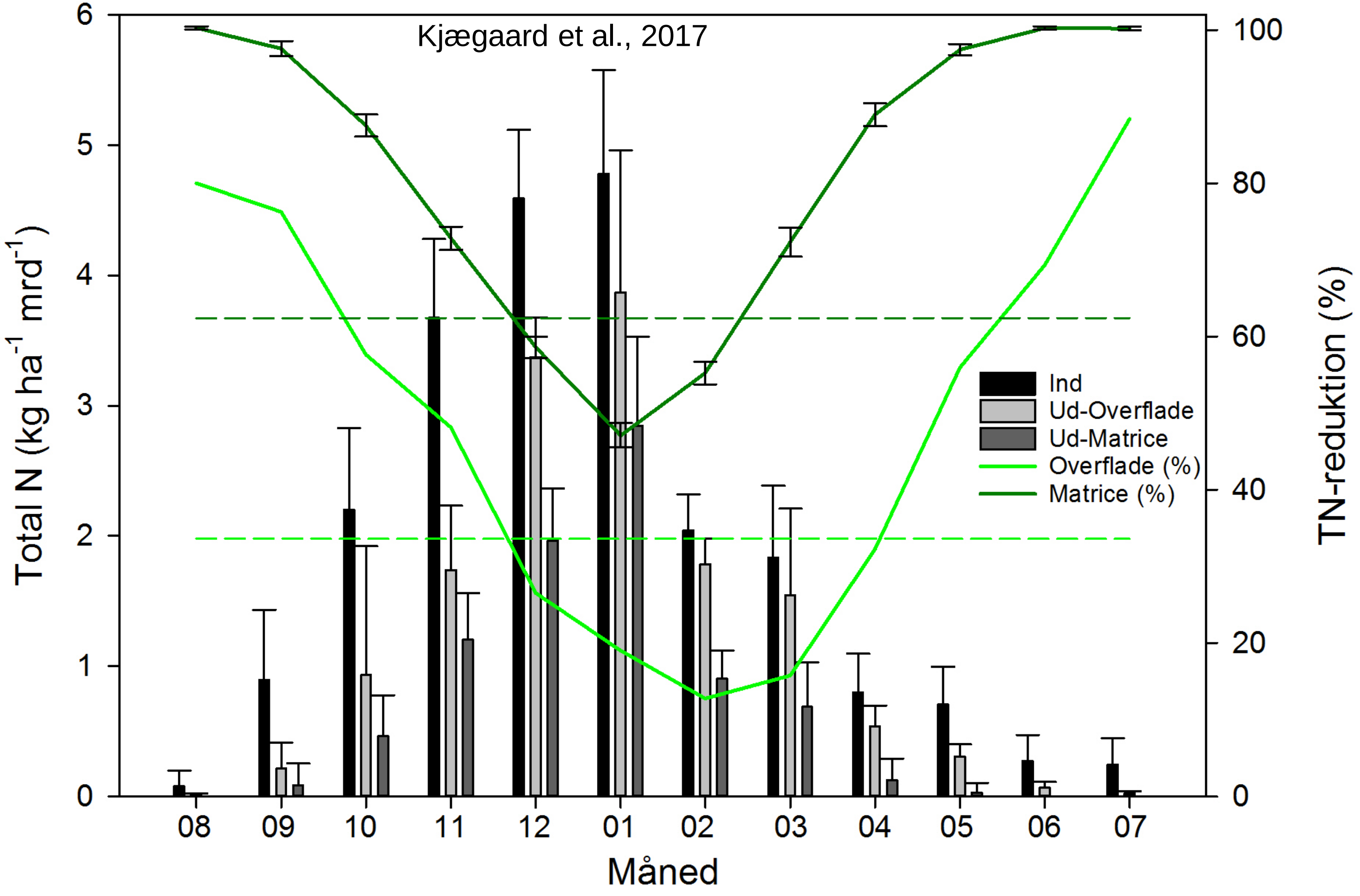
Woodchips filter-bed with storage pond
Size: 0,2-0,25% of drained catchment

Photo: SEGES

Guidelines for the Danish Ministry (Hoffmann & Kjærgaard, 2018)
Guidelines for advisers and constructors (Kjærgaad, 2019)

Hoffmann, C.C. & Kjærgaard, C. 2017. Optimeret kvælstoffjernelse i matricevådområder. S.101-105.
Vand & Jord, nr. 3, 2017

Surface-flow versus bioreactor



SEGES

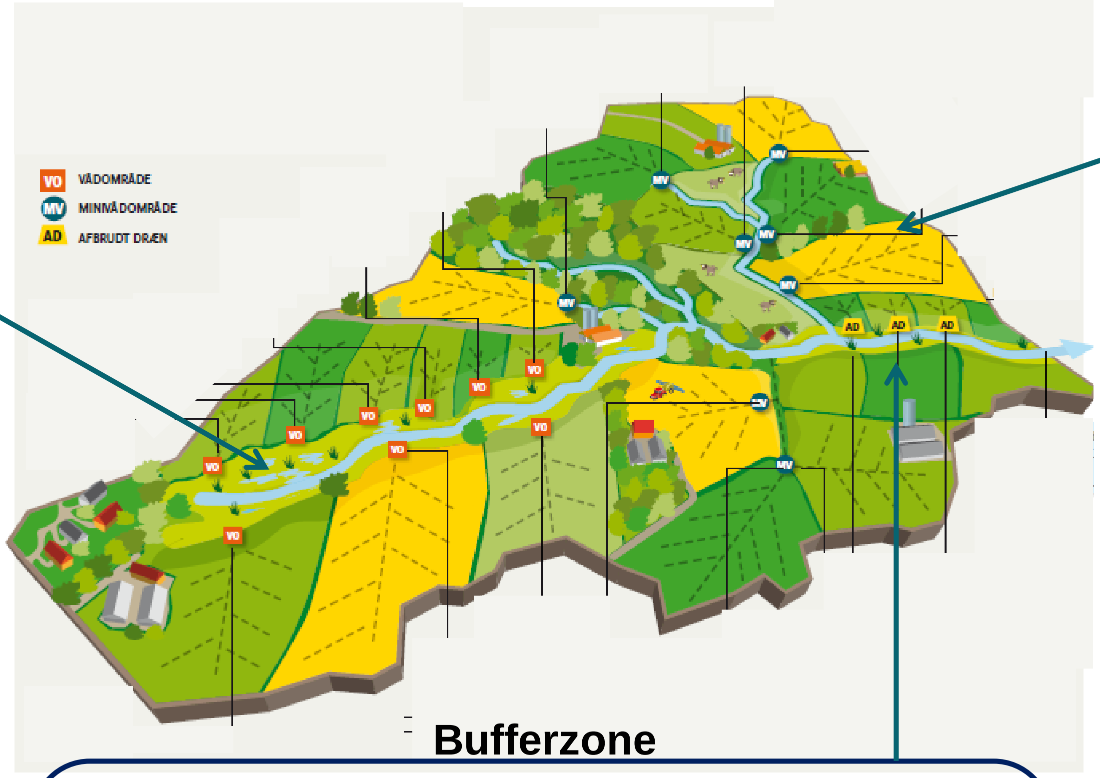
Kjærgaard, C., Hoffmann, C.C., Iversen, B.V. 2017. Filtre i landskabet øger retentionen. Vand & Jord, nr 3, s. 106-110.

