The Danish Concept To Mitigate Nutrients In Drainage Discharge: Four New Options

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WETPOL 2019
AARHUS UNIVERSITY - DENMARK

8th International Symposium
On Wetland Pollutant Dynamics Control
17-21 June, 2019

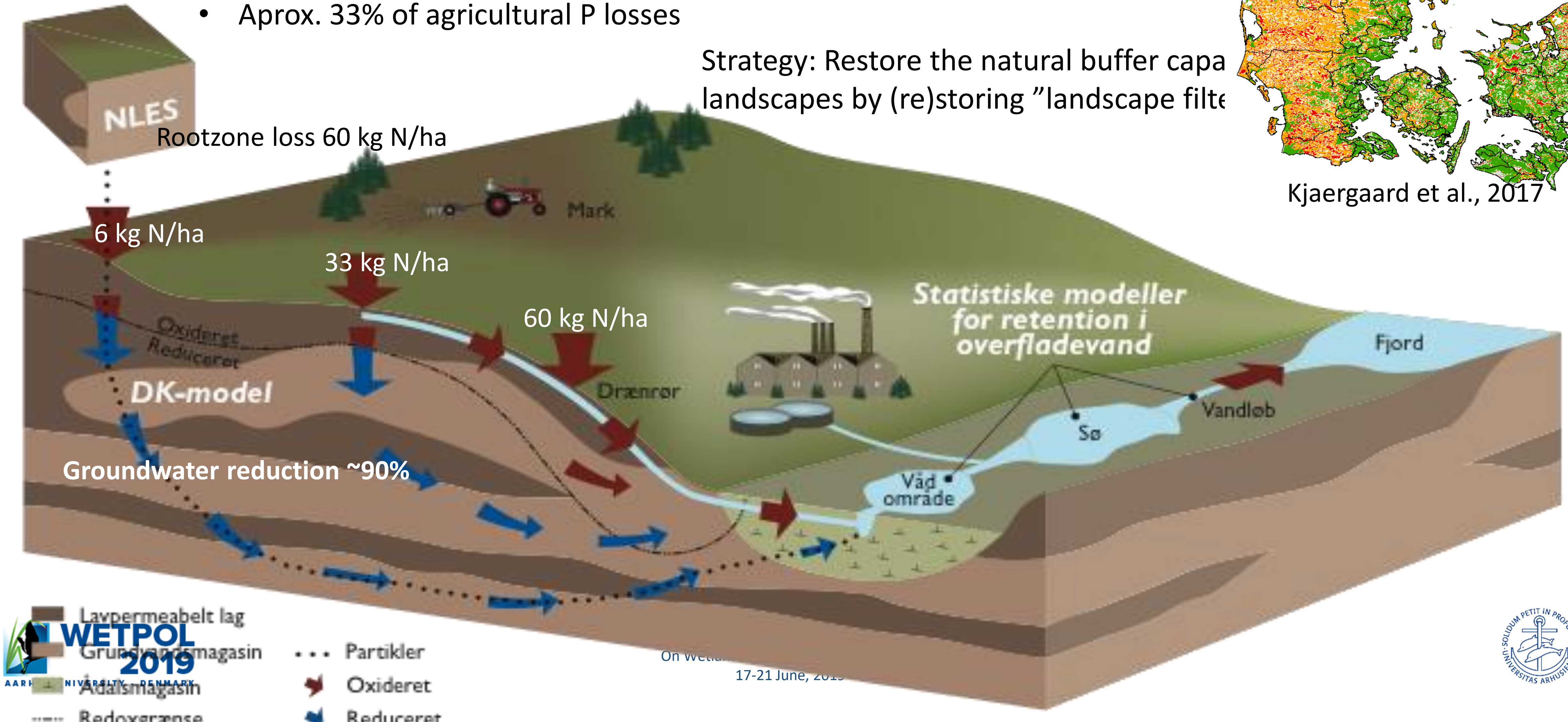
STØTTET AF
Promilleafgiftsfonden for landbrug

Drainage filters is a new targeted mitigation strategy

In DK drainage losses of nutrients accounts for:

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

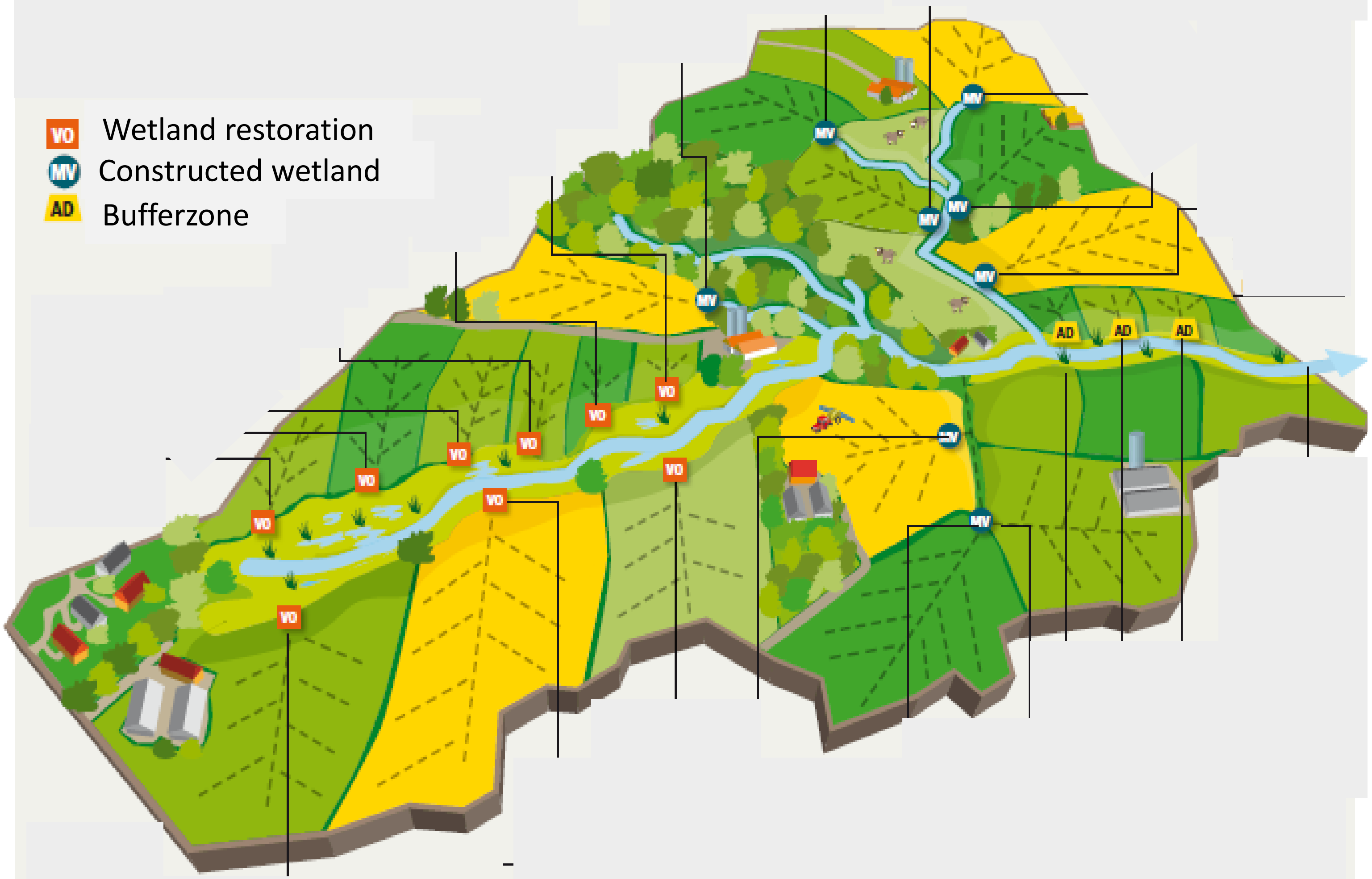
Strategy: Restore the natural buffer capa
landscapes by (re)storing ”landscape filte



