How can we enhance the ecosystem services provided by buffer strips?

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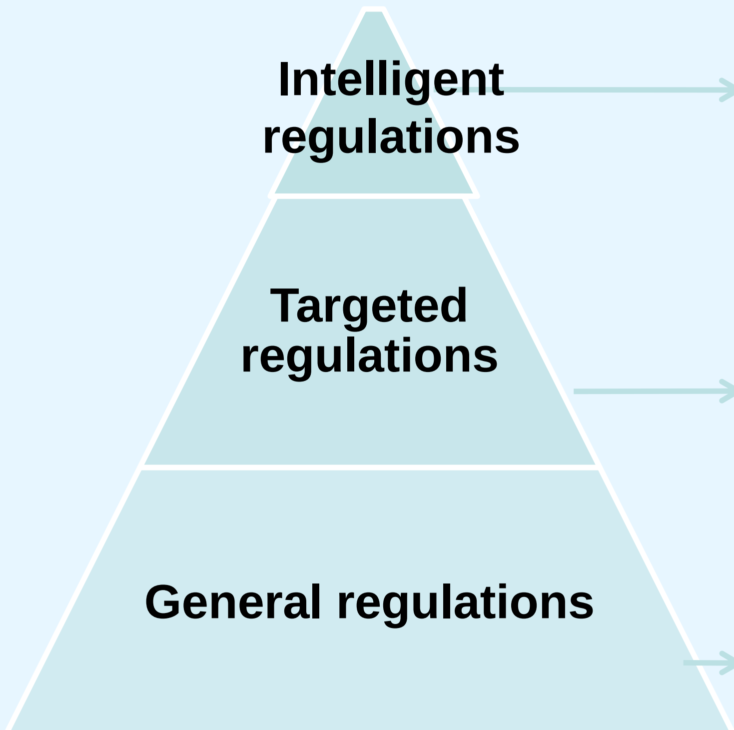
Outline

- **Policy interventions: The General and The Targeted way**
- **Success story of reducing nutrient losses in Denmark**
- **The history of wet riparian zones in Denmark our lost nutrient sink!**
- **The newer ending story about Buffer Strip implementation in Denmark!**
- **Multiple ecosystem services provided by buffer strips**

  Sediments, Nutrients, Pesticides & Nature
- **Testing the Integrated Buffer Zones (IBZs)**

Policy interventions - Buffer Zones/Strips

Locally targeted

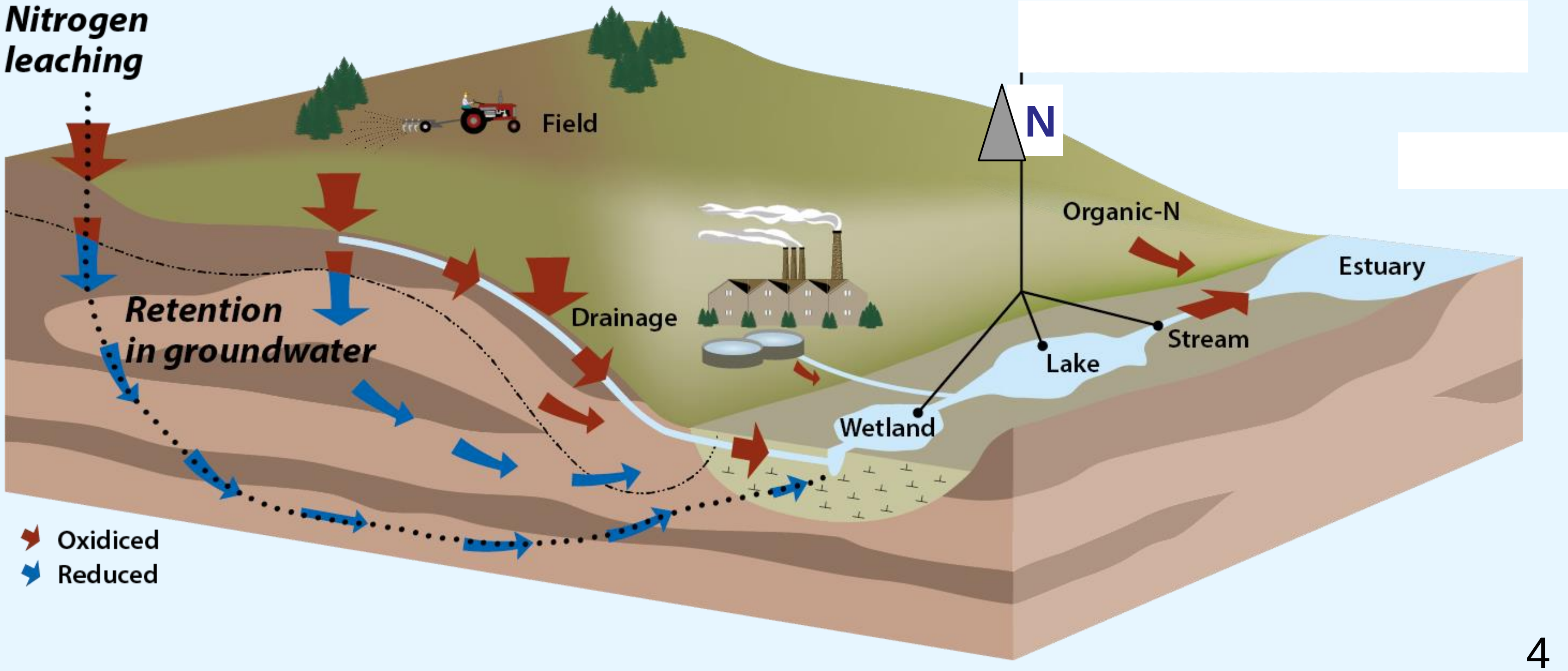


Applied (inter)nationally

- Intelligent regulations: Implemented considering all Ecosystem Services at local scale – multiple use of models and expert knowledge
- Targeted regulations: Implemented considering their buffering effect for sediment and nutrients – assisted by GIS-models
- General regulations: General binding rules – implemented by Acts – e.g. 10 m Buffer Strips

Combatting Land based Nutrient Pollution of Waters

1. Reduce the **Nutrient sources**
2. Enhance the **Nutrient Sinks** (Nutrient retention) – restored wetlands, buffer strips, constructed wetlands, controlled drainage, etc.



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Where and how to go…??