Small local wet-areas within field – potential not investigated

Visions for the targeted nutrient mitigation – restore landscape filters

Kjærgaard, 2018. Kombiner virkemidlerne, og find den optimale løsning. Landbrugsavisen 21. juni 2018.

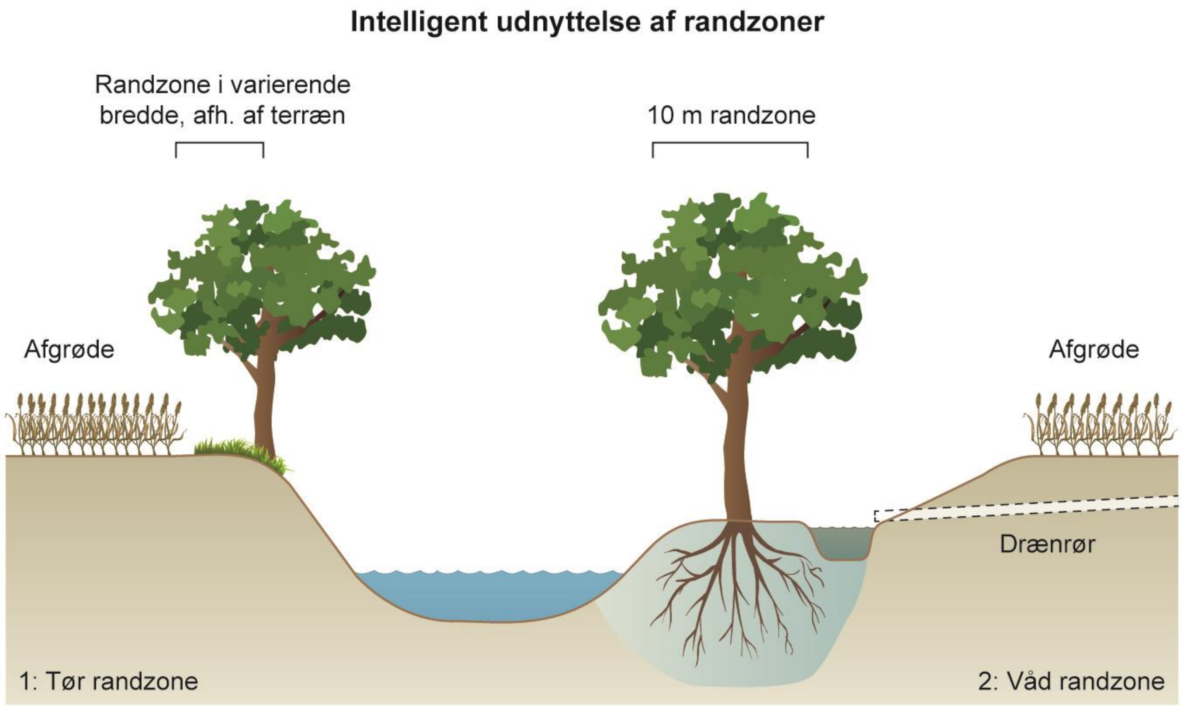
Riparian lowland



Constructed wetlands

Bufferzone

Intelligent bufferzone (IBZ)



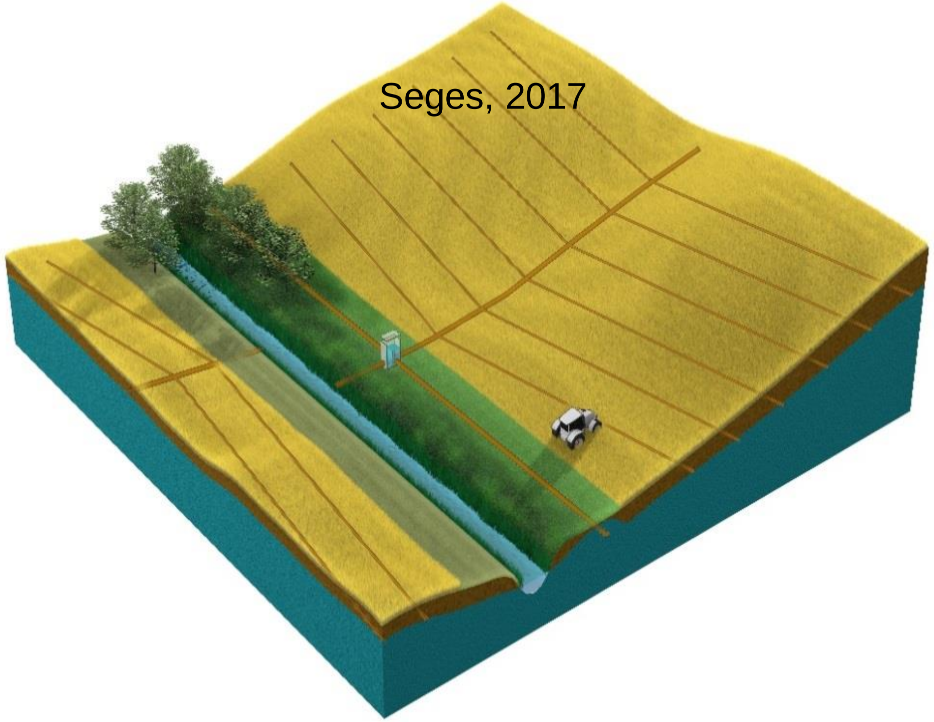
Size: 1% of drainage catchment (infiltation of soil)
Yearly N-reduction: 20-30%
Yearly P-reduction: 40-50%