Kjaergaard et al., 2017

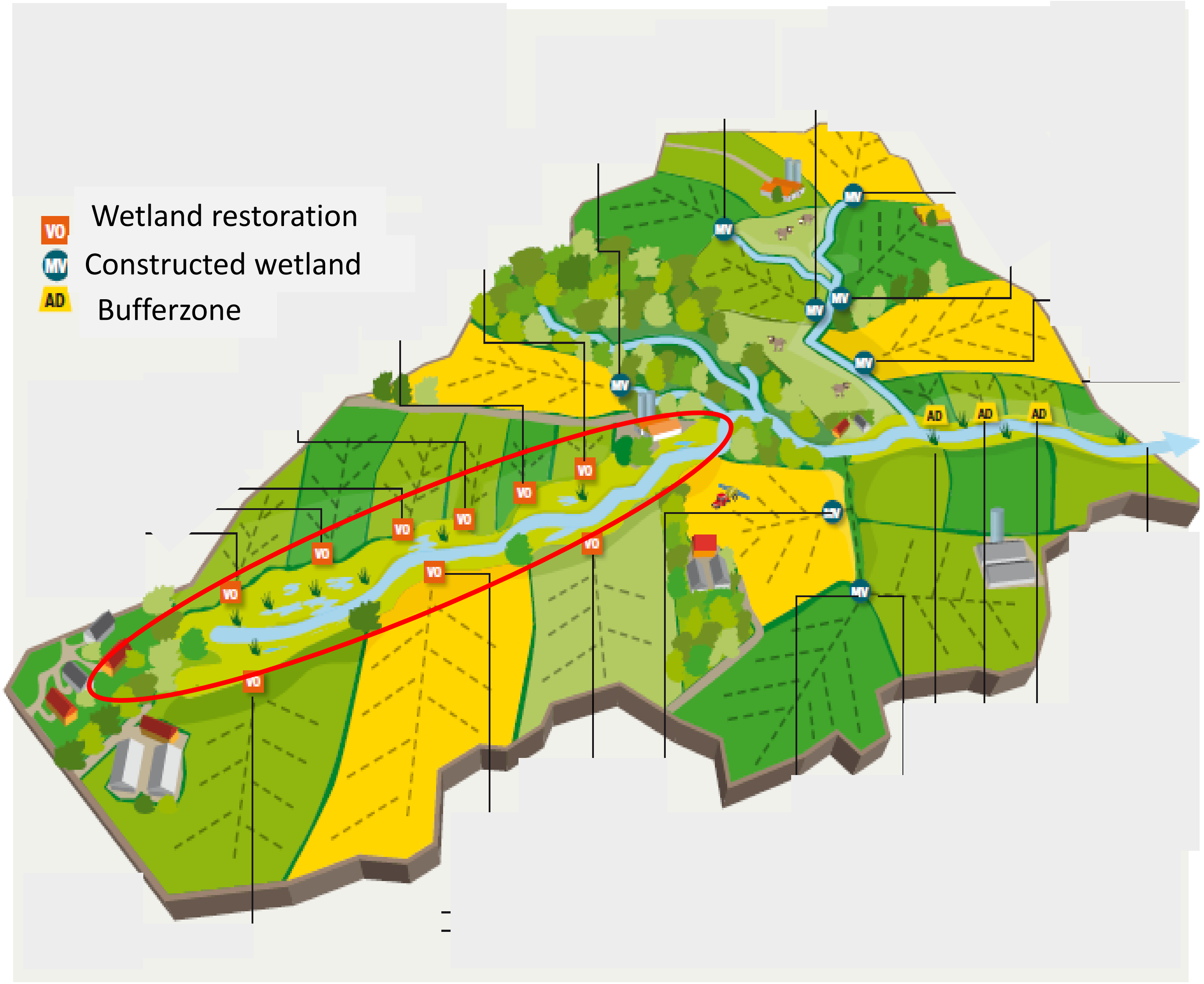
Visions for the targeted drainage mitigation strategy

Different measures at different positions in the landscape (subcatchment)



Visions for the targeted drainage mitigation strategy

Wetland restoration



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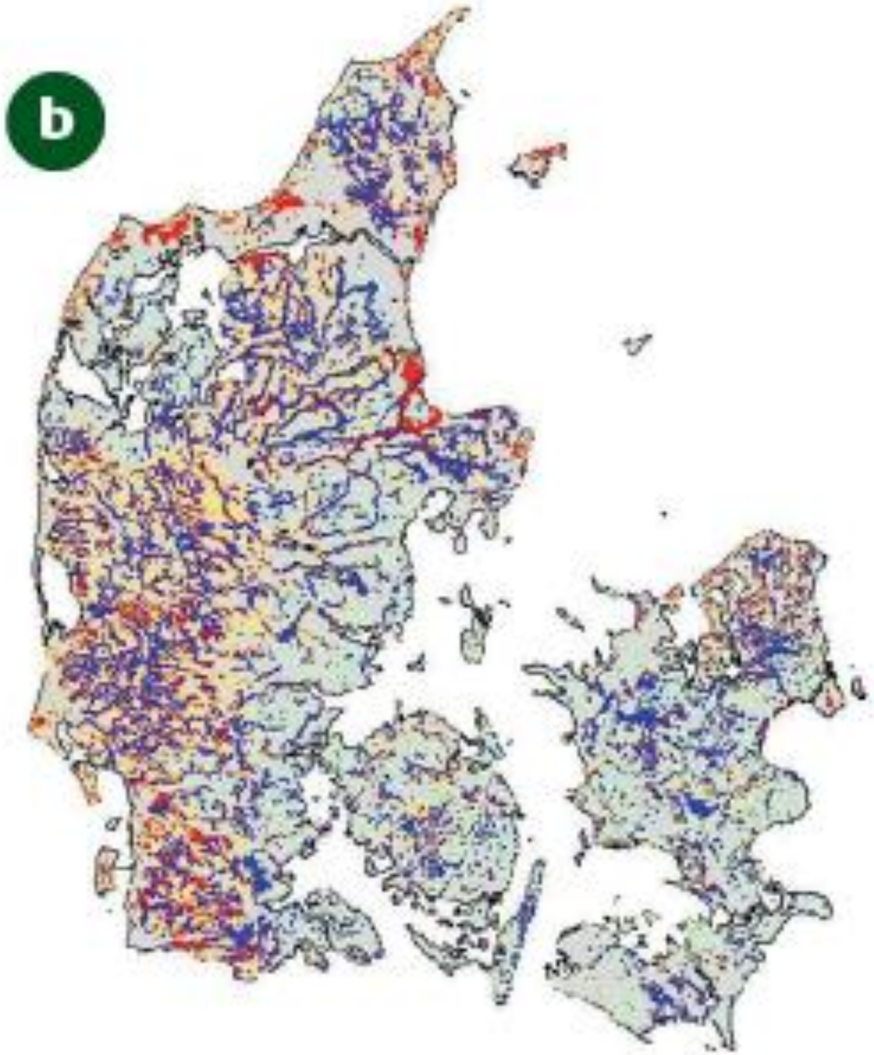
Restoration of riparian wetlands



