Mitigating nutrient losses from agriculture – the role of created wetlands

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Wetpol Conference 2023, Bruges, Belgium

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Content

I) The need for Nutrient management in European agriculture

II) Free water surface wetlands as edge-of-fields measures to reduce field losses of N and P

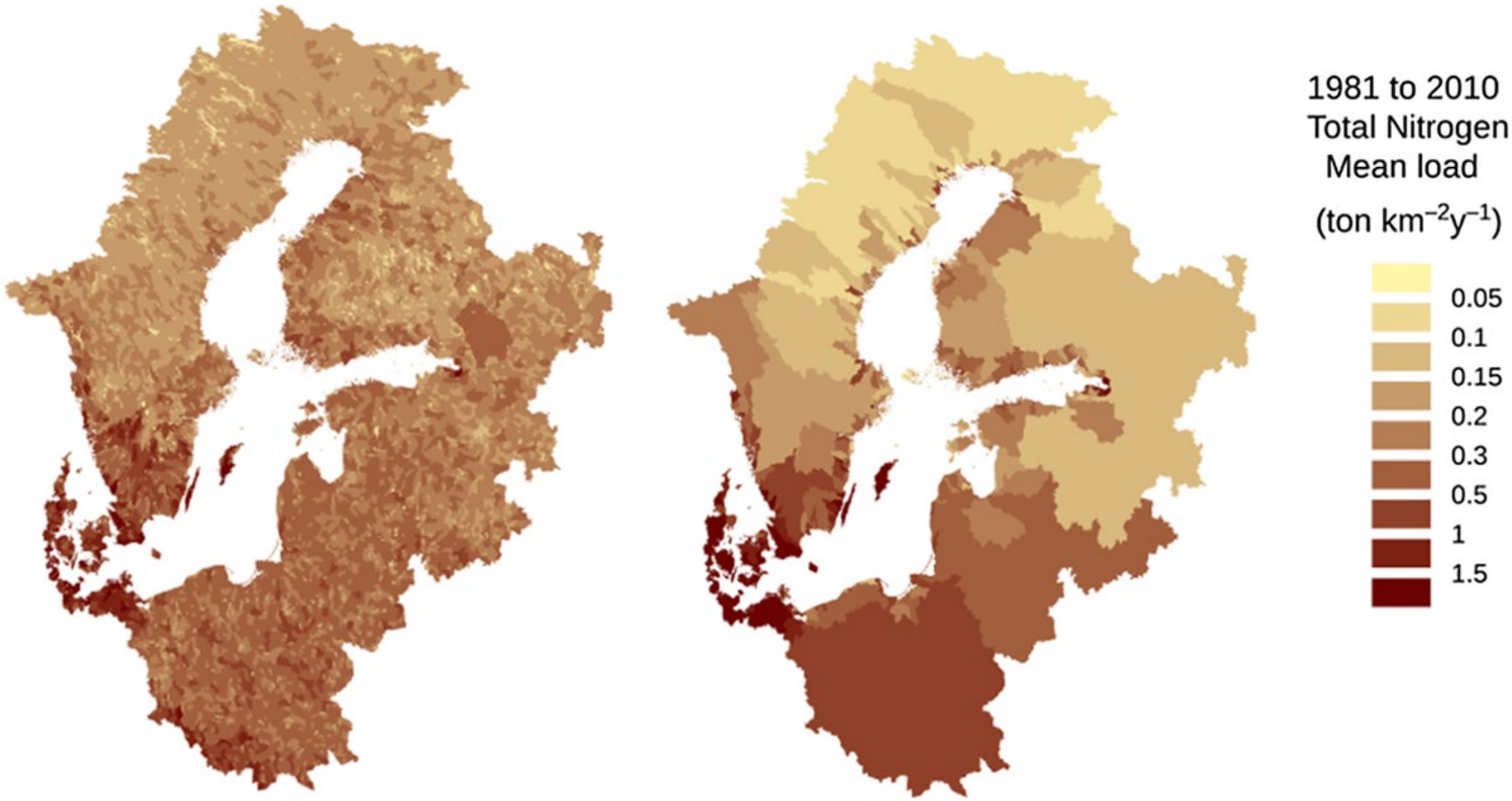
III) How effective are wetlands for reducing field losses of N and P to surface waters ? Challenges to advance the quantitative knowledge

IV) Approach to increase wetland cost-effectiveness

V) Design of wetlands for N removal and P retention

VI) Complementary approaches to mitigate N and P losses

Large need for improved nutrient governance, but it varies spatially



Capell R, Bartosova A, Tonderski K, Arheimer B, Pedersen SM, Zilans A. 2021 From local measures to regional impacts: Modelling changes in nutrient loads to the Baltic Sea. https://doi.org/10.1016/j.ejrh.2021.100867

EEB comments to EUs Integrated Nutrient Management Plan proposal, 2022

- "N inputs exceed critical thresholds for eutrophication in 65-75% of EU agricultural soils" (EEA The European environment – state and outlook 2020)
- "Surplus use of phosphorus has resulted in a build-up of legacy phosphorus in agricultural soils" [...could contribute up to 45% of the transport to the Baltic Sea"" McCrackin et al. 2018] https://doi.org/10.1029/2018GB005914]
- The INMAP should outline, with clear indicators, how the EU will get back to sustainable nutrient flows by 2030...