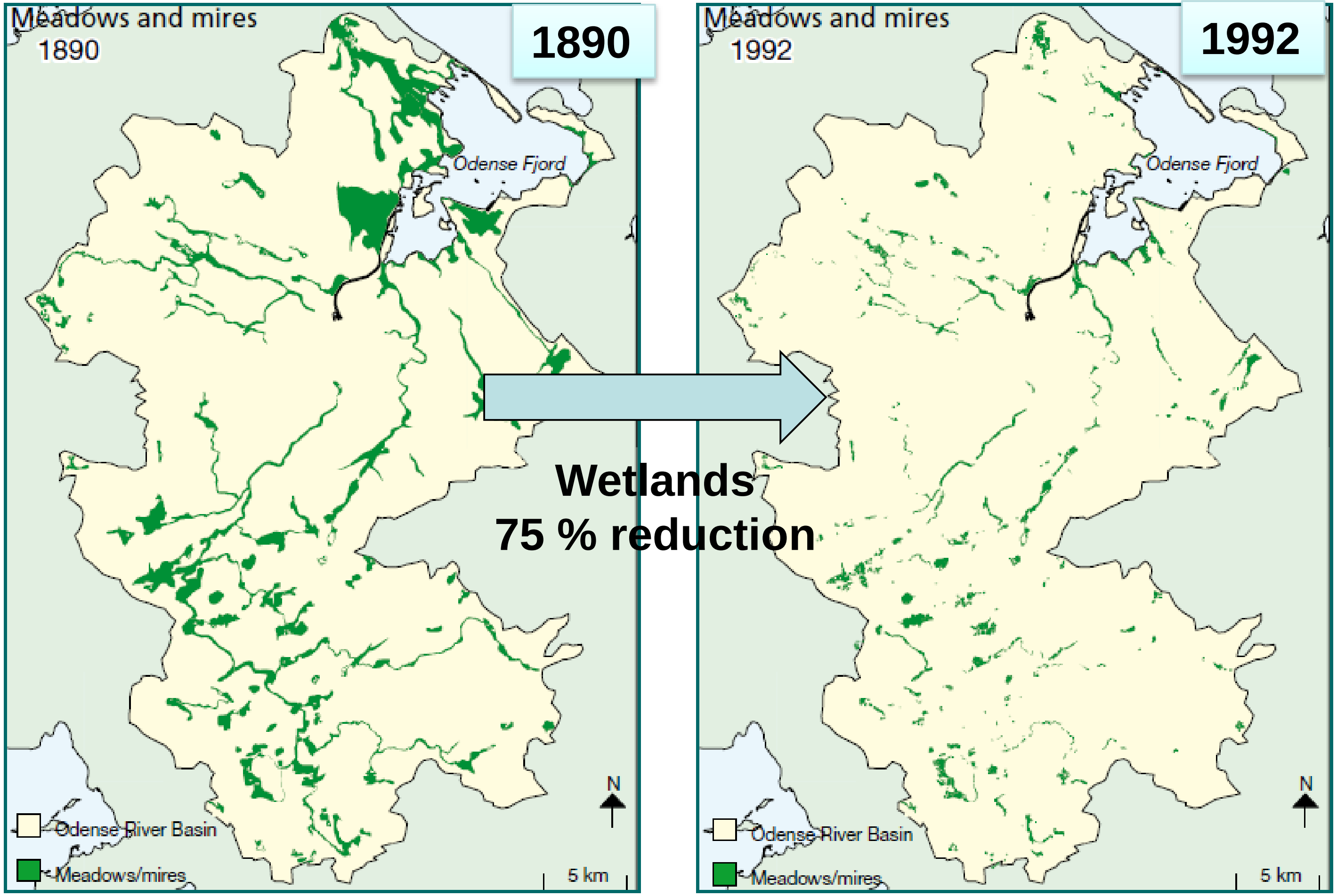
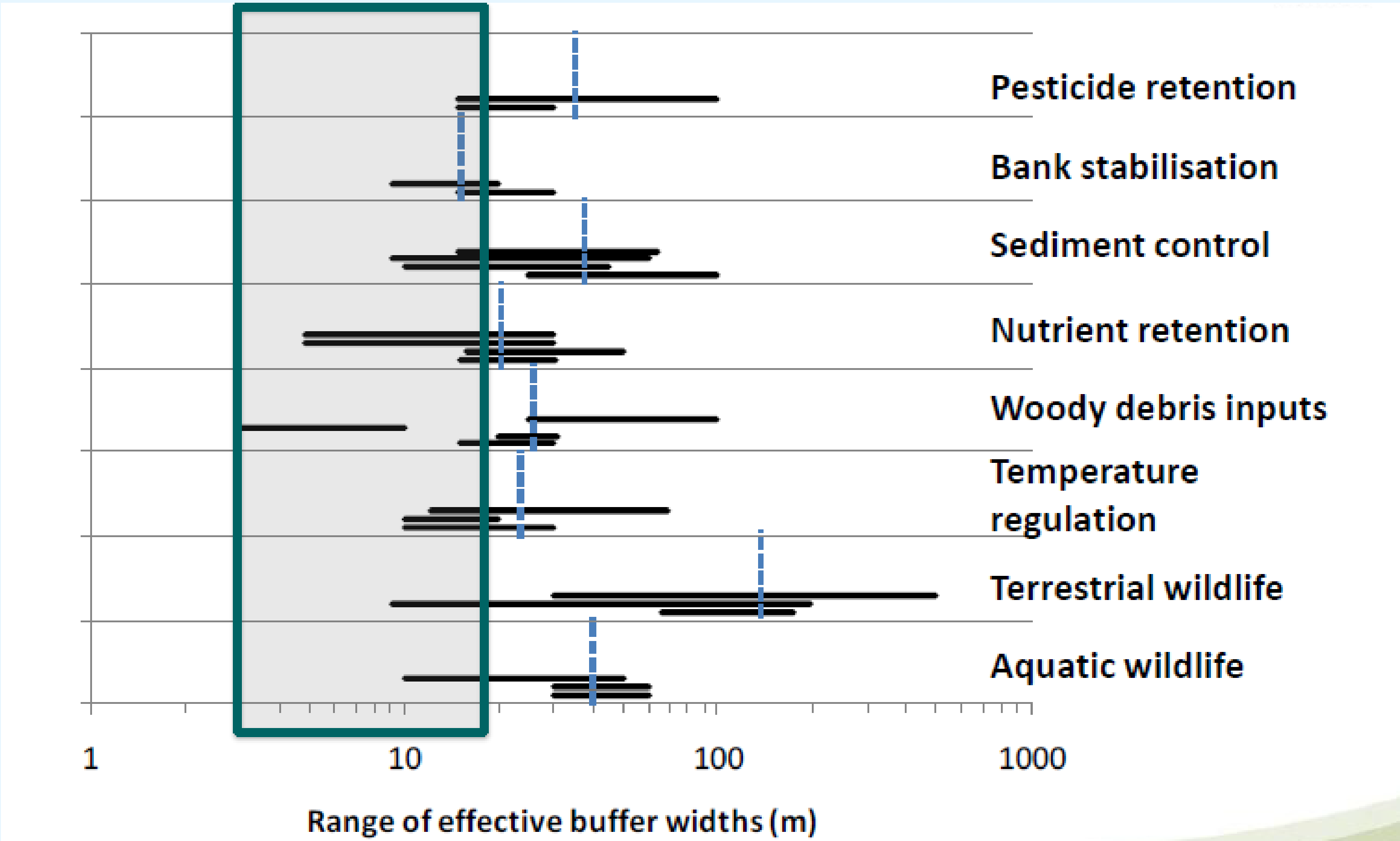


Figure 3.2
Distribution of mires, freshwater meadows and coastal meadows in Odense River Basin in 1890 and 1992. Prepared on the basis of maps from 1890 (1:20 000) and the National Survey and Cadastre map from 1992 (1:25 000). The water bodies in 1890 only encompass those larger than 5 ha. The change from 1890 to the present time is primarily the result of land reclamation and drainage activities.

Buffer width for certain functions/services



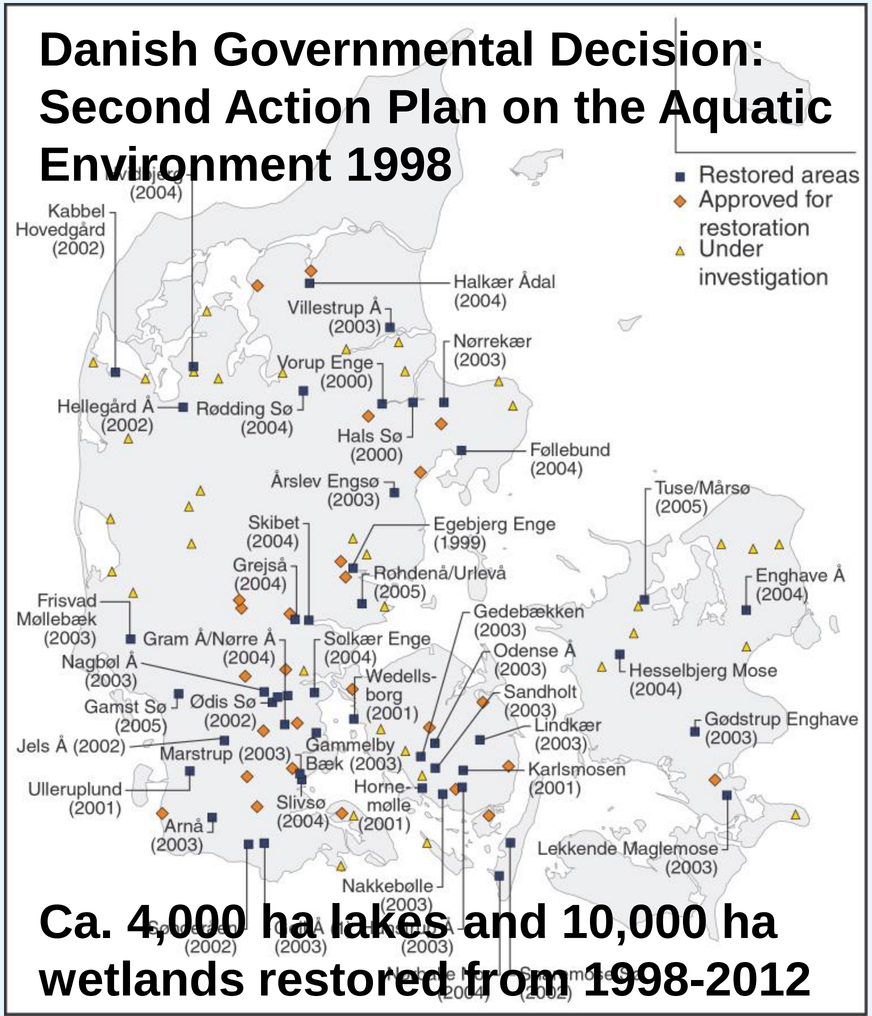
Hawes and Smith (2005)

Will restoration of wetlands increase the removal of N and P from surface waters?