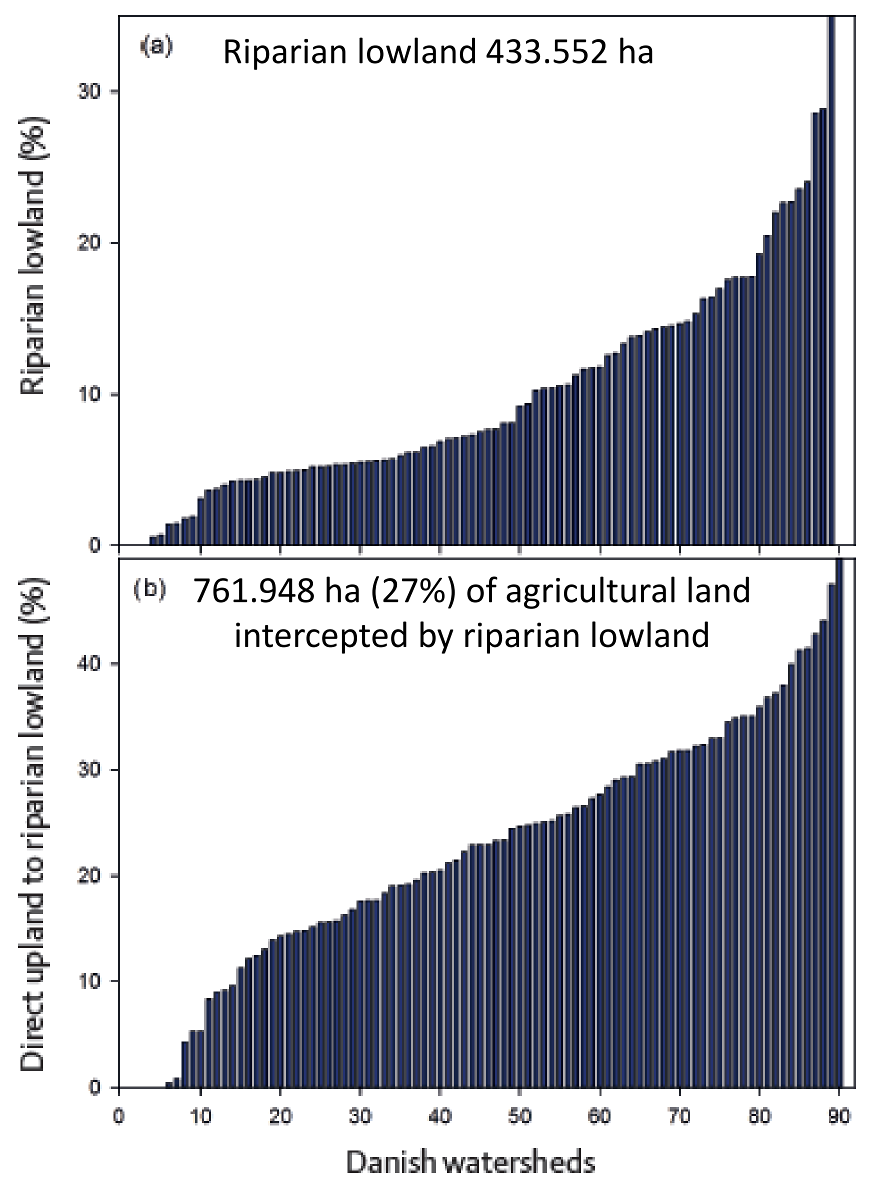
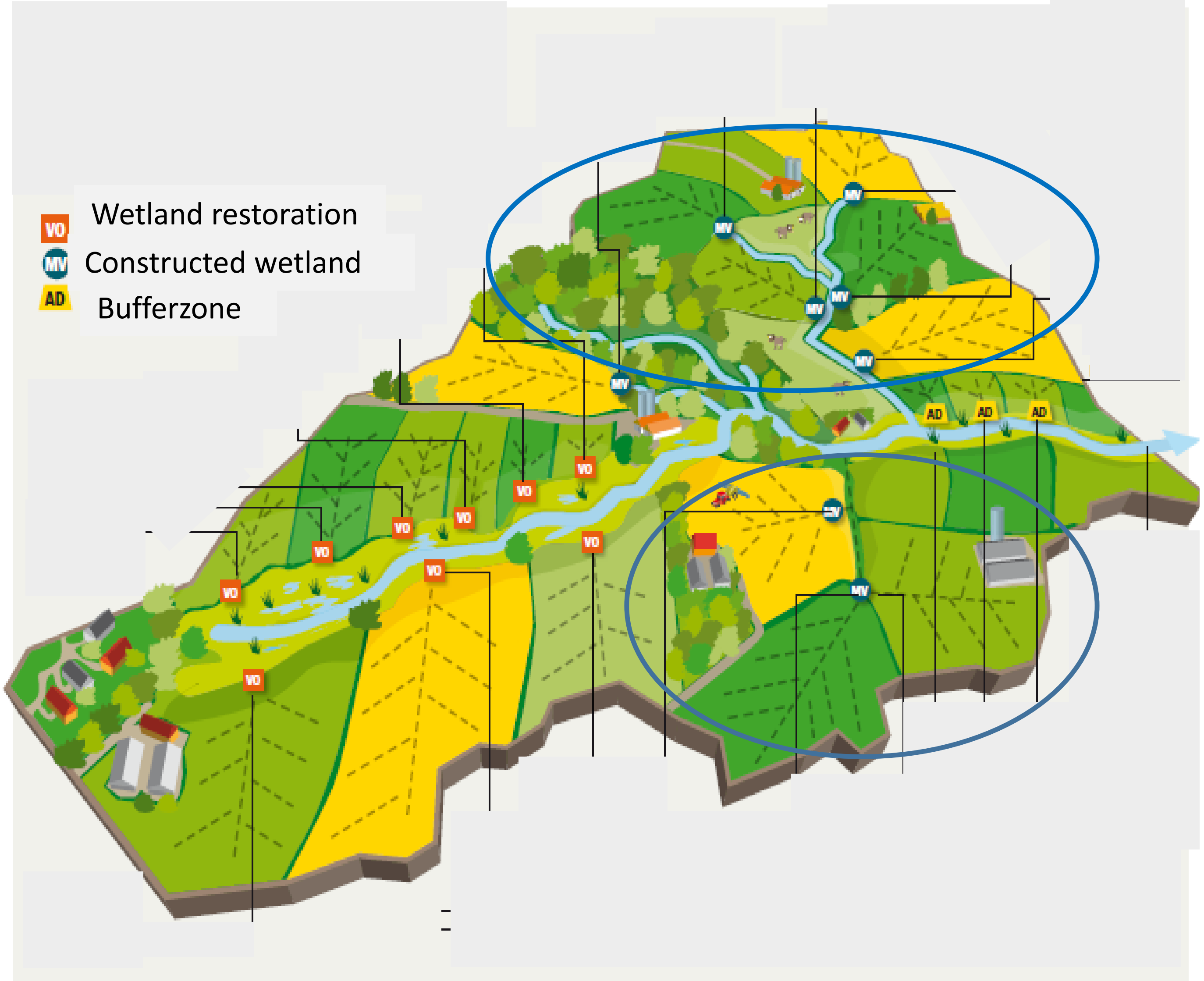


FIGURE 2. (a) Riparian lowland area, and (b) agricultural upland intercepted by riparian lowland in the Danish watersheds.

Kjaergaard & Hørfarter, 2018

Visions for the targeted drainage mitigation strategy

Wetland restoration



Constructed wetlands

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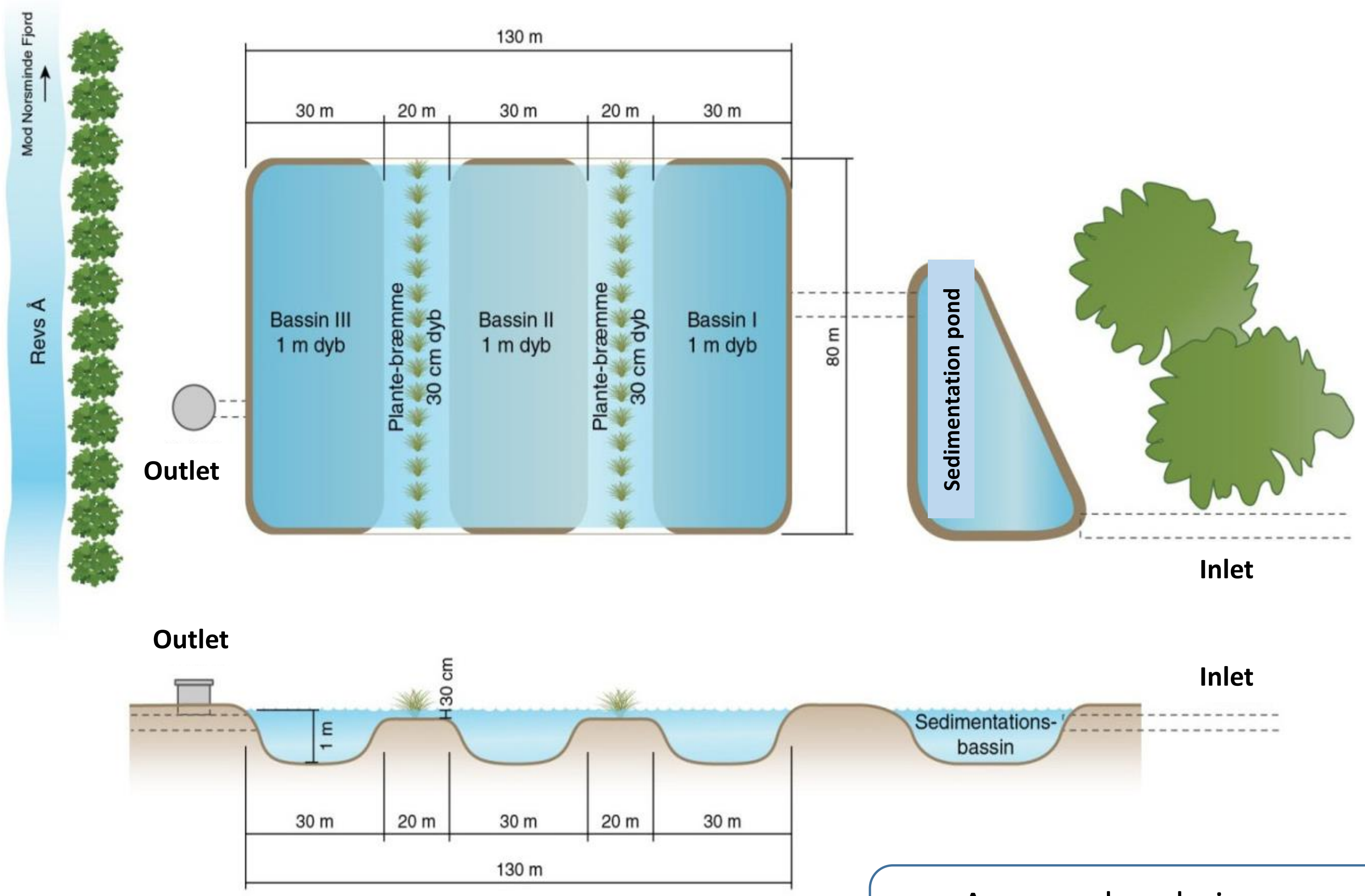
Surface-flow constructed wetlands (SF-CW)