Under ”Guiding principles”

” Nature-based solutions such as landscape features, buffer strips, wetlands and flooding zones, are proven as cost-effective solutions to tackle nutrient pollution in many different configurations… “





Evidence based mitigation measures

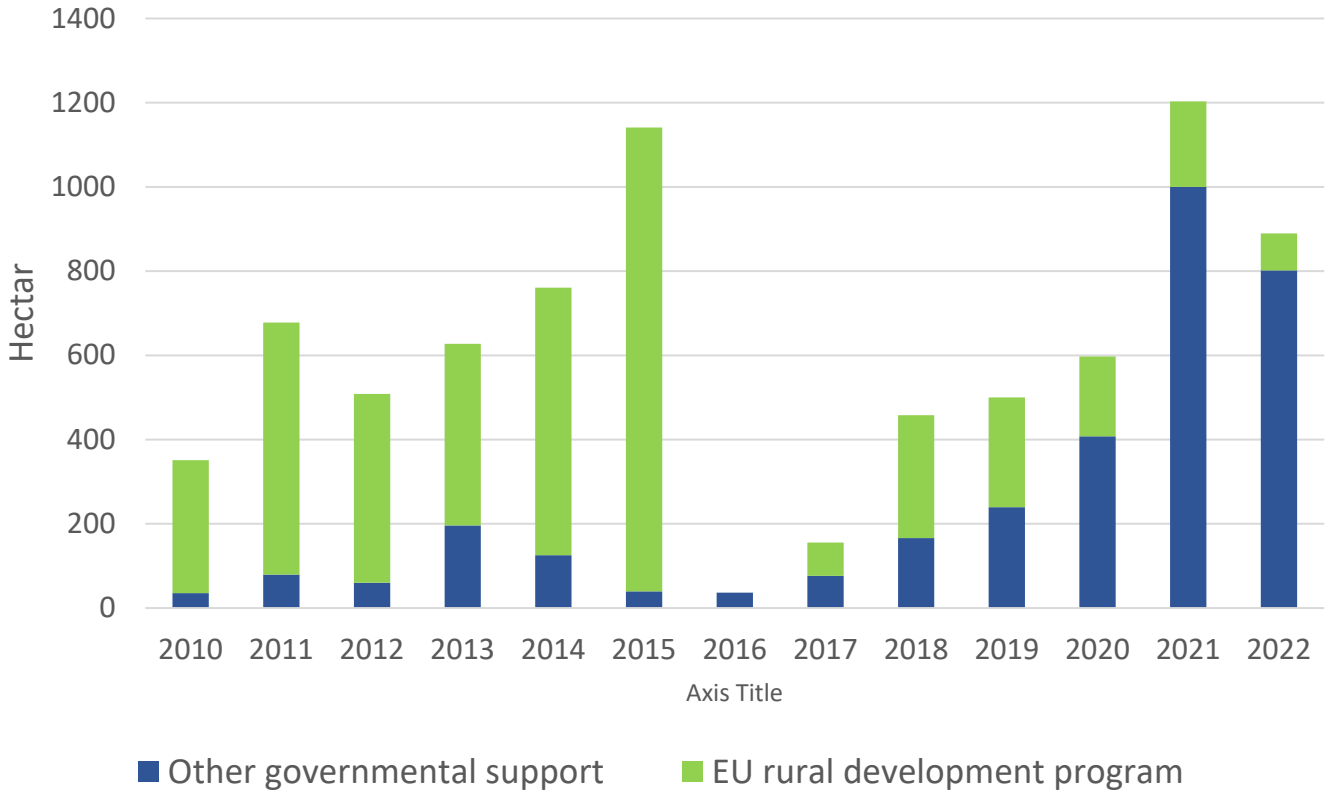
Suggested goal for wetlands created to mitigate nutrient losses from agriculture

i) Ensure that wetlands created for agricultural nutrient loss mitigation are as cost-effective as possible

while

ii) also other ecosystem services are promoted to the extent possible without compromising the nutrient mitigation goal

Wetlands are still constructed and restored in the Swedish landscape – are they cost-effective?



7813 hectar total

How effective are created or restored freshwater wetlands for nitrogen removal and phosphorus retention?

- removal rates (g m^{-2} y^{-1} *or* kg ha^{-1} yr^{-1})

- relative removal (% of load)