River Skjern
2200 hectares   34 mill. Euro

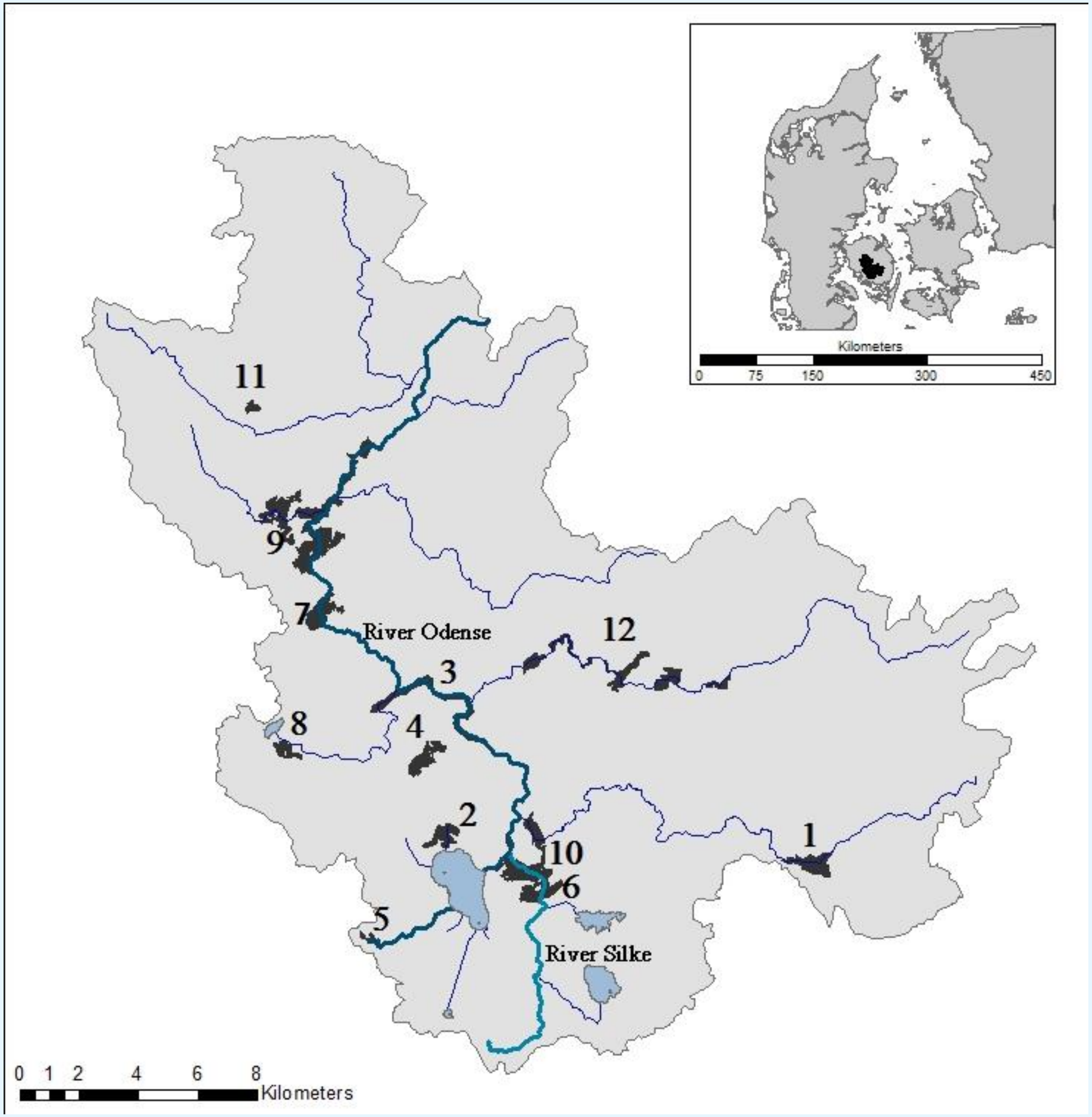
Lake Bølling
Area: 375 ha + 375 ha meadow

Danish Governmental Decision: Second Action Plan on the Aquatic Environment 1998



Ca. 4,000 ha lakes and 10,000 ha wetlands restored from 1998-2012

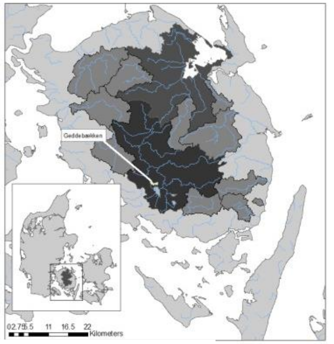
The number and position of the 12 restored wetlands along the River Odense during the period 2003-2011

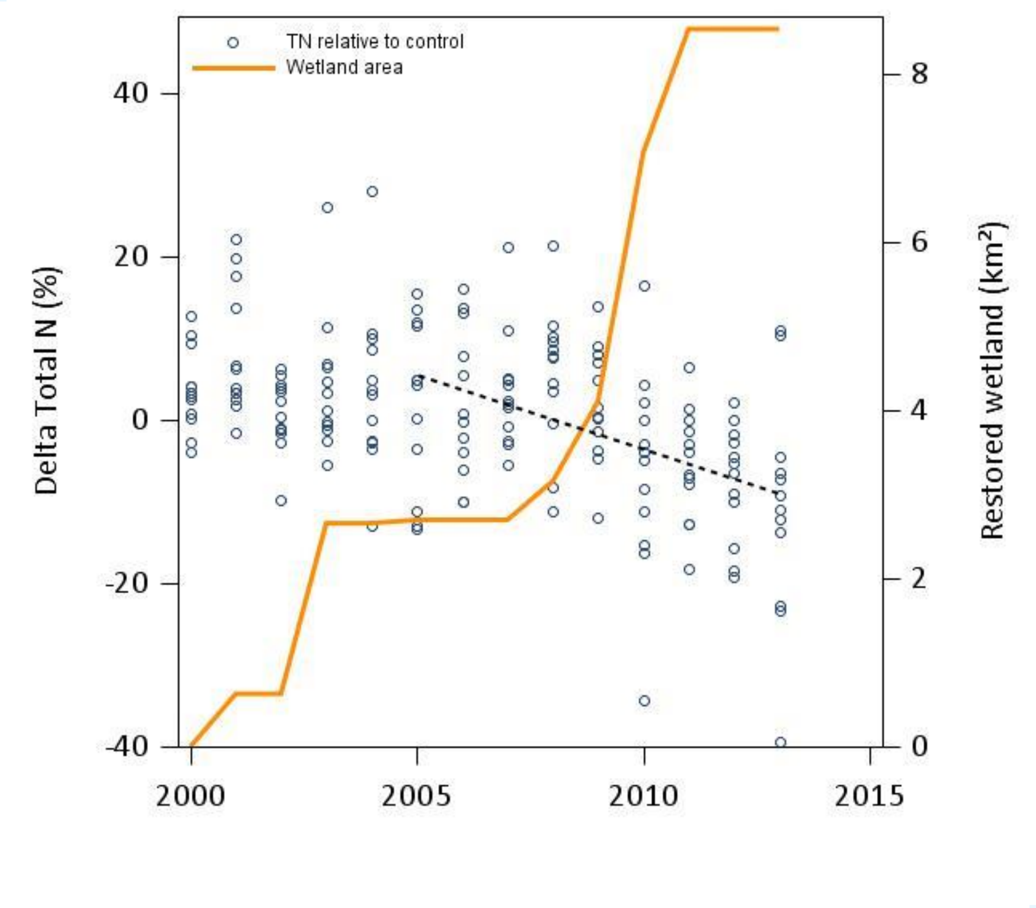


Reach 4 – 3500 ha wetland along the re-meandered main channel in River Odense catchment in 2010