Kronvang et al. 2017. Vand & Jord, nr 3

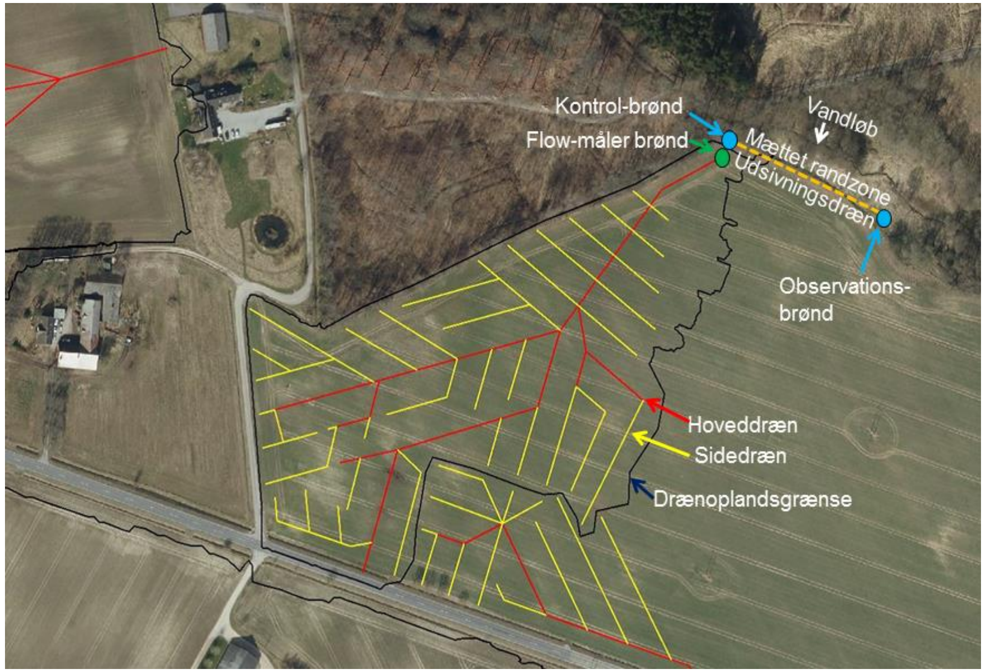
Saturated buffer zones

First Danish projects started in 2018 (SEGES)

- Denitification in the bufferzone (soil type, geochemistry)
- Retention of particulate-P (risk of *in situ* P-mobilization)
- Hydraulic capacity -> buffer zone: draiange catchment ratio



Seges, 2017



Photos:Charlotte Kjærgaard

Implementation strategy

Where should we implement targeted drainage measures to ensure a cost-efficient mitigation strategy?

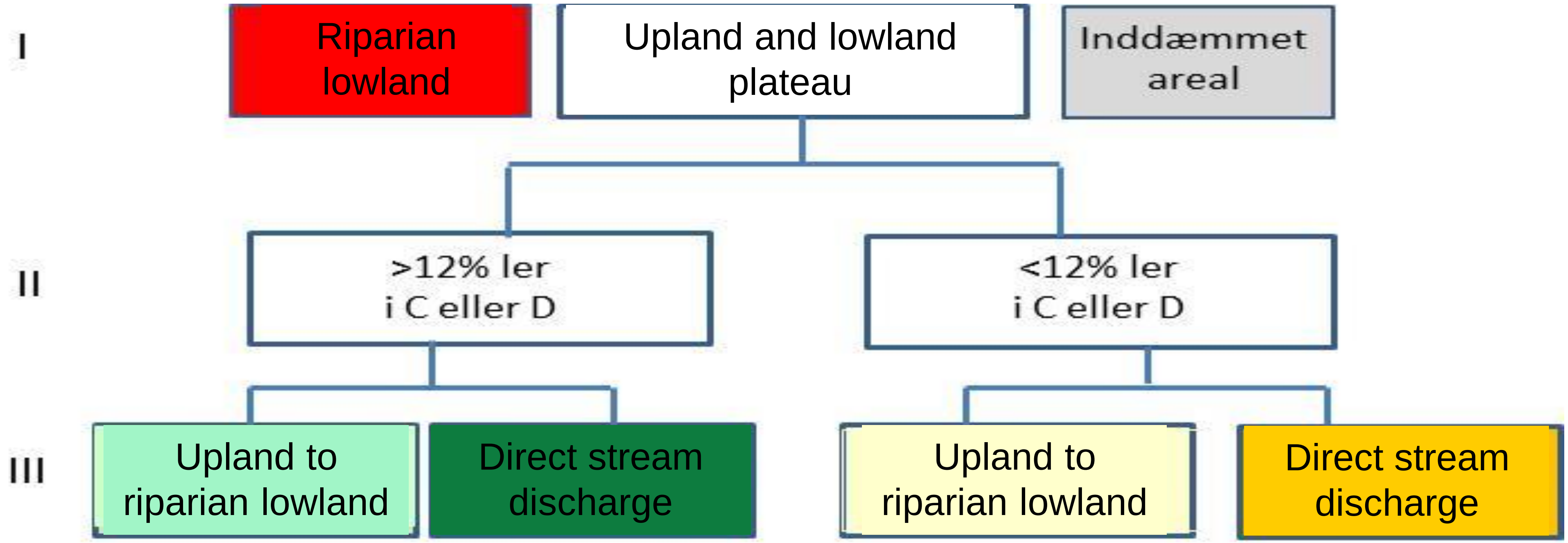
Kjærgaard, 2018. Kombiner virkemidlerne, og find den optimale løsning. Landbrugsavisen 21. juni 2018.