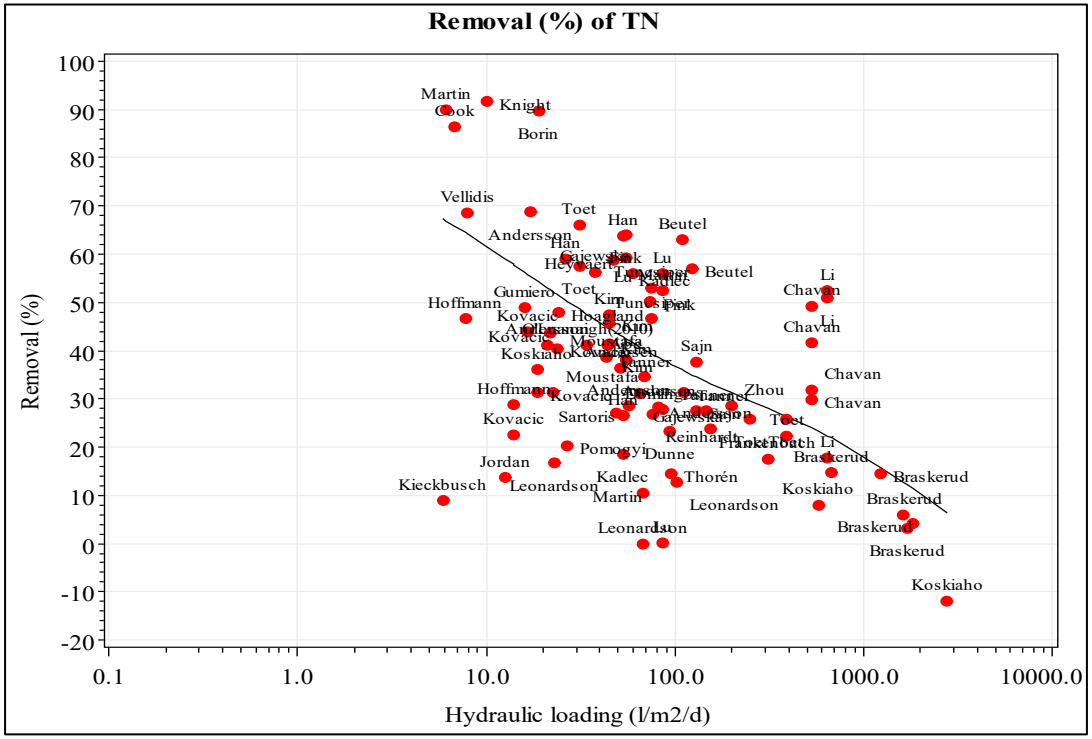
How cost-effective are created or restored freshwater wetlands for nitrogen removal and phosphorus retention?

- cost per removed kg N or P (EUR kg^{-1} yr^{-1})
- allocation between N and P?
- allocation to other values/services ?

1) Area specific N removal increases with increasing N load. [181 ± 251 g m^{-2} $year^{-1}$]

2) Removal in % of load decreases with increasing load. [39 ± 21 % of load]

Evidence-base:
203 wetlands;
103 receiving agricultural runoff



Land, M., Granéli, W., Grimvall, A., Hoffmann, C. C., Mitsch, W. J., Tonderski, K. S., & Verhoeven, J. T. A. 2016. How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review
https://doi.org/10.1186/s13750-016-0060-0

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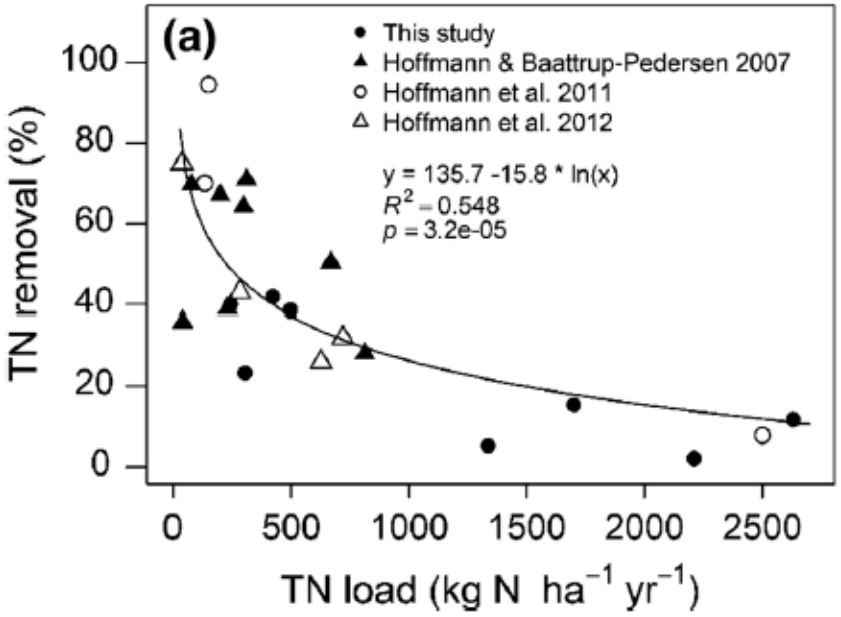
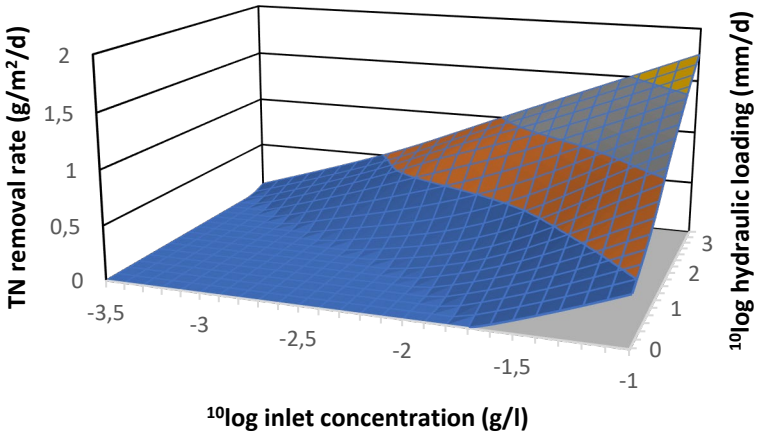
Recent observations Free water surface wetlands receiving water from agricultural fields