Comparing Control catchment and Odense River

Monthly N concentrations: (Odense River - Control catchment) difference in (%)

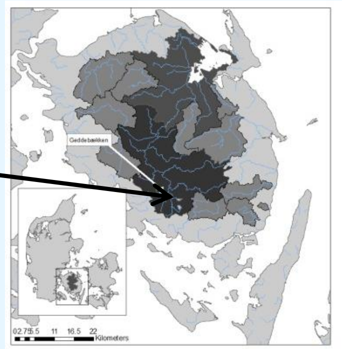




River Odense catchment
1.8 ha restored wetland per km^2 catchment area

Control catchment
0.5 ha restored wetland per km^2 catchment area

Restored wetland: Example Geddebæk

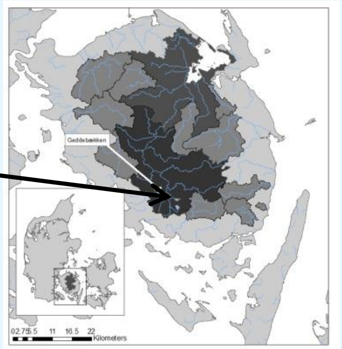


1990

Gauging station

Lake Arreskov sø

Restored wetland: Example Geddebæk

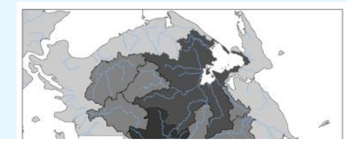


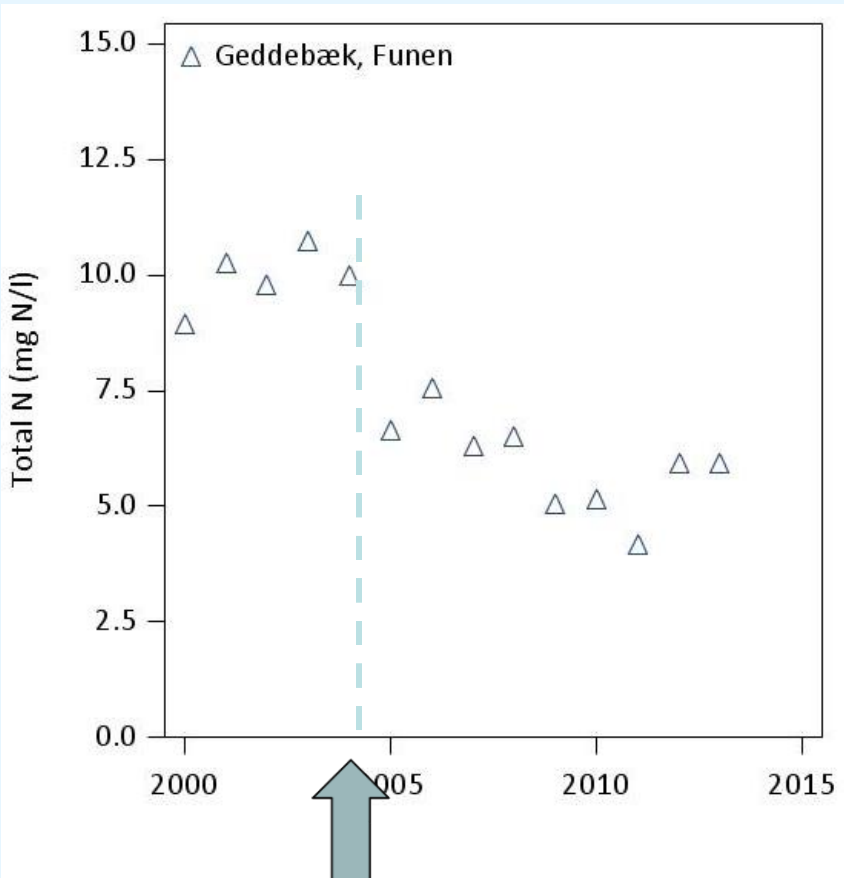
2005

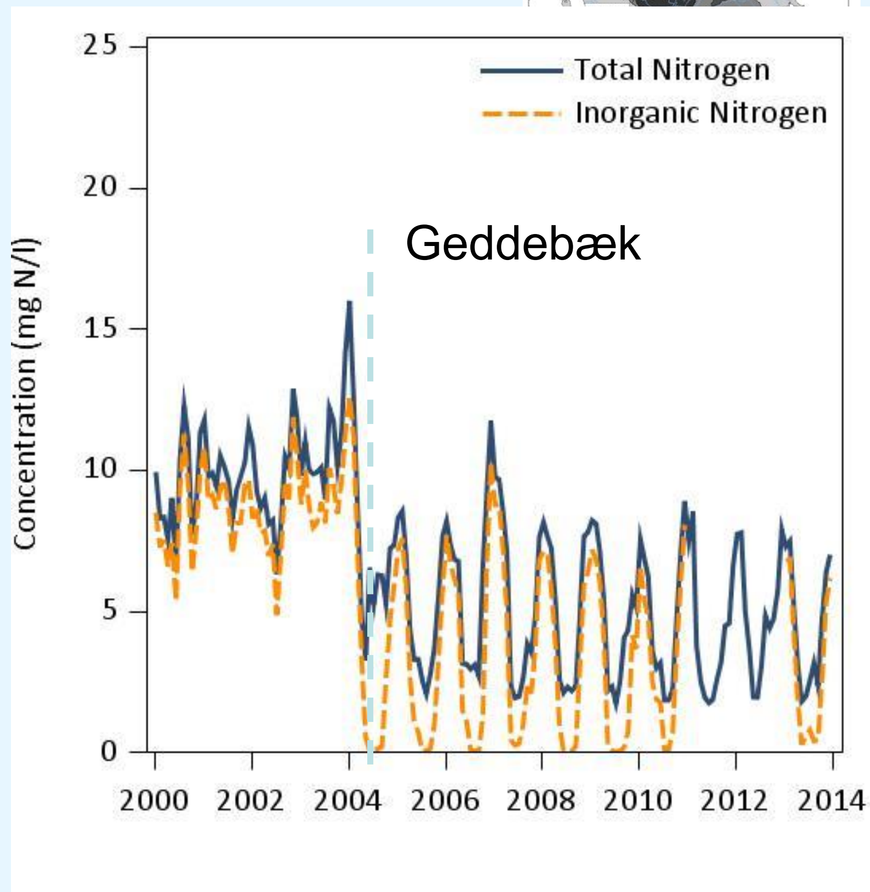
Gauging station

Lake Arreskov sø

Restored wetland: Example Geddebæk

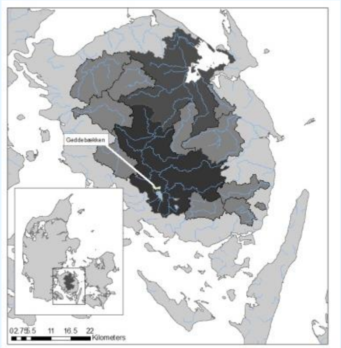






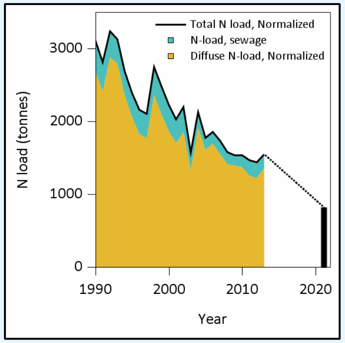
Restored wetland; Geddebæk (44 ha)