Strategy for implementing targeted measures

Criteria

1. Reduction requirement (coastal targets)
2. **Suitability of agricultural areas (drainage discharge dominated areas)**
3. Nutrient losses by drainage - quantitative significant
4. Quantitative environmental impact on coastal water (N)

Nationalt suitability map for implementing drainage measures



Kjærgaard, C, Bach, E.O., Greve, M.H., Iversen, B.V. 2016. Kortlægning af potentielle områder til etablering af konstruerede minivådområder. DCA – Nationalt Center for Fødevarer & Jordbrug, 19. december 2016.

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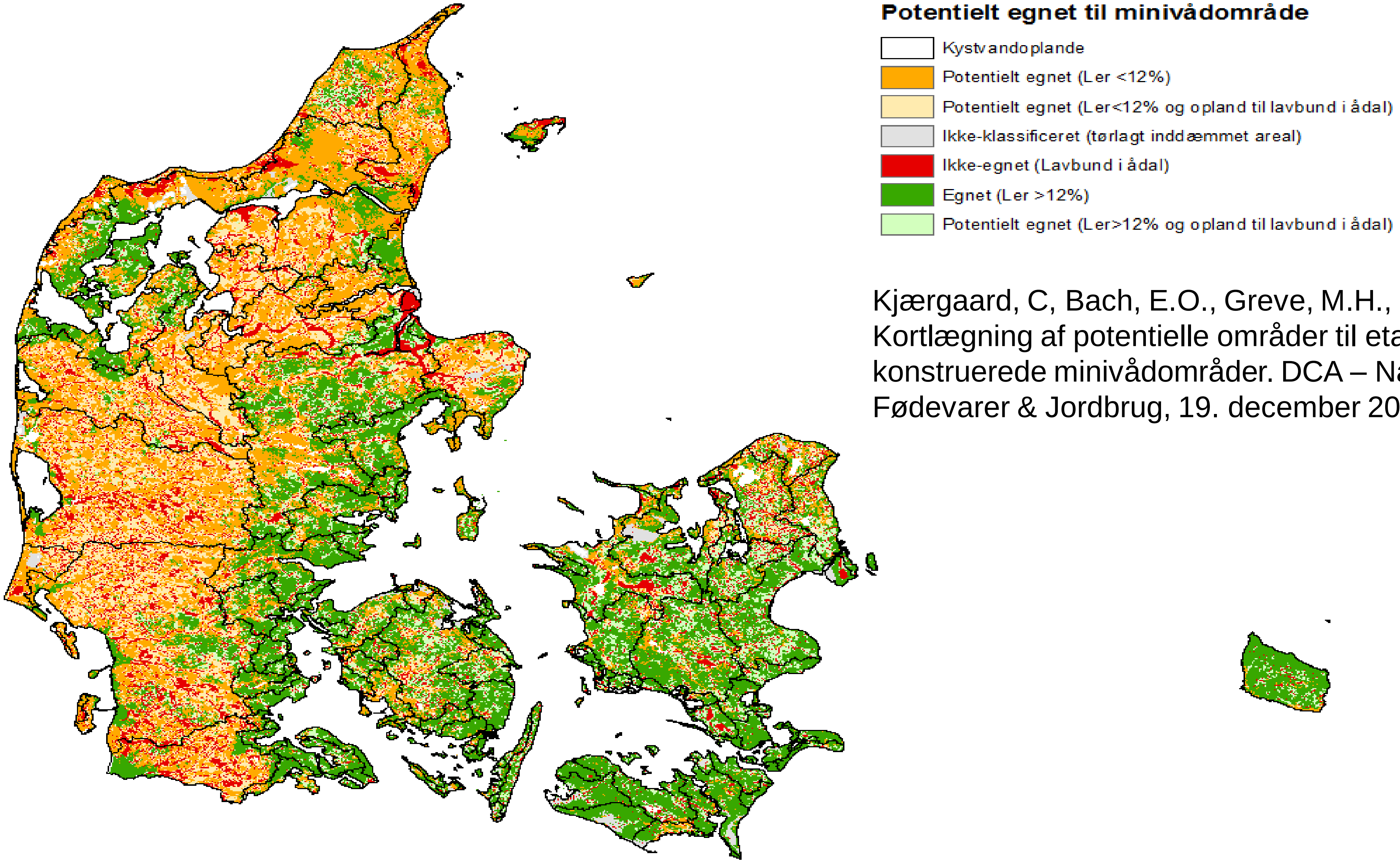

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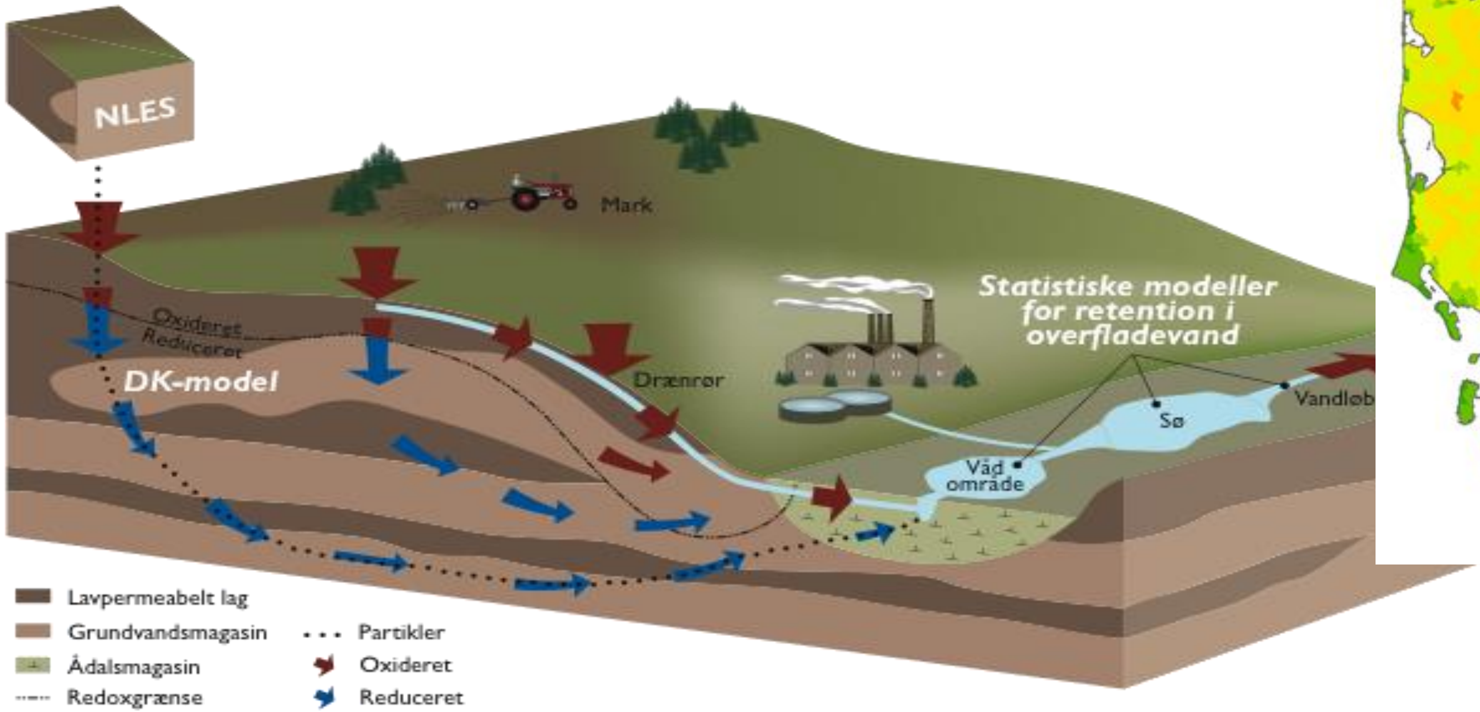
Strategy for implementing targeted measures