Removal TP g m^{-2} yr^{-1}	TP Efficiency (% of load)	Removal TN g m^{-2} yr^{-1}	TN Efficiency (% of load)	Reference *Review*
13 (-17–240)	*41 (-422–99)*	*181 (-0.3 –1270)*	*39 (-13 – 93)*	*Land et al. 2016*
3.7 (1.2-5.7)	46 (31 -64)			Mendes et al. 2018
		38.8	42	Dal Ferro et al. 2018
0.27 (-.28 –1.0)	-8 (-29 –18)	15.2 (4.2 – 30.8)	22 (2 – 40)	Audet et al. 2020
0.68 (±4.2)	18 (± 46)	60 (± 69)	40 (± 17)	*Vodder Carstensen et al. 2020*

Load of N is negatively related to the wetland N removal efficiency (% of load)

Positively related to the area specific removal





Audet, J., Zak, D., Bidstrup, J. *et al.* Nitrogen and phosphorus retention in Danish restored wetlands. *Ambio* **49**, 324–336 (2020). https://doi.org/10.1007/s13280-019-01181-2

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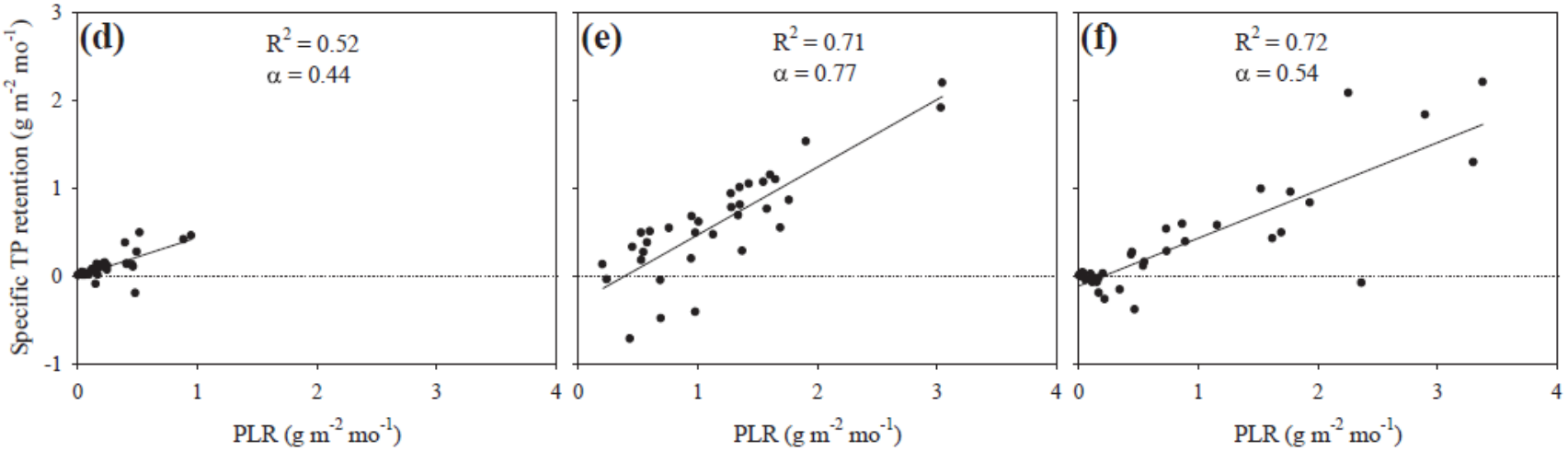
P load (concentration * hydraulic load) is a reasonable predictor for P removal – but P species are important



PP/TDP < 1

PP/TDP > 1

PP/TDP > 1

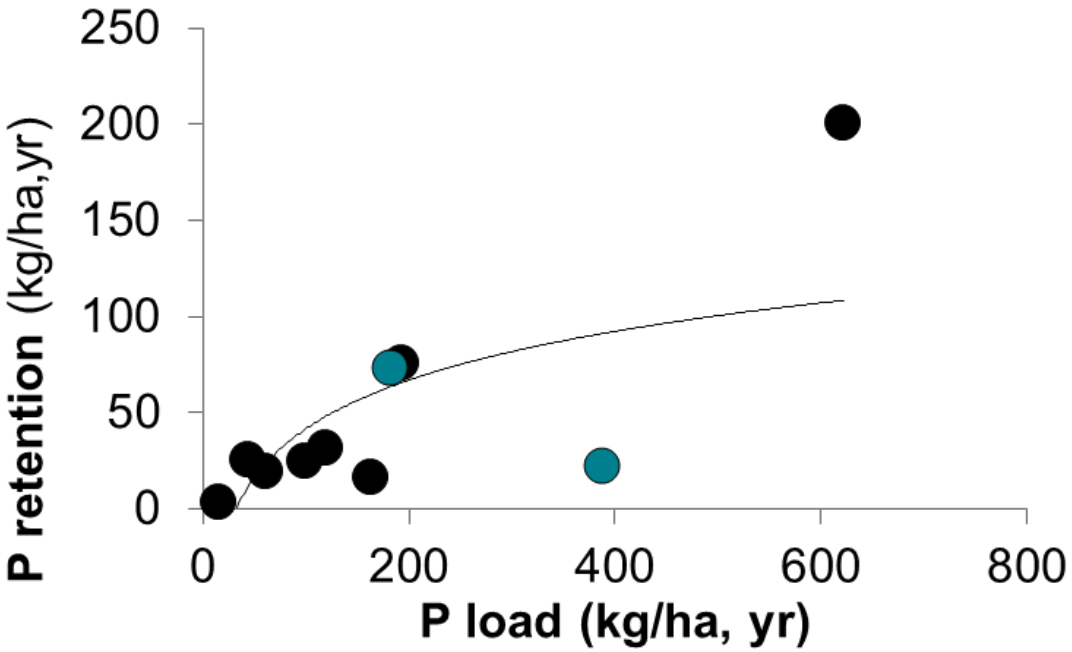
Mendes, L. R. D., Tonderski, K., Iversen, B. V., & Kjaergaard, C. 2018. Phosphorus retention in surface-flow constructed wetlands targeting agricultural drainage water. https://doi.org/https://doi.org/10.1016/j.ecoleng.2018.05.022