<u>Summa: 1990-2013:</u>
N Load: Odense Estuary
Tonnes N per year

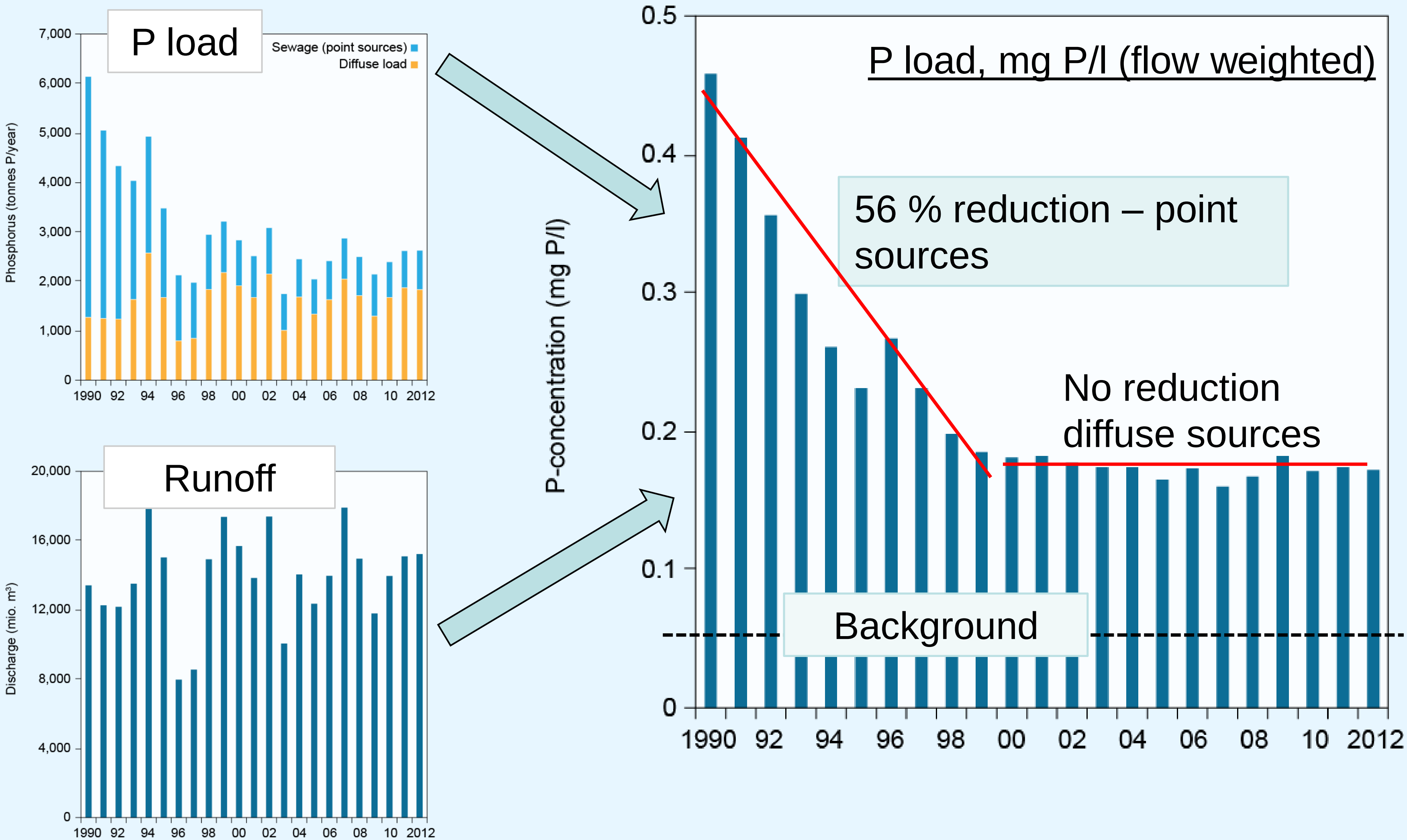


	1990	**2013**	**2021**
Total N load ….	3150	1500	**830 ?**
Sewage……………..…..	450	200	
Diffuse load …..	2700	1300	…..

Restored wetlands: ….. 150 - 200 tonnes N/year
General measures: … 1200 – 1250 tonnes N/year



Buffer strips first introduced as a voluntary mitigation option for farmers to assist in lowering P inputs to surface waters from fields - 2004



The History of Danish Buffer Strip's (BSs)

- **1992: Mandatory 2 m uncultivated BSs along all natural streams and protected streams – ca. 28,000 km watercourses.**
- **2003: The Environmental Action Plan III included 10 m uncultivated BSs as a voluntary mean to reduce N and P pollution of surface waters with an aim to have 50,000 ha established in 2015.**
- **2012: Buffer Strip Act (June 2012): Mandatory 10 m wide BSs along all watercourses with running water in summer (ca. 60,000 km) and all lakes >100 m^2. Compensation for arable land was 300 EURO per year. Grassland 150 EURO per year.**
- **2014: New Buffer Strip Act: Mandatory 9 m wide BSs along all natural and protected watercourses (ca. 28,000 km) and lakes >100 m^2 .**
- **2015: New Buffer Strip Act proposed by new Government - no mandatoryBuffer Strips (18th September 2015)**

Intelligently established Buffer Strips:

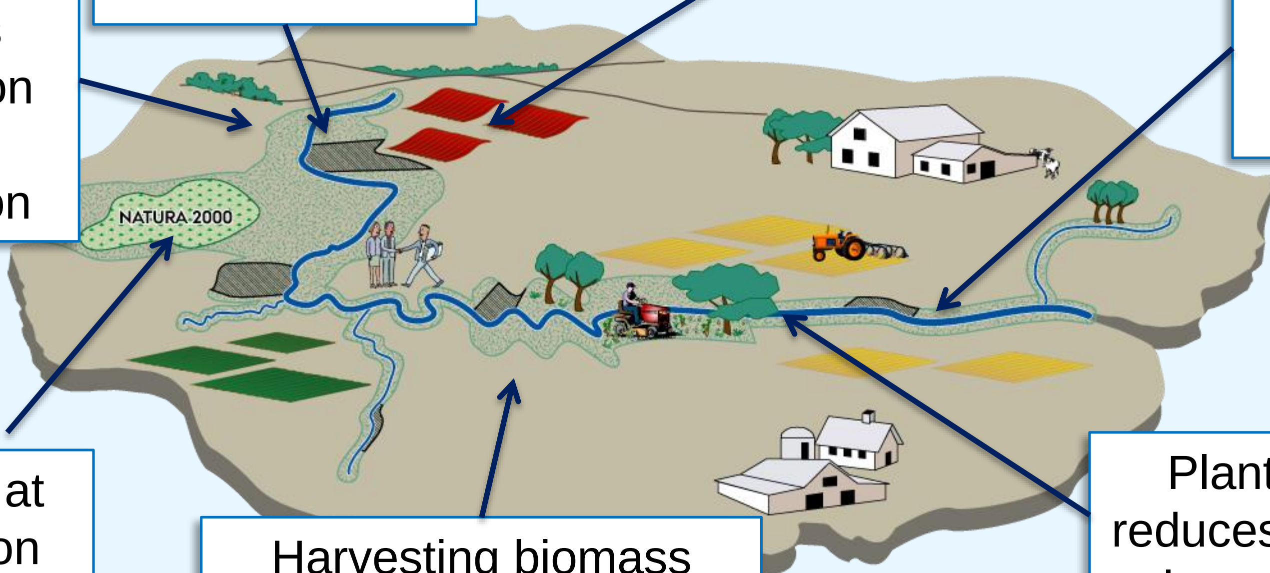
Multiple ecosystem services are provided by BSs and they should be targeted after local conditions and local needs