From Kjaergaard & Hoffmann, 2013



25 SF-CWs implemented 2010-2014

Dimensions

- Size: 1% of the drainage catchment area
- Minimum HRT ~1 day

Annual N effects

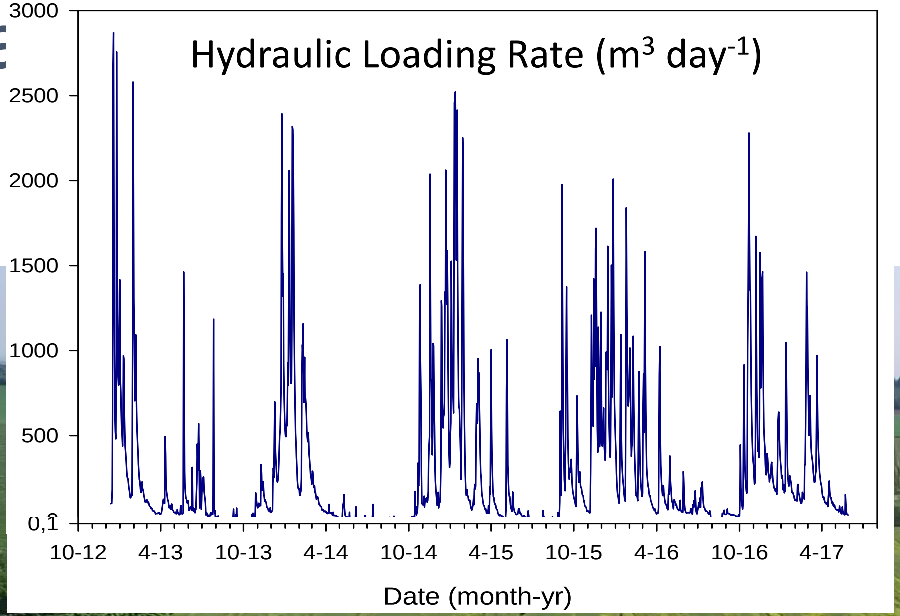
- 17-45% (average 25%) N-reduction
- Major controlling factor temperature
- ***Kjaergaard et al., 2014; 2017a,b; 2019***

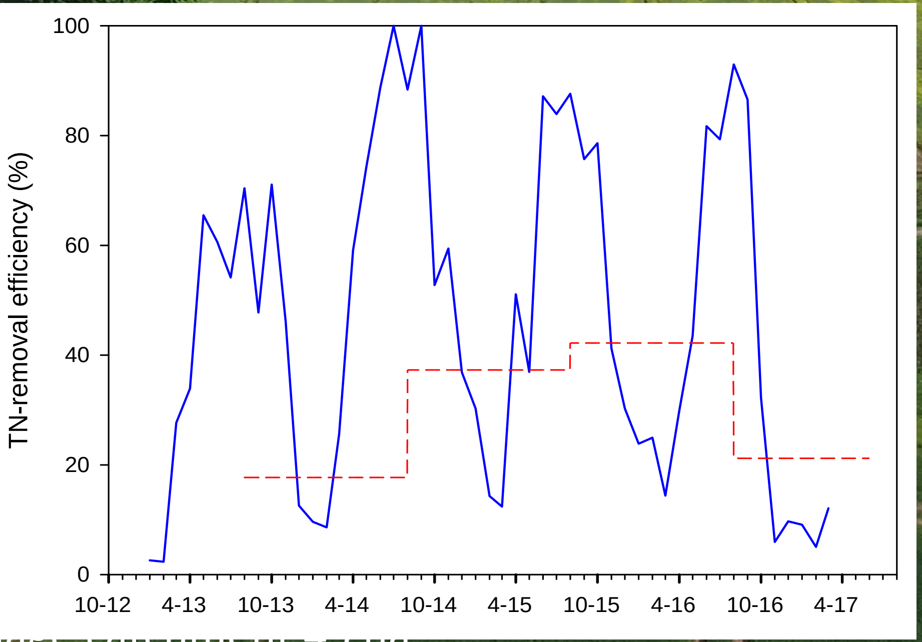
Annual P effects

- 30-80% (average 43%) P-retention
- Controlled by PLR, P-forms and Fe:P ratio
- ***Mendes et al., 2018a. Ecological Engineering***
- ***Mendes et al., 2018b. Geoderma***

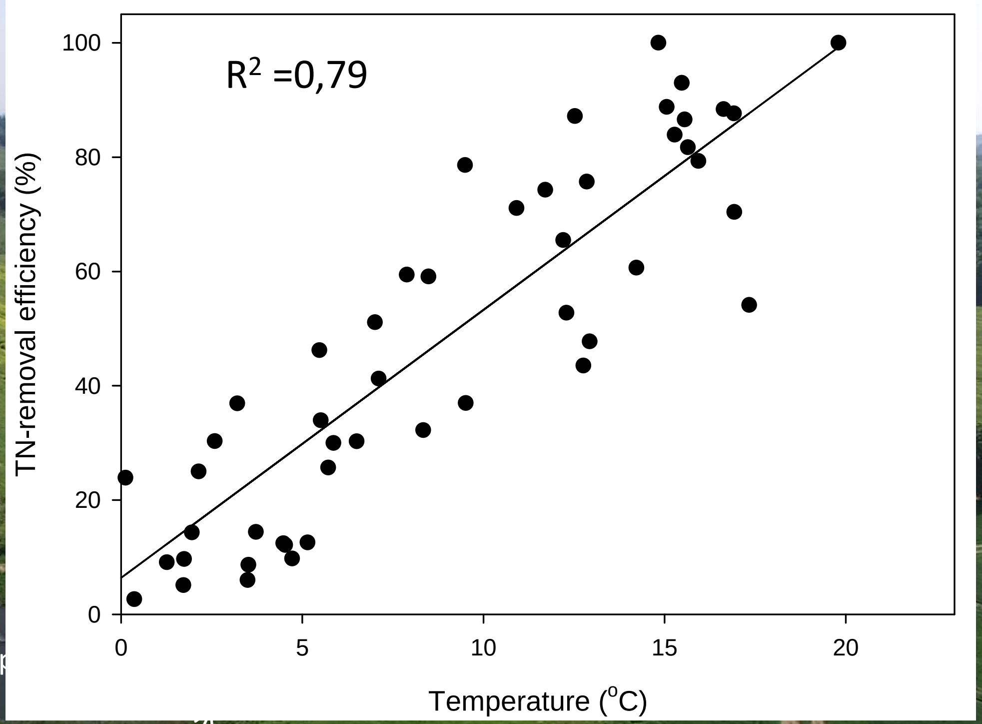
- Approved as drainage measure 2017
- 1.000-1.500 SF-CW in 2018-2021 targeting 900 ton N/yr

Surfa… nd Fillerup, Odder (2010)