Costly to set up and maintain high quality sampling programmes to assess loads and retention

- Continuous water flow measurements IN and/or OUT
- Flow proportional water sampling if possible

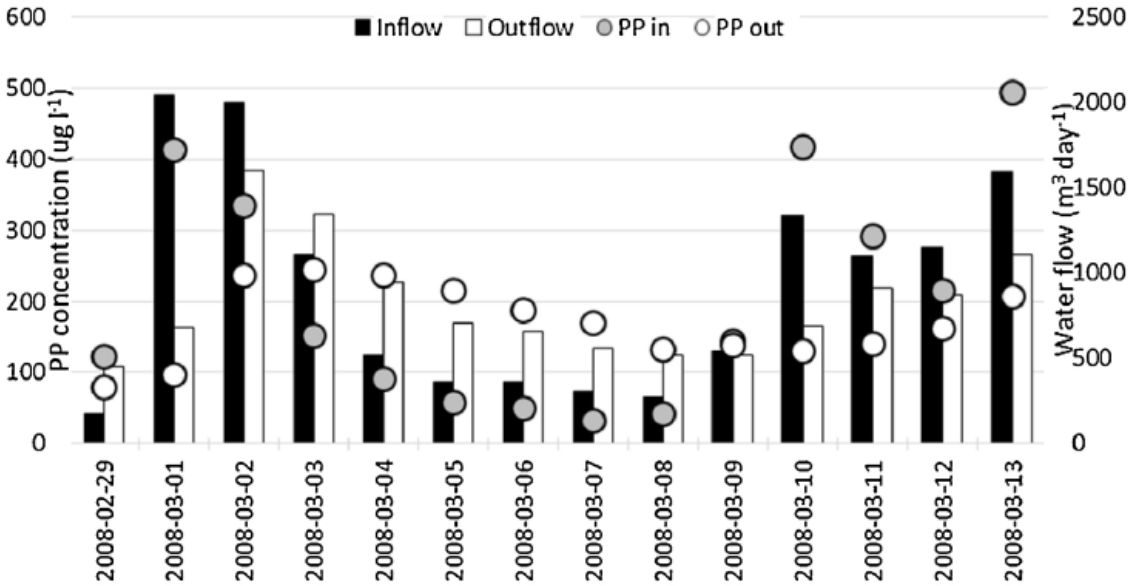


P-wetlands in Sweden, monitored with flow proportional sampling, show high retention



Pia.geranmayeh@slu.se Results in prep.

Challenge: How to assess loads ? Highly variable water flows, concentrations and water composition



Model desirable placement & size, based on catchment models

Step 1

Wetland size (m^2)

High resolution elevation model (DEM)

deliniate catchment & Q accumulation

Step 2

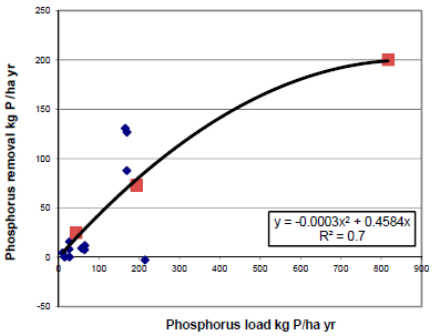
Nutrient load (N & P)

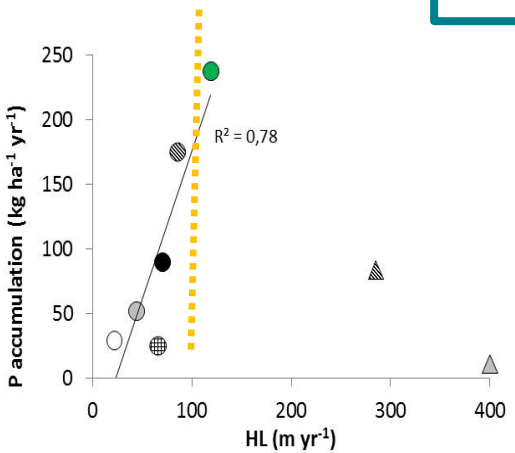
Q * Nutrient conc (landuse, soiltype,slope, crop, climate)

Step 3

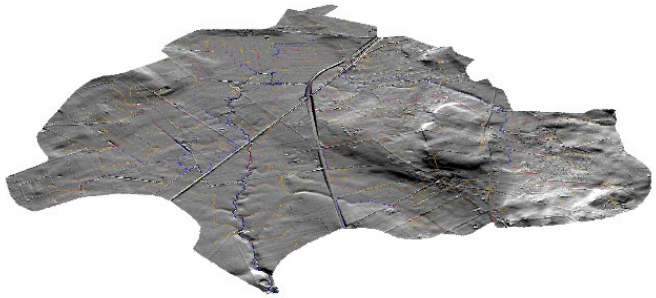
Nutrient retention (N & P)