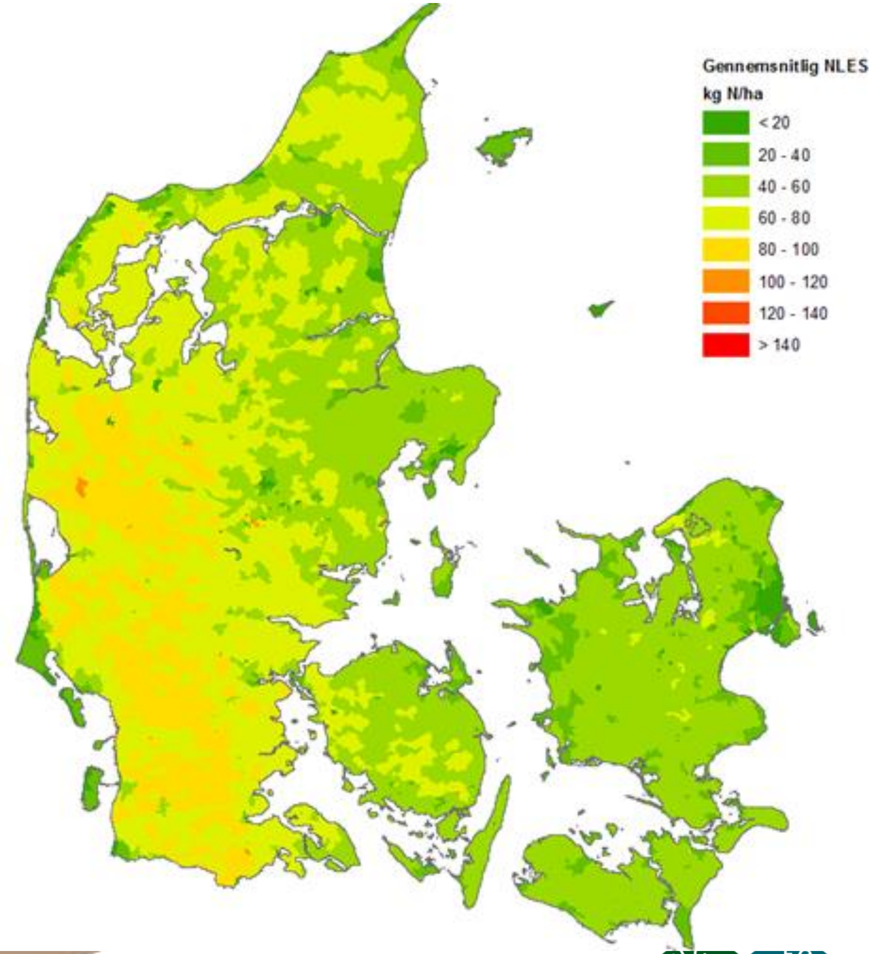
Criteria

N-losses from rootzone

1. Reduction requirement (coastal targets)
2. Suitability of agricultural areas (drainage discharge dominate
3. **N-losses by drainage - quantitative significant**
4. Quantitative environmental impact on coastal water (N)



N-loss from the rootzone corrected for the drainage fraction



SEGES

Kjærgaard, C. & Børgesen, C.D. 2017.