Kjaergaard, Hoffmann, Pugliese, Iversen, 2019



Deep

Shallow vegetation zone

SF-CV

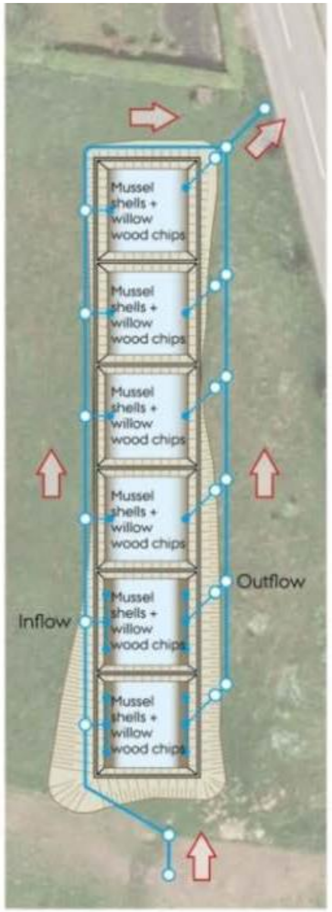
Drainage catchment 45 ha

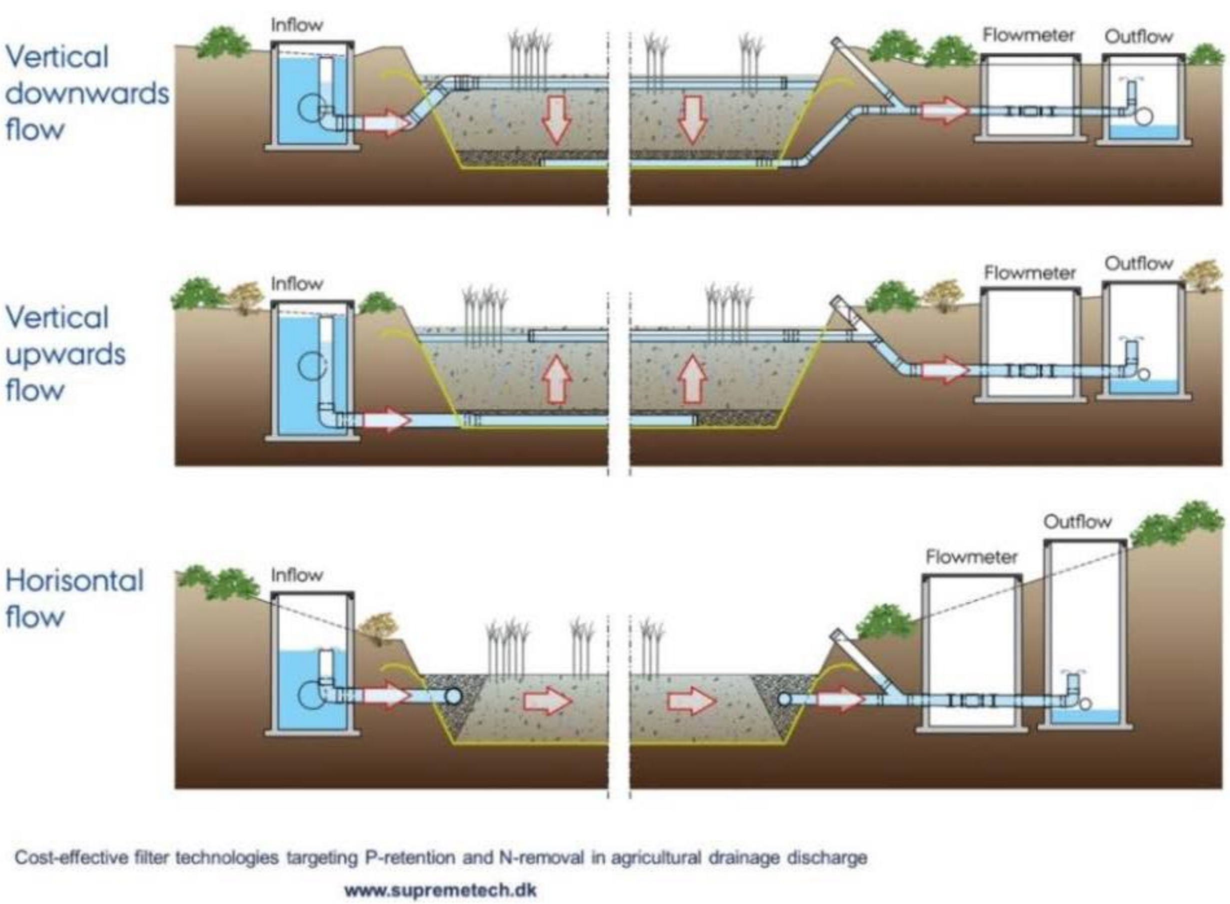
Drone photo: SEGES

Sub-surface flow willow woodships based bioreators

www.supremetech.dk

From Hoffmann & Kjaergaard, 2014





- Six bioreactors constructed 2012
- Filterbeds 100 m^2 and 1 m depth
- Woodchips:seashell ratios 25:70; 50:50
- 3 hydrological designs

Annual N effects

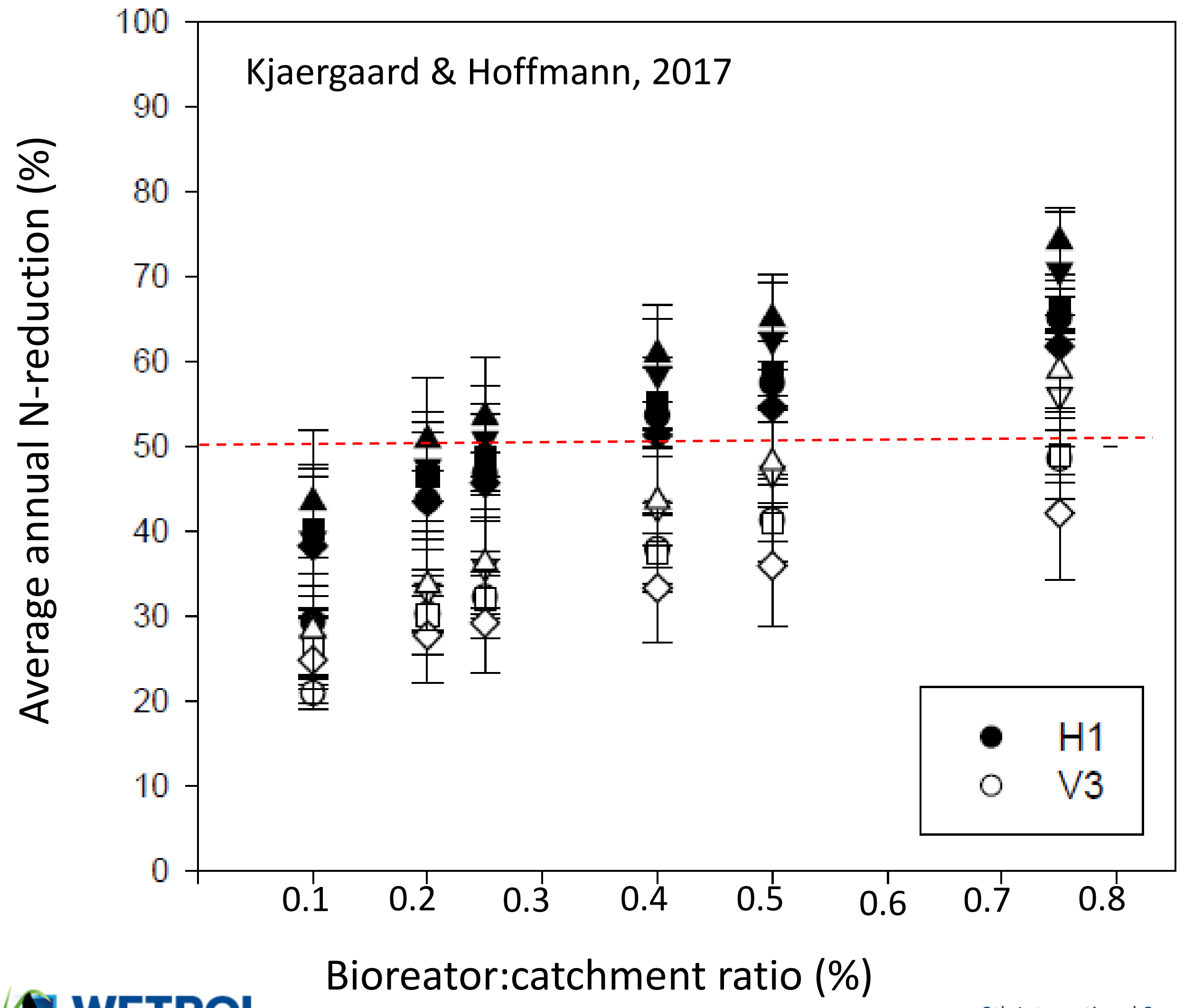
- 45-64% N-reduction
- Water temperature and HRT explained 84-90% of variation in N-reduction efficiency
- ***Hoffmann, Larsen & Kjaergaard, 2019. JEQ***