Eq. based on Nutrient load





$$Watersurface\ (m^2) = \frac{Discharge\ (m^3)}{HL(m)}$$



Ambio
https://doi.org/10.1007/s13280-020-01349-1

ENVIRONMENTAL EFFECTS OF A GREEN BIO-ECONOMY

Optimizing placement of constructed wetlands at landscape scale in order to reduce phosphorus losses

Faruk Djodjic, Pia Geranmayeh, Hampus Markensten

Siting & Sizing tool

https://arcg.is/1HC001

Model Wetland Nutrient potential southern Sweden 2023

→ choose wetland type

ArcGIS StoryMaps ● Low - High ● ° 0.1– 5 ha ◯

Nutrient Biodiversity Flow

1. Vattenvägar i landskapet 2. Ytavrinning och erosion 3. Näringsämnestransporter 4. Våtmarkernas potential 5. Översvämningsr

Djodjic, F., P. Geranmayeh and H. Markensten. 2020. Optimizing placement of constructed wetlands at landscape scale in order to reduce phosphorus losses. Ambio. doi:10.1007/s13280-020-01349-1.

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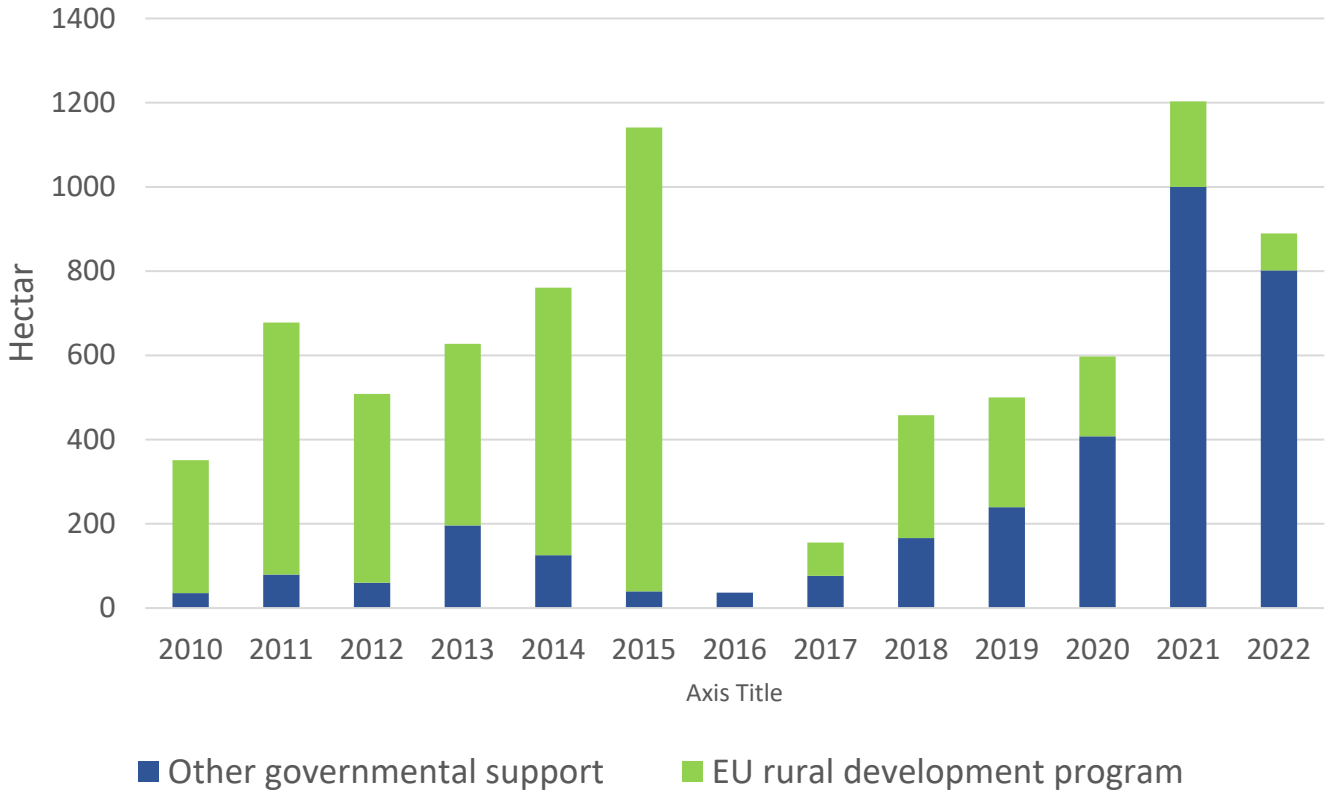
Wetlands are still constructed and restored in the Swedish landscape – are they cost-effective?