Reduces pesticide losses

Retains soil and P from runoff

Decreases CO_2 emission by C sequestration

Reduces N-leaching losses

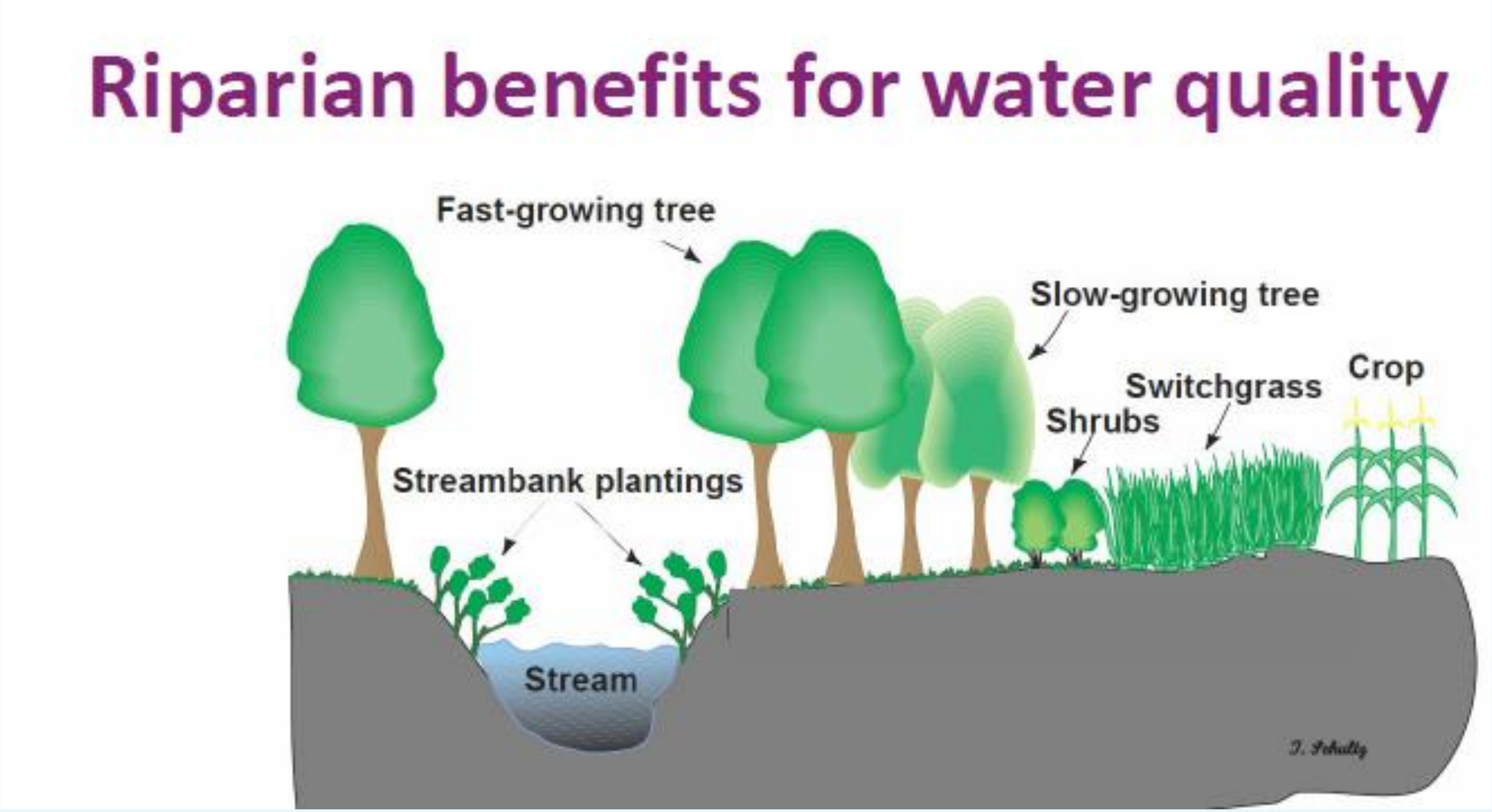


Wider BSs at conservation areas increases biodiversity

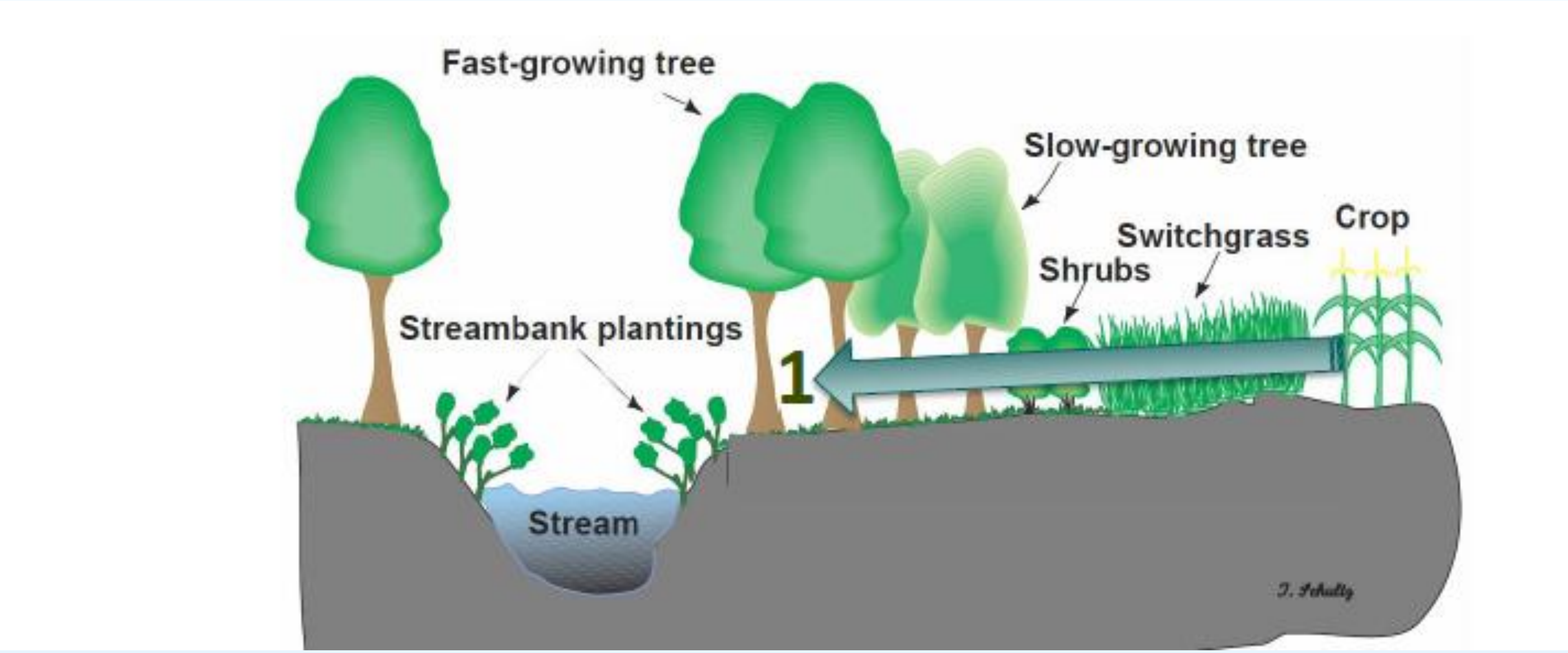
Harvesting biomass removes N & P and increases biodiversity on a longer time scale

Planting of trees reduces bank erosion losses and gives shade and energy to streams

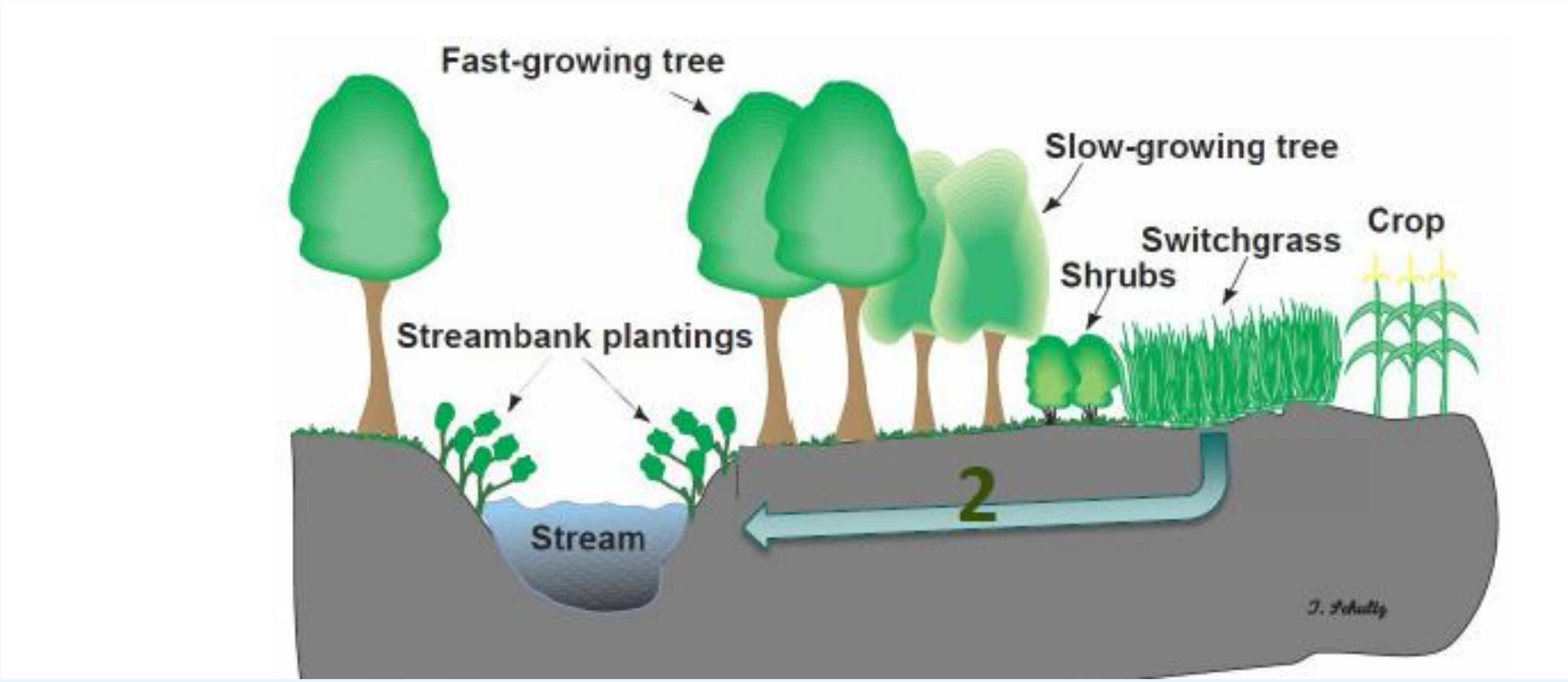
Three aspects to benefiting water quality