Annual long-term P effects (2013-2017)

- Increasing <0 to 48% P-retention
- Net retention of PP
- ***Carstensen, Larsen, Kjaergaard, Hoffmann, 2019. J. Environmental Management***

Upscaling woodships based bioreators

www.supremetech.dk



SupremeTech bioreactor N-models (**Hoffmann, Larsen & Kjaergaard, 2019. JEQ**) was used to establish relations between

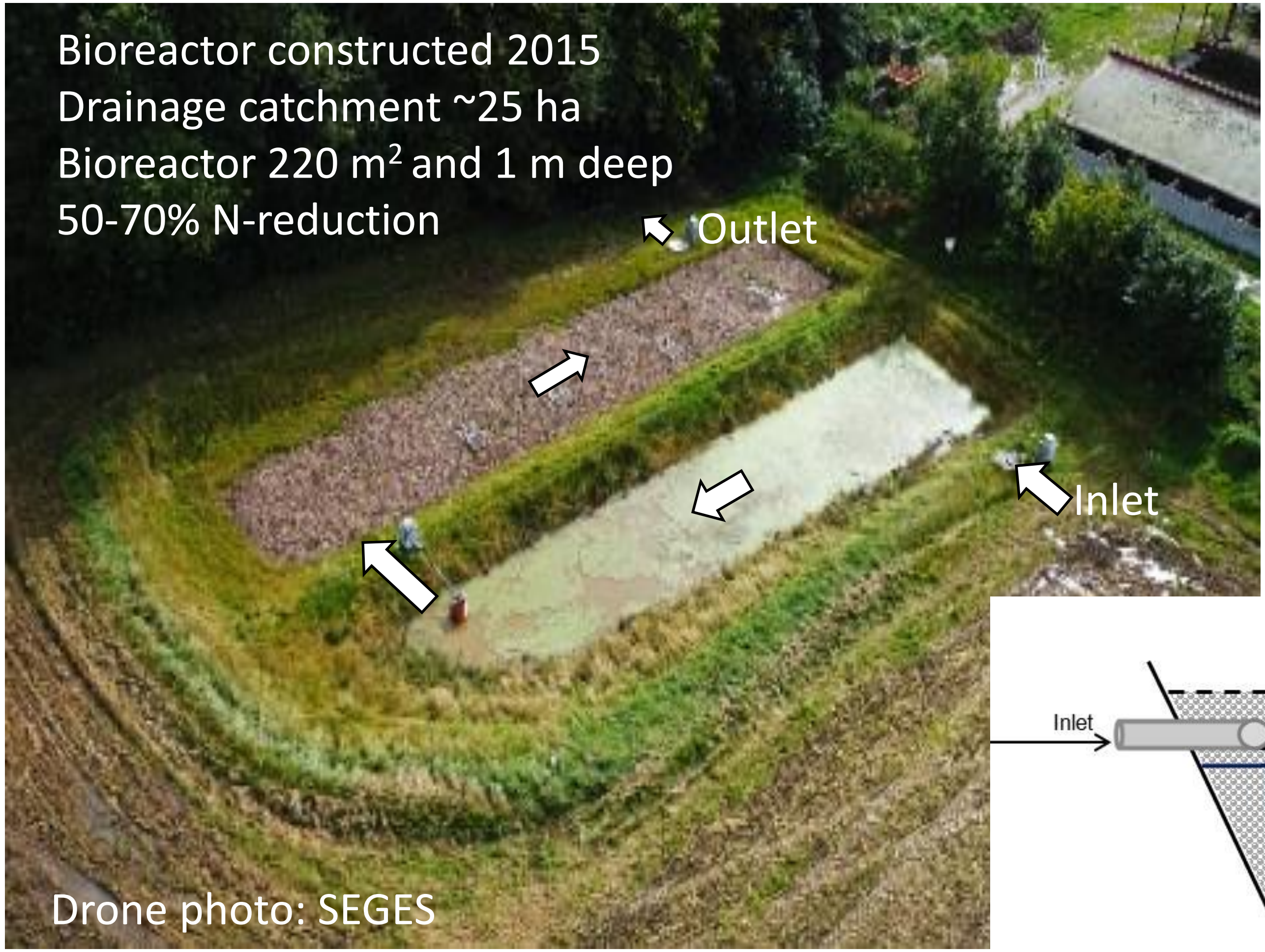
- average annual N-reduction and bioreactor:catchment ratio

using drainage hydrograph series (climate normalized data) from variable Danish regions

- Bioreactors approved* 2018
- National design guidelines for dimensioning

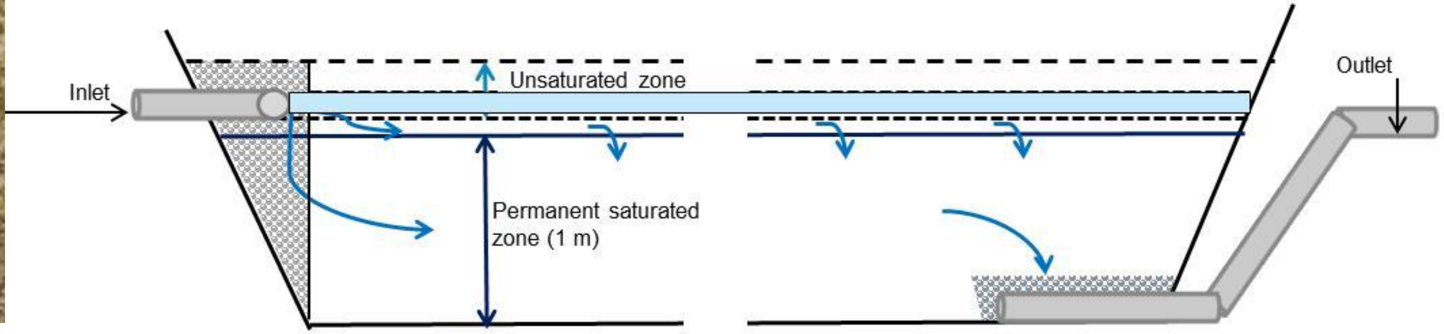
Hoffmann & Kjærgaard, 2018

Woodships based bioreator with storage pond (www.idrain.dk)