Strategy for implementing targeted measures

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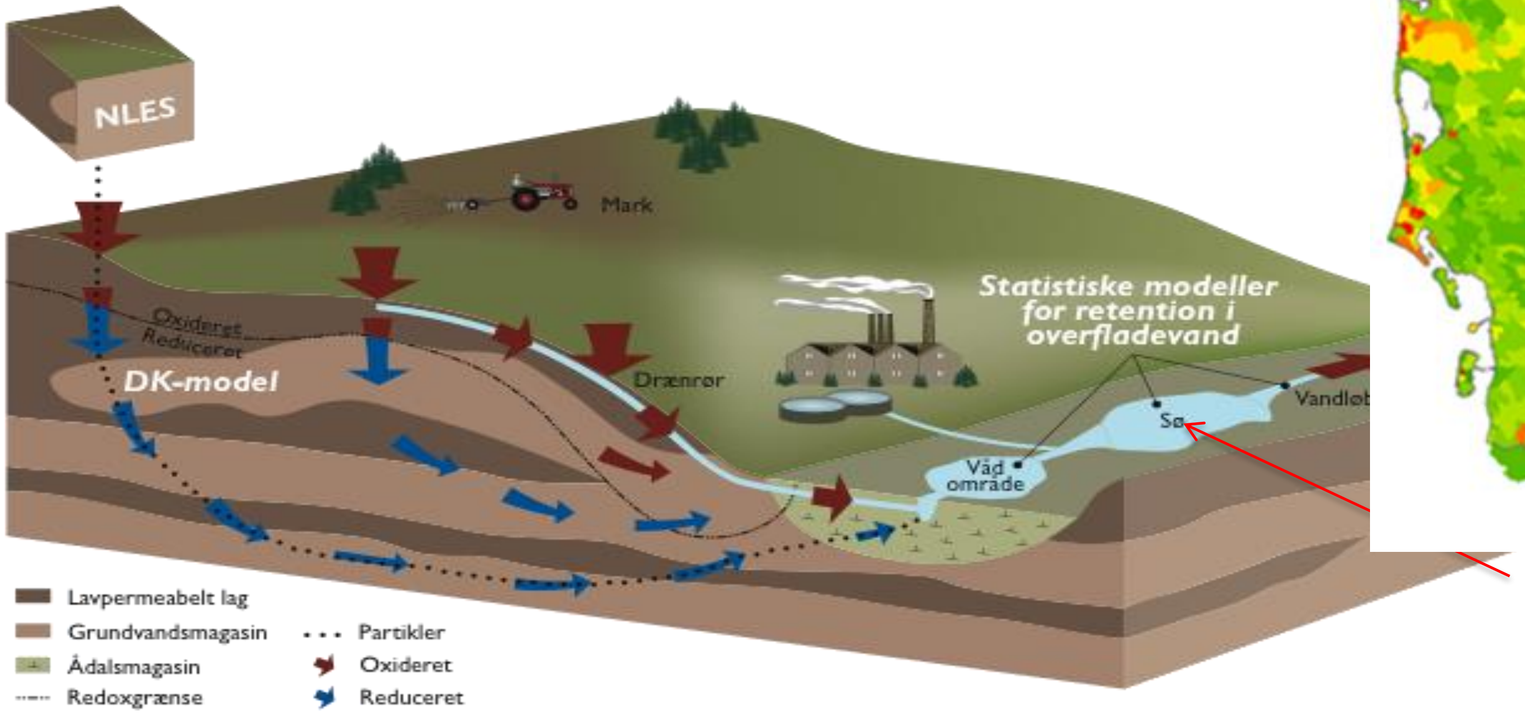
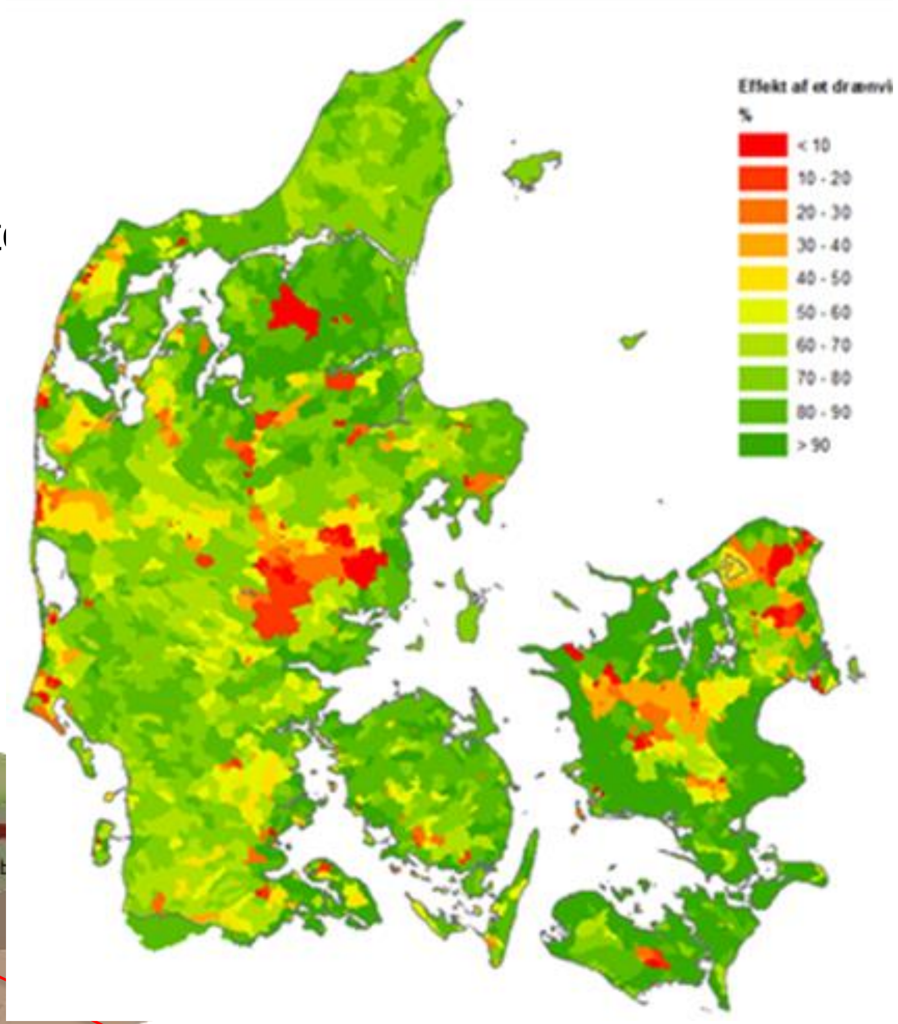