7813 hectar total

Modelled 144 existing wetlands

Many wetlands receives low nutrient load
→ low nutrient retention

East Clay soil 15% Agricultural land

West Sandy soil 60% -"-

ELSEVIER

Journal of Environmental Management

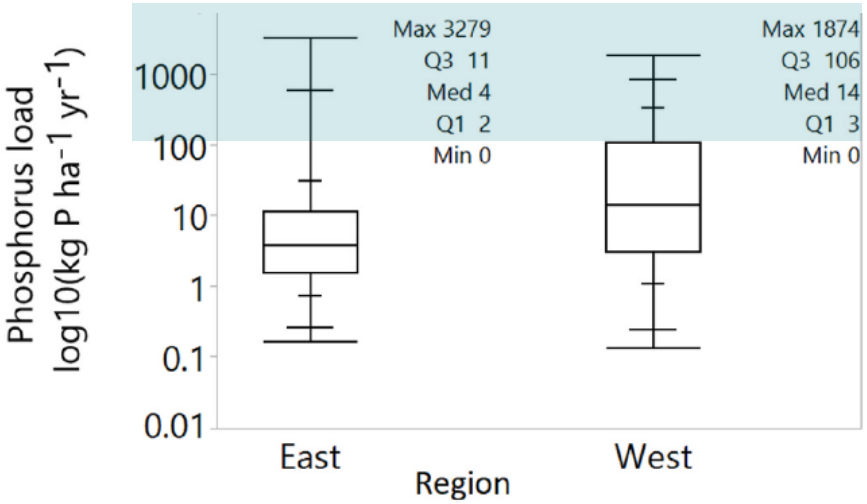
journal homepage: www.elsevier.com/locate/jenvman

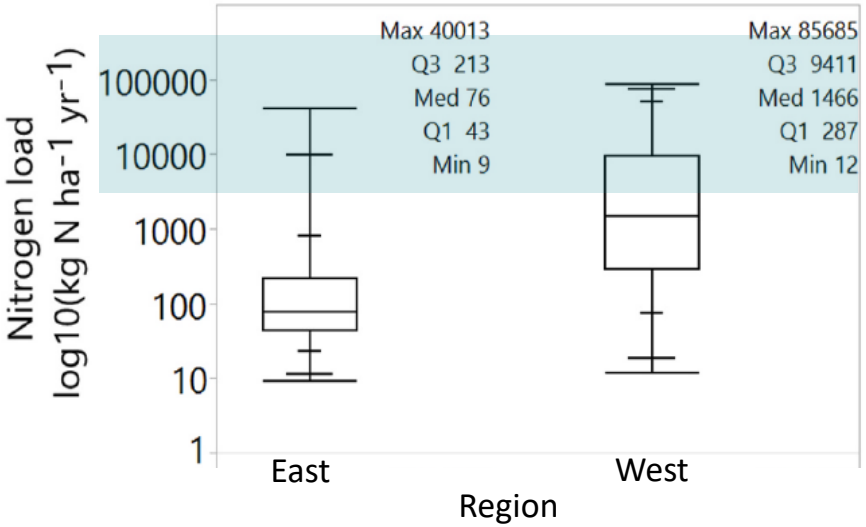
Research article

Cost effectiveness of nutrient retention in constructed wetlands at a landscape level

F. Djodjic *, P. Geranmayeh, D. Collentine, H. Markensten, M. Futter

The Department of Aquatic Sciences and Assessment, SLU, P.O. Box 7050, SE-75007, Uppsala, Sweden





Djodjic, F., P. Geranmayeh, D. Collentine, H. Markensten & M. Futter. 2022. Cost effectiveness of nutrient retention in constructed wetlands at a landscape level. J Env.Mgmt doi:https://doi.org/10.1016/j.jenvman.2022.116325.

Cost effectiveness (1EUR = 12 SEK)

	P	N
Wetlands	<500 kr/ kg P	<100 kr/kg N
East	8%	10%
West	25%	~50%

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journal homepage: www.elsevier.com/locate/jenvman