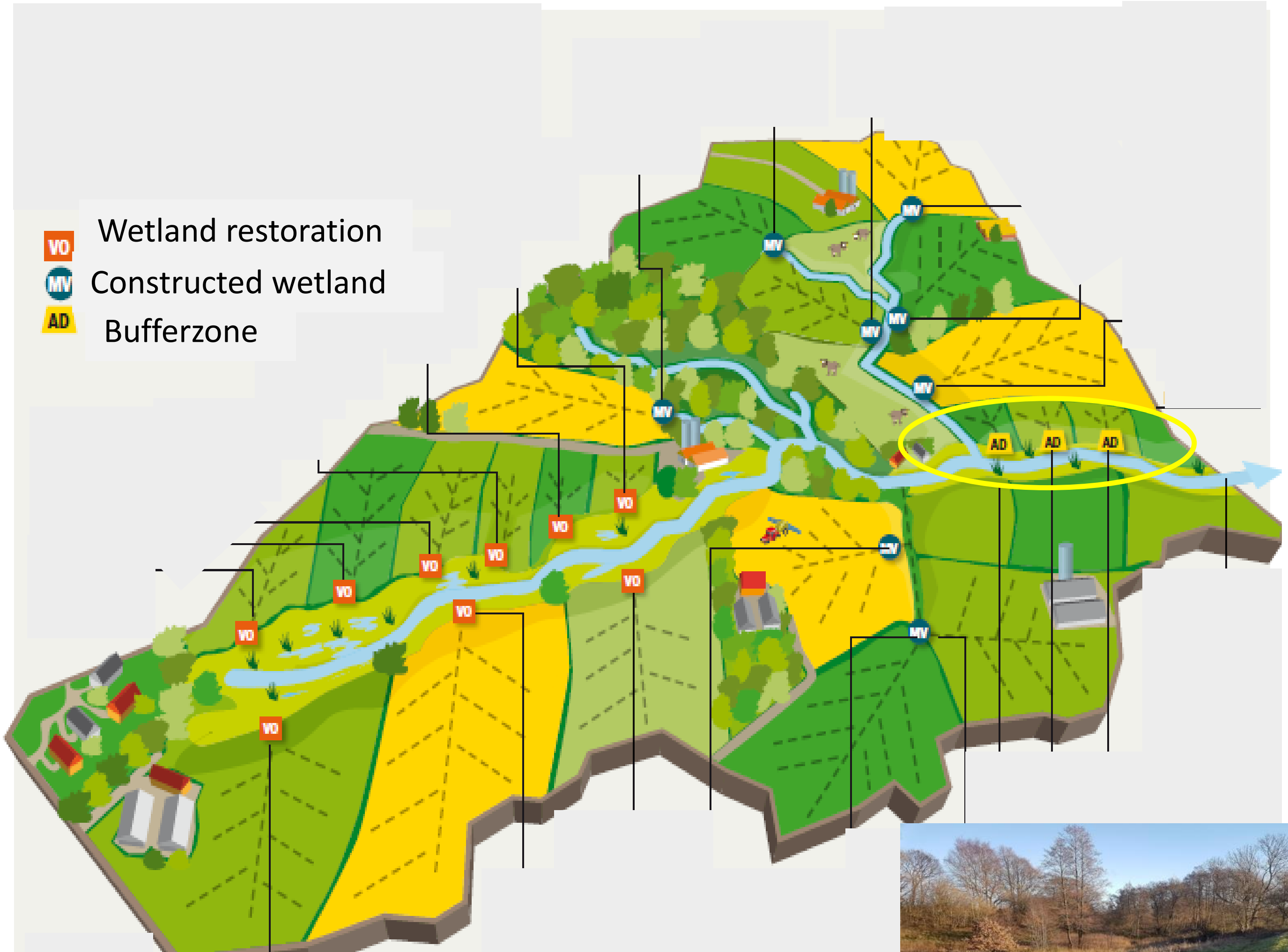
Proto bioreactor type approved* 2018

- Size: 0.2-0.25% of drainage catchment
- Storage pond optional
- Aerobic top layer (reduces CH_4-emissions)
- Re-oxygenation of effluent required
- Guidelines (Hoffmann & Kjaergaard, 2018)



Visions for the targeted drainage mitigation strategy

Wetland restoration



Constructed wetlands

Bufferzone measures

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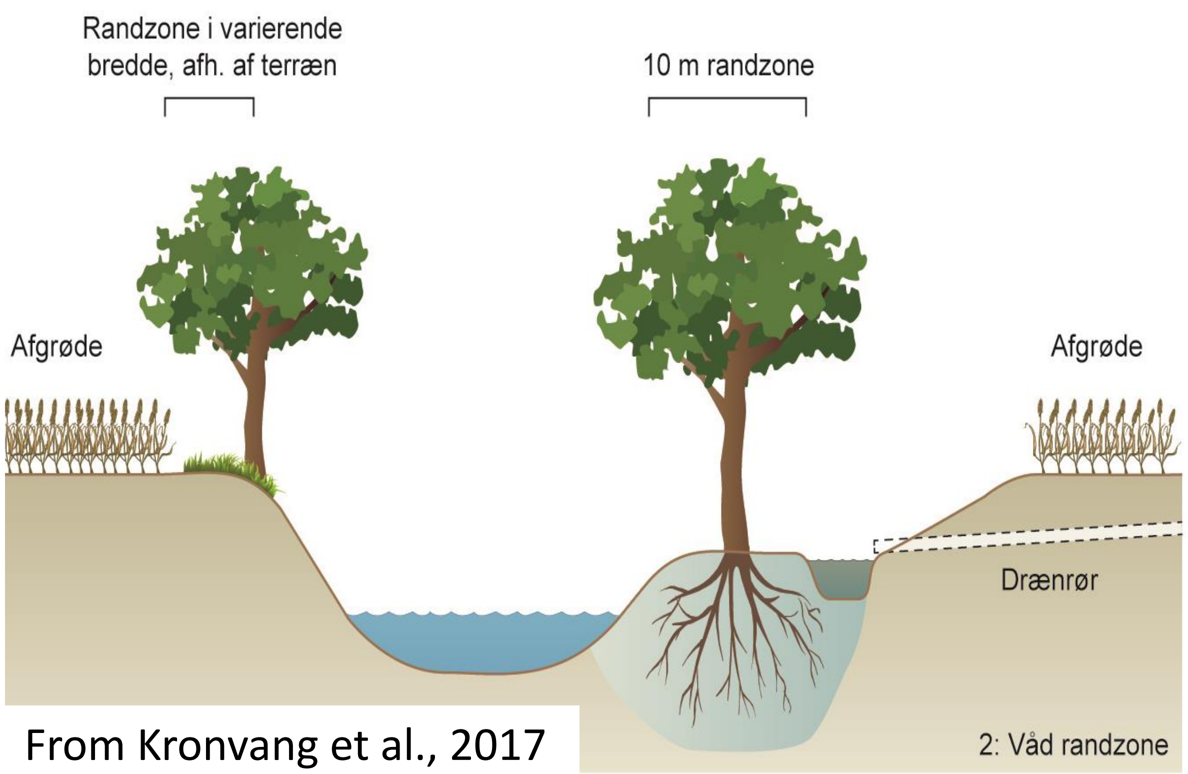
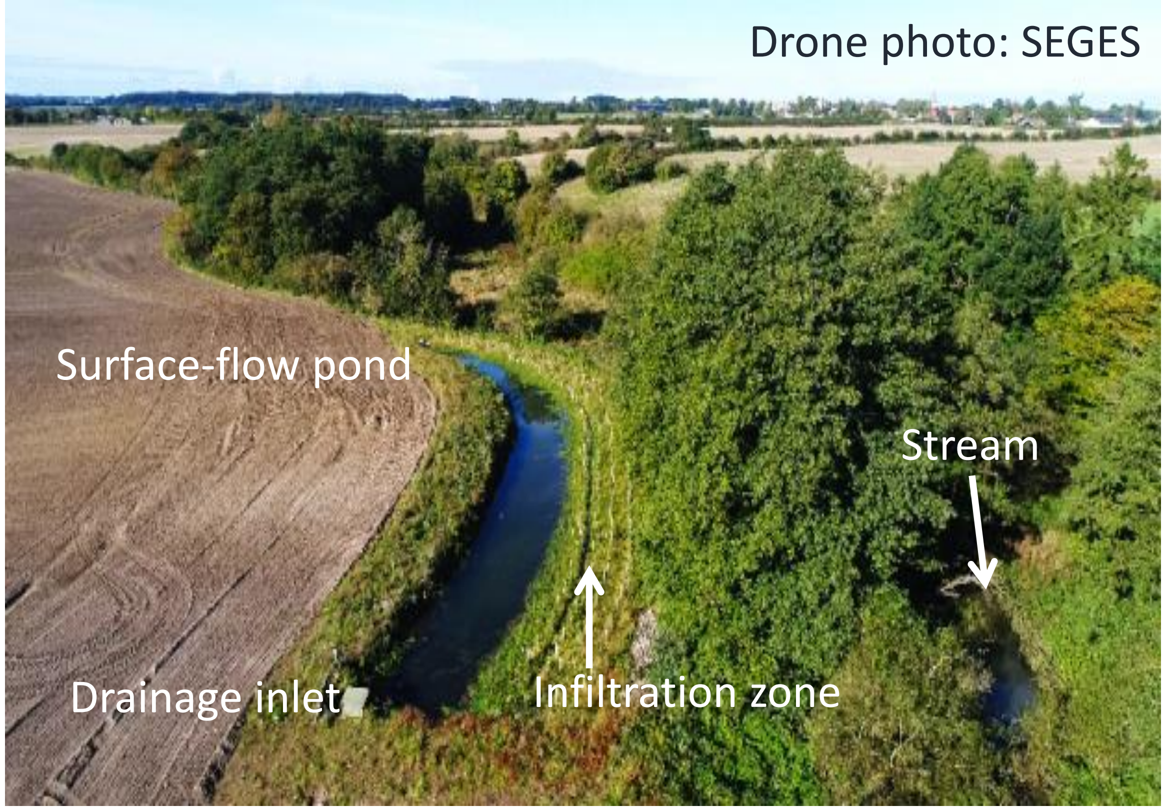
Integrated bufferzones (IBZ)

www.buffertech.dk

Tile-drain intercepted by surface-flow pond followed by infiltration in planted bufferzone