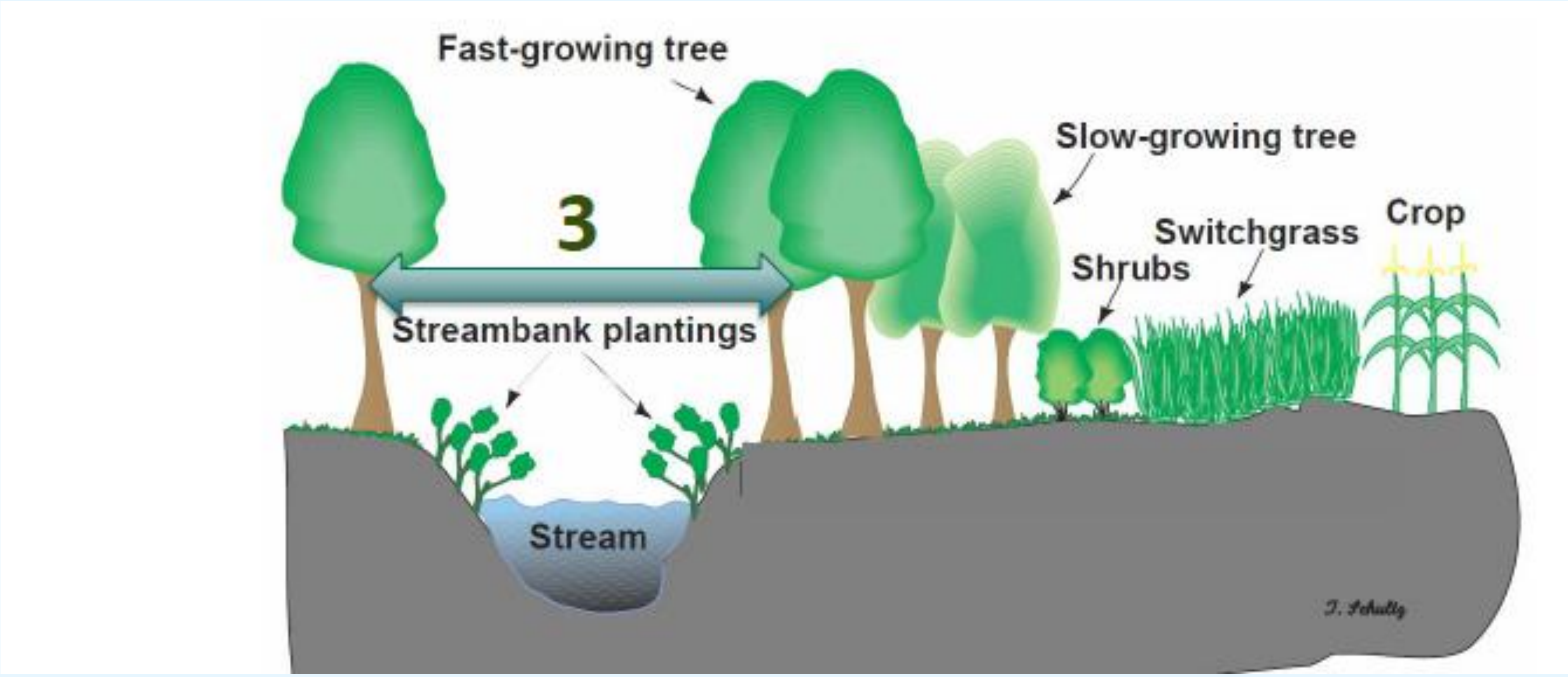
1. Runoff control of sediments and associated substances



2. Within soil nutrient processing



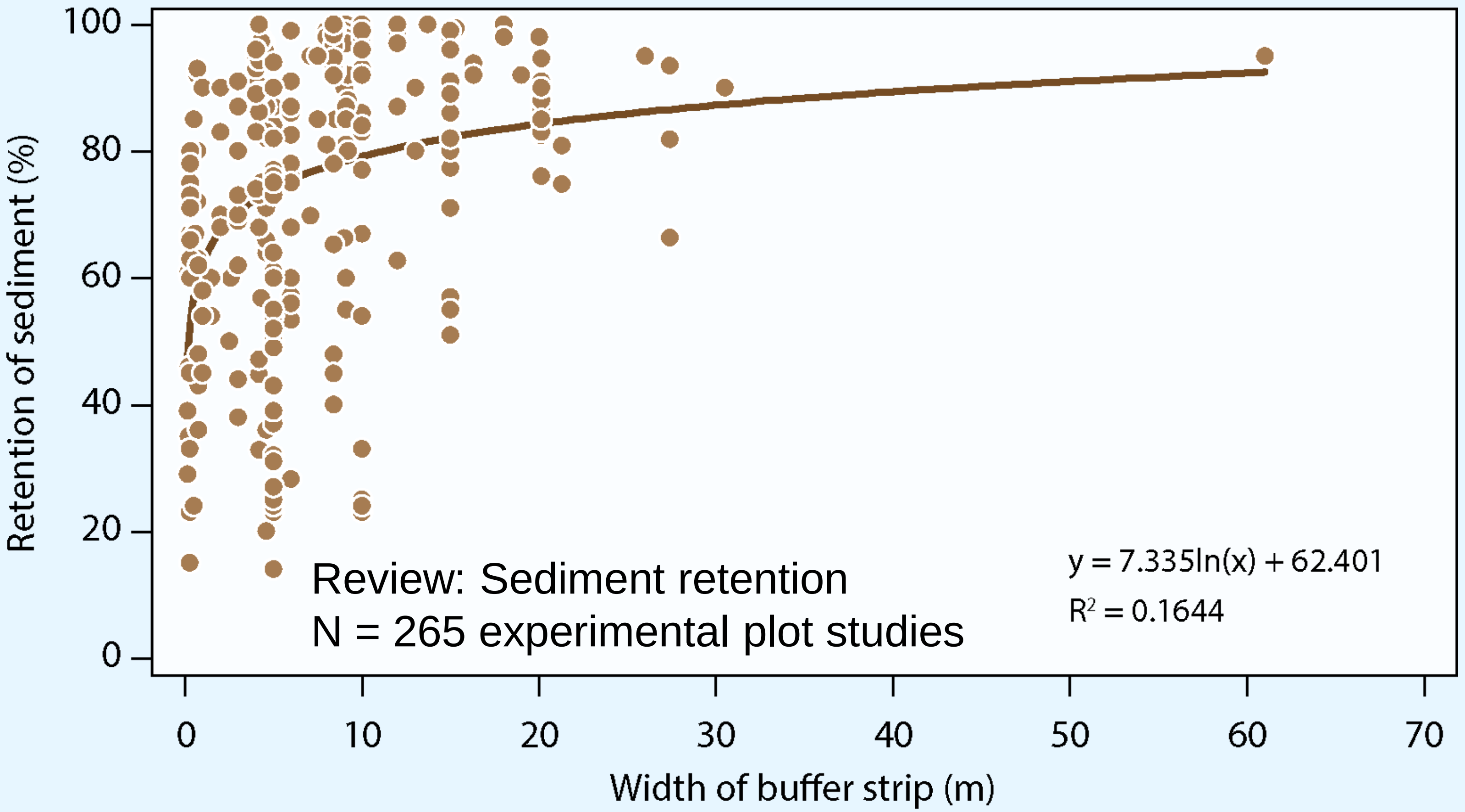
3. Beneficial interactions between terrestrial biodiversity, aquatic ecosystems and nutrient processing