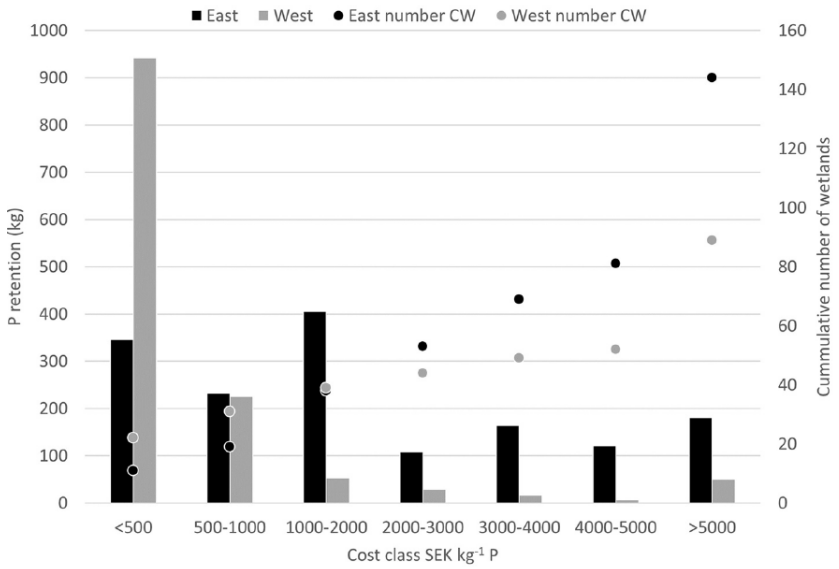
Research article

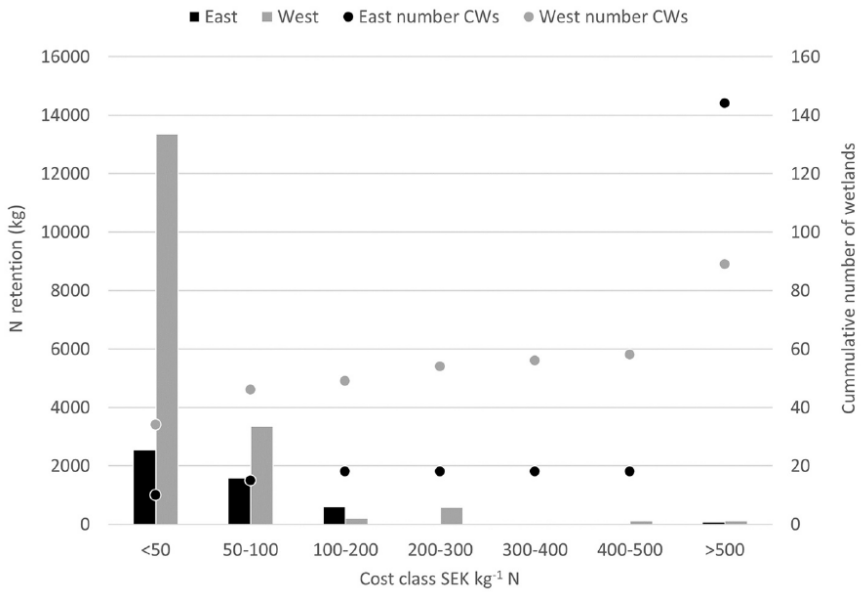
Cost effectiveness of nutrient retention in constructed wetlands at a landscape level

F. Djodjic *, P. Geranmayeh, D. Collentine, H. Markensten, M. Futter

Buffer zones 725-45 392 kr/kg P Catch crops 85-182 kr/kg N

Assumed same construction cost as purpose unknown





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Challenge: How to ensure that (the most) cost-effective measures are implemented ?

- Uniform rules are easier for administration (e.g. All should reduce the same amounts (tot. or % of loss)

HOWEVER

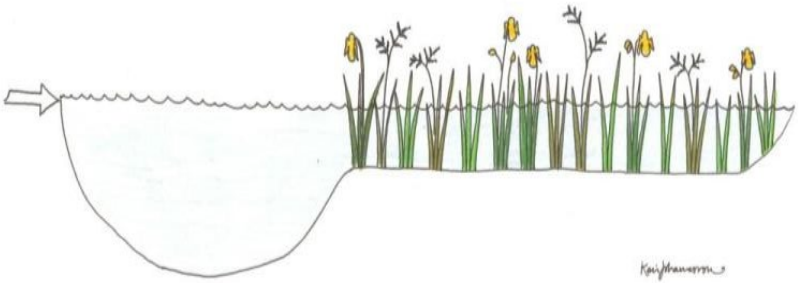
- Needs to reduce nutrient loads vary spatially (water ecological status)
- Spatially differentiated rules/subsidies are more cost-effective/efficient but require a lot of competence

Design: For nitrogen removal, emergent plant communities are favorable – but risk for hydraulic problems.

Wetlands with varied vegetation are beneficial for hydraulic efficiency and benefit biodiversity

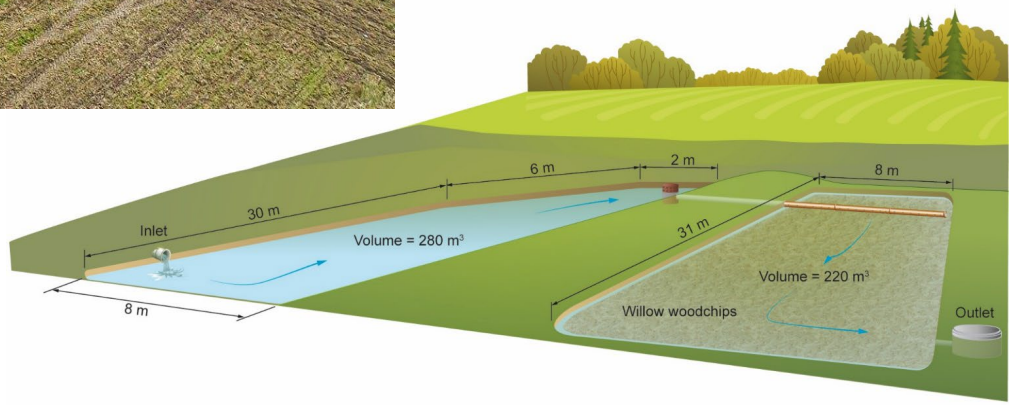
In Sweden, P-wetlands for particulate P removal

- Deep area (1-1.5m)
  - Submersed or floating species colonize
- Shallow area (0.3-0.4m)
  - Planted with emergent species, e.g. Carex, Scirpus sp.



Biofilters for N and P removal from drainage water

New design with storage pond for peak flow events



Multifunctional wetlands – other ecosystem services?

Wetland located to retain and remove P and N in farm yard runoff, produce fish and support more biodiversity

Harvesting aquatic biomass from agricultural wetlands for nutrient recycling

Society

Nutrient rich
waters & wetlands

Eutrophic sea

Renewable nutrients

Renewable energy

Valorisation
and
bioenergy

Harvest

Harvest

Inmatning

Mellanlagring

Lastning

Uppsamling

Transport

Hackning

Uppsamling

Source: Tomas Kjellqvist, Biototal Ltd & Agrosea Ltd

The role of wetlands for mitigating N and P losses – final reflections

- Wetlands can be a cost-effective measure, compared with other measures
- N and P load is the single most important factor for the nutrient removal in wetlands
- Choosing location is a key success factor for nutrient retention – catchment N and P models are useful but more studies are needed
- Education is dearly needed as measures need to be adapted to catchment specifics
- More studies are needed on ways to improve and value multiple functions in created wetlands

Thanks for your attention !

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