From Kronvang et al., 2017



Size: 1% of drainage catchment
Not yet approved

Nutrient effects

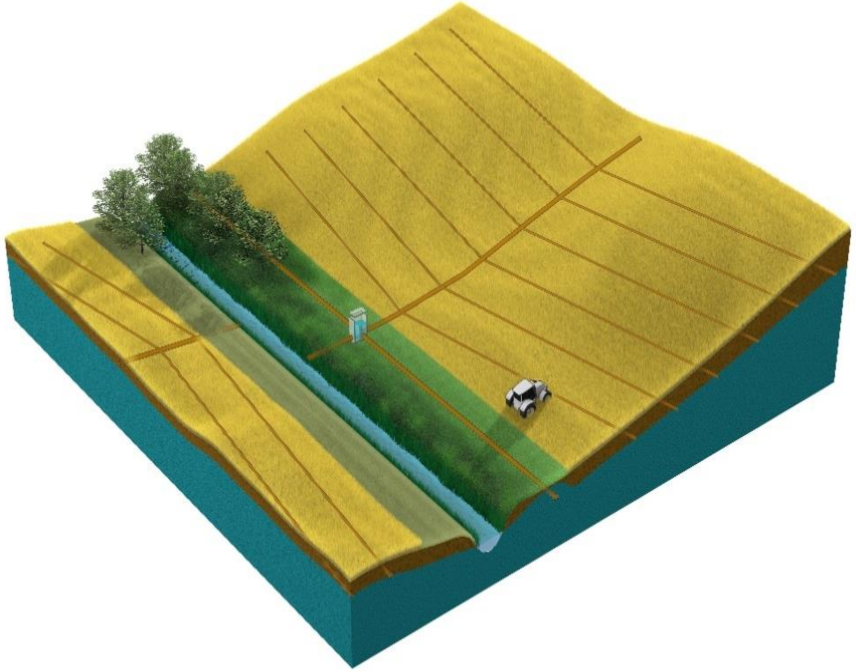
- Annual N-reduction: 20-36%
- Annual P-retention: 40-50%

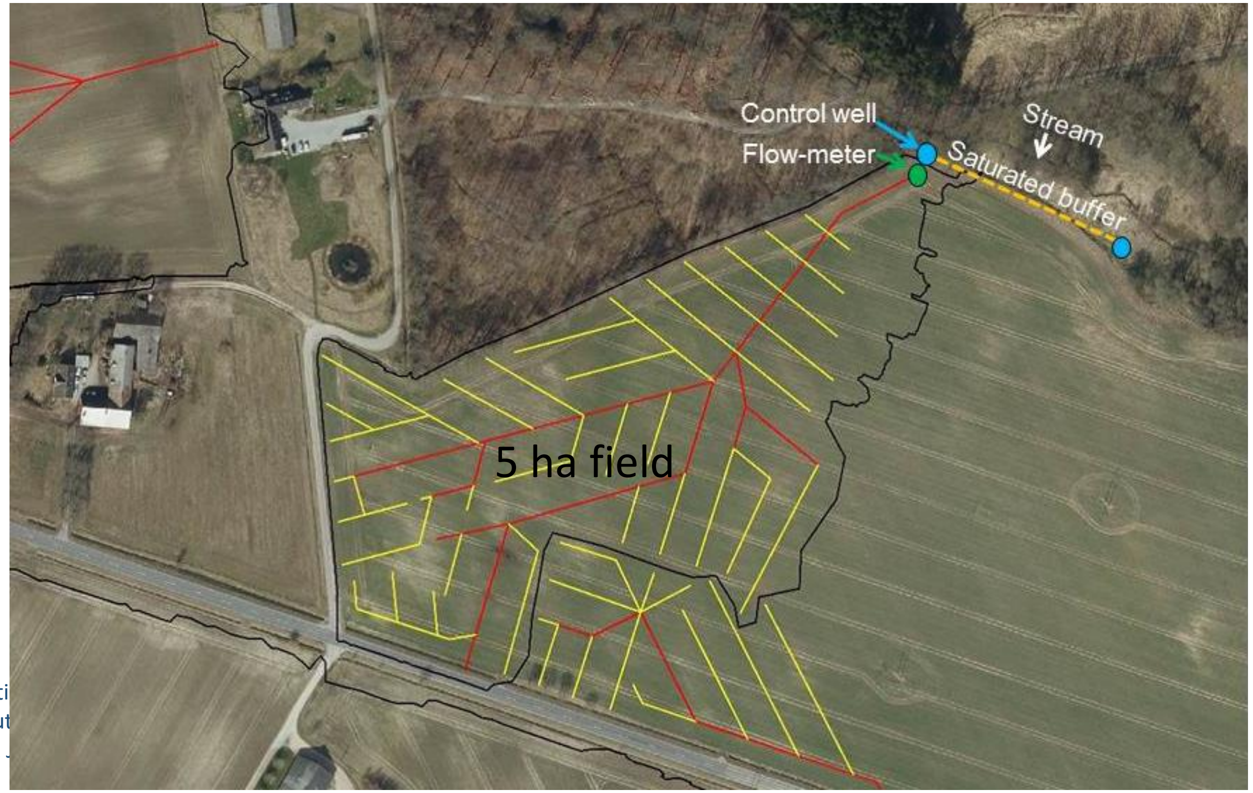
References

- Kronvang et al., 2017
- Zak et al., 2018

Saturated bufferzones

Tile drains are intercepted and drainage water allowed to infiltrate in the buffer zone

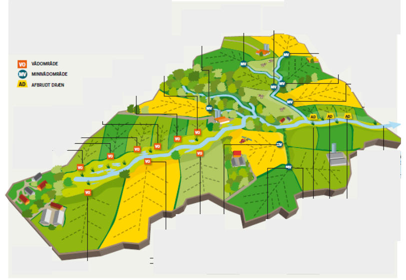




First Danish projects 2018-2020 (SEGES, AU-BIOS)

- Denitrification rates in the bufferzone
- Phosphorus effect (P-retention vs. in situ P-release)
- Hydraulic capacity -> soil type specific

Four drainage mitigation measures – summarizing



Mitigation measure	Position in landscape	Area required (% of drainage catchment)	N-reduction efficiency %	P-retention efficiency %	Negative side-effects
Riparian lowland / restored wetland	Lowland	10*	50 (20-100)	Risk evaluation	P-release risk GHG-emission* Oxygen depletion Sulfide production
Surface-flow wetland	Upland tile-drained field	1	25 (17-45)	43 (30-80)	Effluent temp. may increase during summer (2-5^{o}C)
Subsurface-flow bioreactor	Upland tile-drained field	0,2-0,25	50 (45-70)	<0 to 48 (changes over time)	GHG-emission Oxygen depletion Sulfide production (considered in guidelines)
Integrated buffer zone	Bufferzone tile-drained field	1	20 (20-36)	40-50	

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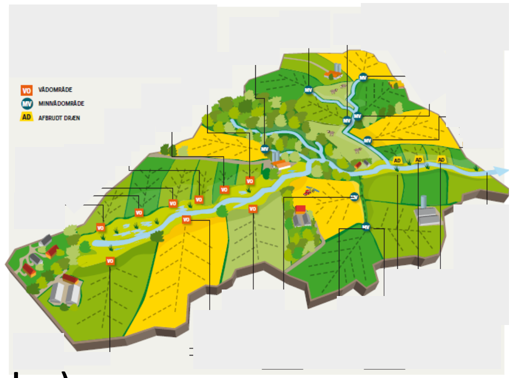
Mitigation stategy and cost-efficiency



What is required to reach the N-reduction target in 2021 for a ID15 subcatchment with four measures?

- Calculations conducted for a ID15 subcatchment (1.500 ha) with 70% agricultural area (1.050 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 (very low maintenace cost)
** Constuction cost depreciation in 5 years (not including new supply of woodchips every 5 years)

Thank you for your attention

Photo: Carsten Søbog

Funding projects

- SupremeTech (www.supremetech.dk), Danish Strategic Research Council, 2010-2016
- iDRAIN (www.idrain.dk), GUDP, 2011-2017
- SF-CWs, MFVM, 2013-2017, Environmental Technology Fund
- Buffertech (www.buffertech.dk), 2012-2017, Innovation Fund Denmark
- Innovation Platform for Drainage Measures, Promilleafgiftsfonden for Landbrug, 2018-2020