N-reduction in surface water from 0-100%

SEGES

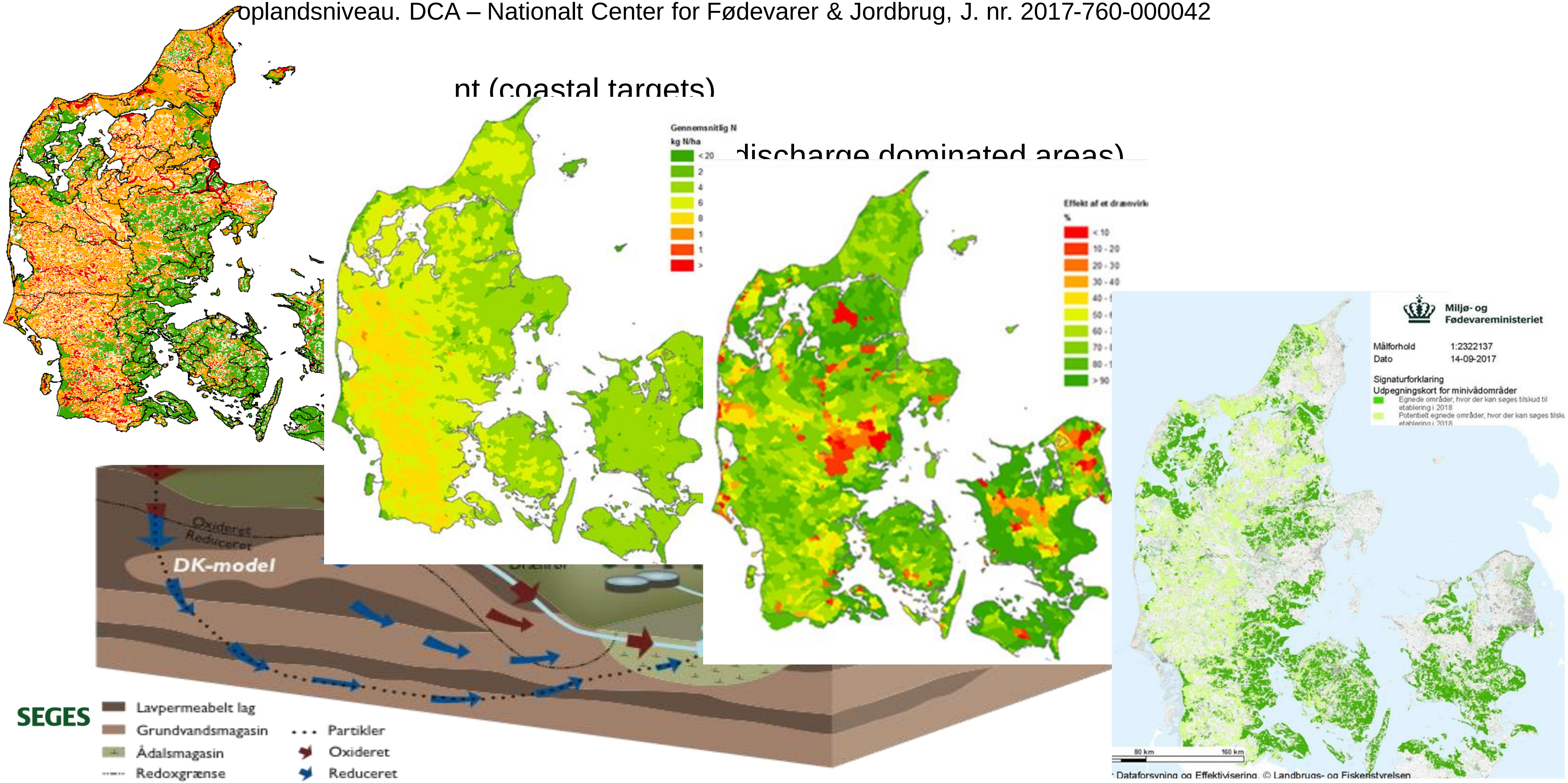
Kjærgaard, C. & Børgesen, C.D. 2017.

National deignation maps for implementing drainage filters

Kjærgaard, C. & Børgesen, C.D. 2017. Udarbejdelse af minivådområdeeffekt (kg N pr. ha minivådområde) på ID15 oplandsniveau. DCA – Nationalt Center for Fødevarer & Jordbrug, J. nr. 2017-760-000042

nt (coastal targets)

discharge dominated areas)



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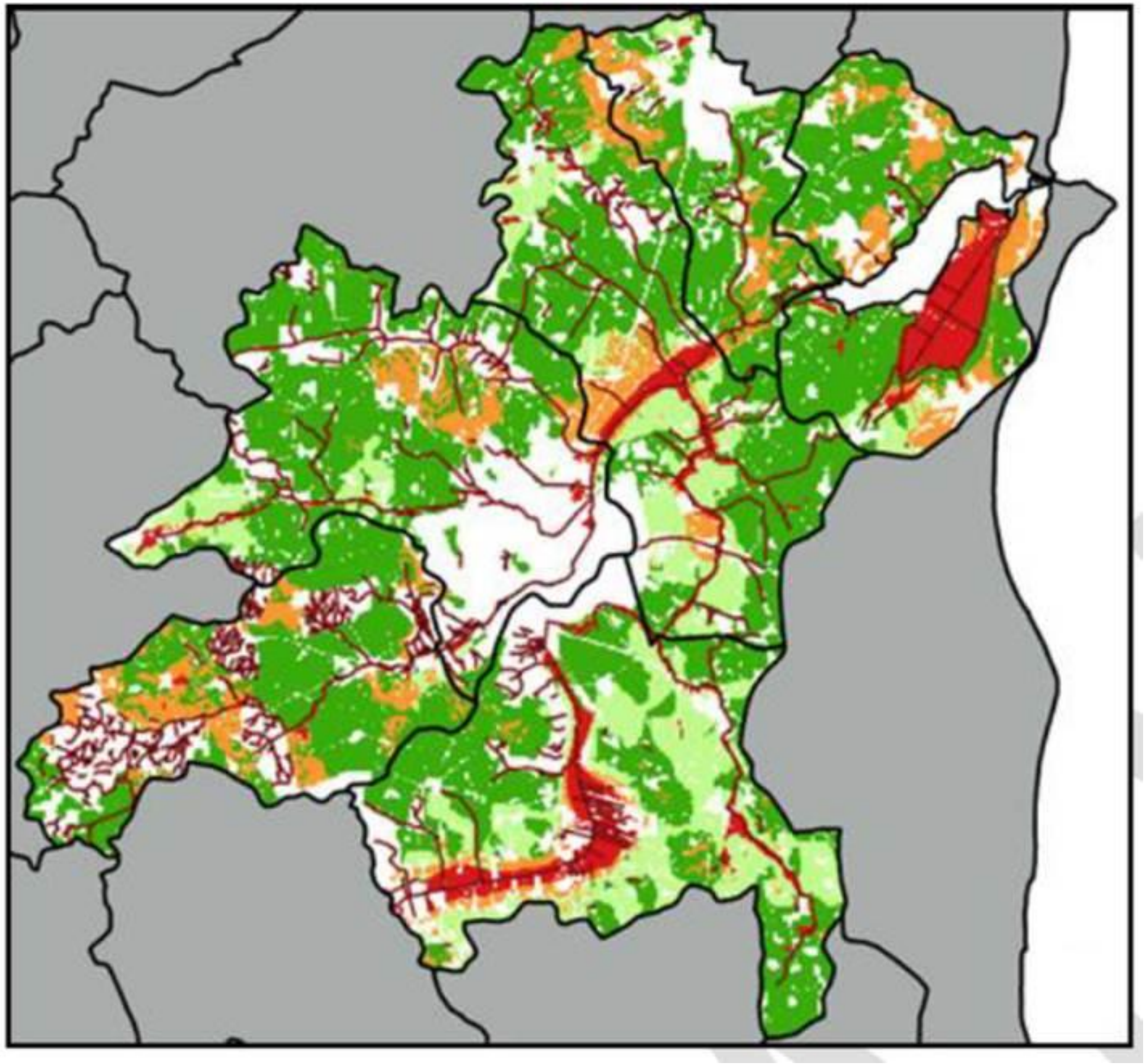
Case: Mitigation strategy – Norsminde Fjord catchment

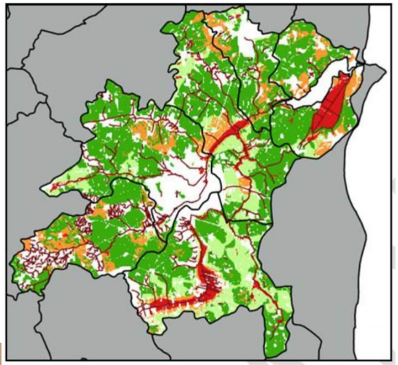


Catchment (10.100 ha) including six ID15 subcatcments (1500 ha units)

ID15 subcatch ment	Suitable for CWs (%)	Upland drained to riparian lowland (%)	Riparian lowland (%)
43600028	61	4,4	16
43600041	50	33	11
43600042	75	11	2,5
43600043	61	22	6,2
43600051	73	1,1	0,9
43602599	72	5,4	1,1
Total	**4.815 (63)**	**1.224 (16)**	**541 (7)**

Kjærgaard, C., Hoffmann, C.C., Iversen, B.V. 2017. Filtre i landskabet øger retentionen. I: Filtre i landskabet, Vand & Jord, nr. 3, s. 106-110

Case: Mitigation strategy – Norsminde Fjord catchment



Mitigation measure	Position in landscape	Area required (% of drainage catchment)	N-red. eff (%)	P-ret. eff (%)
Riparian wetlands	Riparian lowland	10*	20-100	Risk evaluation
Surface-flow constructed wetlands	Upland	1	20-30	30-80
Subsurface-flow constructed wetlands	Upland	0,2-0,25**	50-70**	N.A.

SEGES

Kjærgaard, C., Hoffmann, C.C., Iversen, B.V. 2017. Filtre i landskabet øger retentionen. I: Filtre i landskabet, Vand & Jord, nr. 3, s. 106-110

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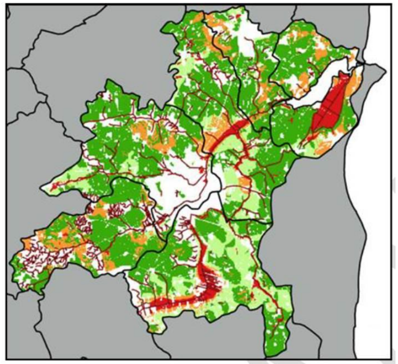
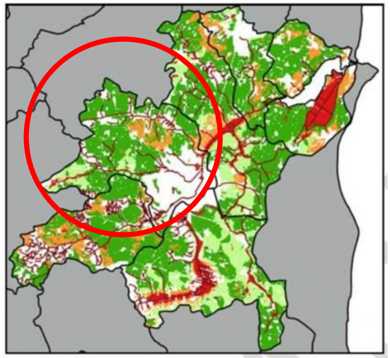
Case: Mitigation strategy – Norsminde Fjord catchment



Measure	Catchment	Area	Yearly N-effect		Mitigation potential scenarios	
	ha	ha	Ton N/yr	Kg N/ha	Ton N/yr	Ton P/yr
Baseline	7.500	7.500	-	-	173	4,7
Riparian wetlands	1.224	122	18-35	148-287	18-35 (N-red. 10-20%)	Risk eval.
Surface-flow CW	4.815	48	51	1.063	69-86 (N-red. 40-50%)	1.9-2.4 (43-54%)
Subsurface-flow CW	4.815	12	95	7.917	113-130 (N-red. 67-75%)	N.D.

Kjærgaard, C., Hoffmann, C.C., Iversen, B.V. 2017. Filtre i landskabet øger retentionen. I: Filtre i landskabet, Vand & Jord, nr. 3, s. 106-110

Mitigation strategy – Norsminde Fjord catchment



Subcatchment (ID15) N-reduction taget in 2021 = 2.594 kg N/yr

- Calculations conducted for a ID15 subcatchment (1500 ha) with 70% agricultural area (1050 ha)
- Average N-leaching from rootzone ~60 kg N/ha and average N-retention is 62%

Mitigation measure	N-reduction target (kg N/yr)	N-effect rootzone (kg N/ha/yr)	N-effect on coastal load (kg N/ha/yr)	Required area of measure (ha)	Cost of measure (€/ha/yr)	Cost of mitigation strategy (ID15) €/yr
Catch crops	2.594	30	11.4	**228**	94	21.319
Set-aside	2.594	50	19.0	**137**	535	73.092
SF-CW	2.594	14	6.75	**3.84**	87*	33.433
Bioreactor	2.594	27	13.5	**0.38**	51**	9.773

*Construction cost depreciation in 10 years
** Constuction cost depreciation in 5 years (not including new supply of woodchips every 5 years)

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Kjærgaard, C., Hoffmann, C.C., Iversen, B.V. 2017. Filtre i landskabet øger retentionen. I: Filtre i landskabet, Vand & Jord, nr. 3, s. 106-110

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Thanks

Photo surface-flow constructed wetland: Carsten Søbog