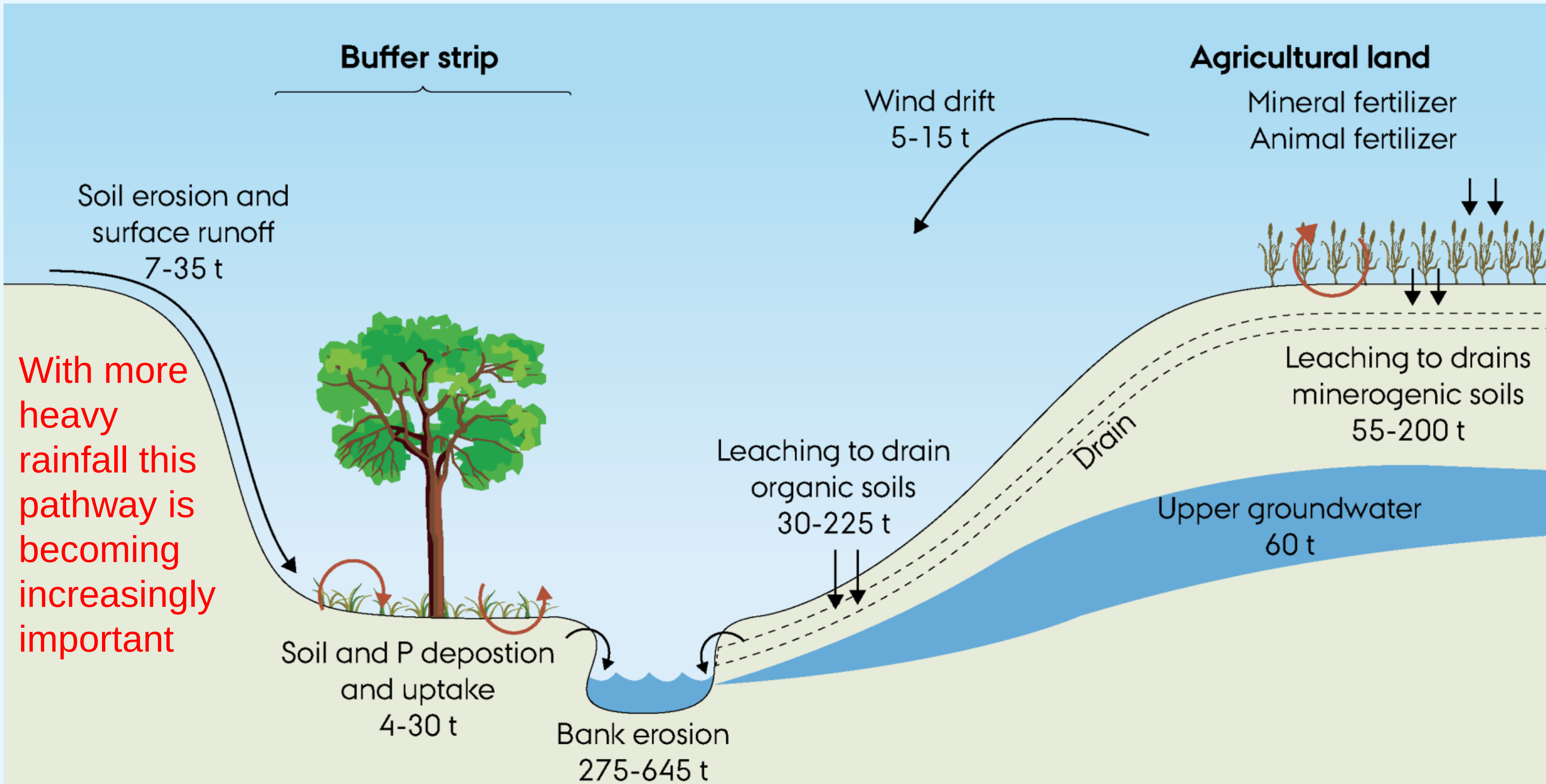
Buffer strips intercept soil material from erosion and surface runoff before it enters surface waters

BUT – efficiency and lifetime can be improved when the width is planned according to local conditions

Buffer strips -
Their efficiency for sediment retention

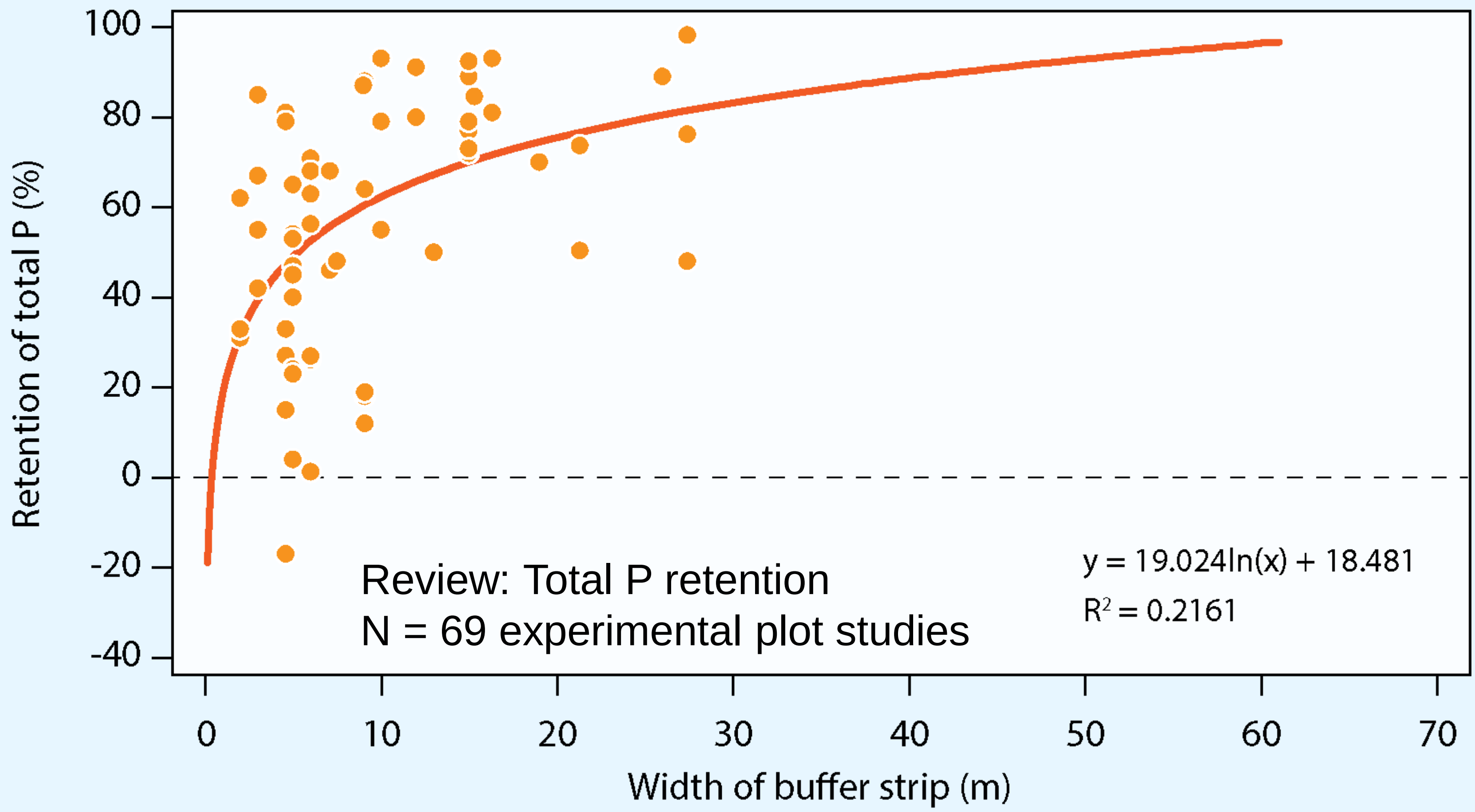


Phosphorus pathways in DK - national estimate !



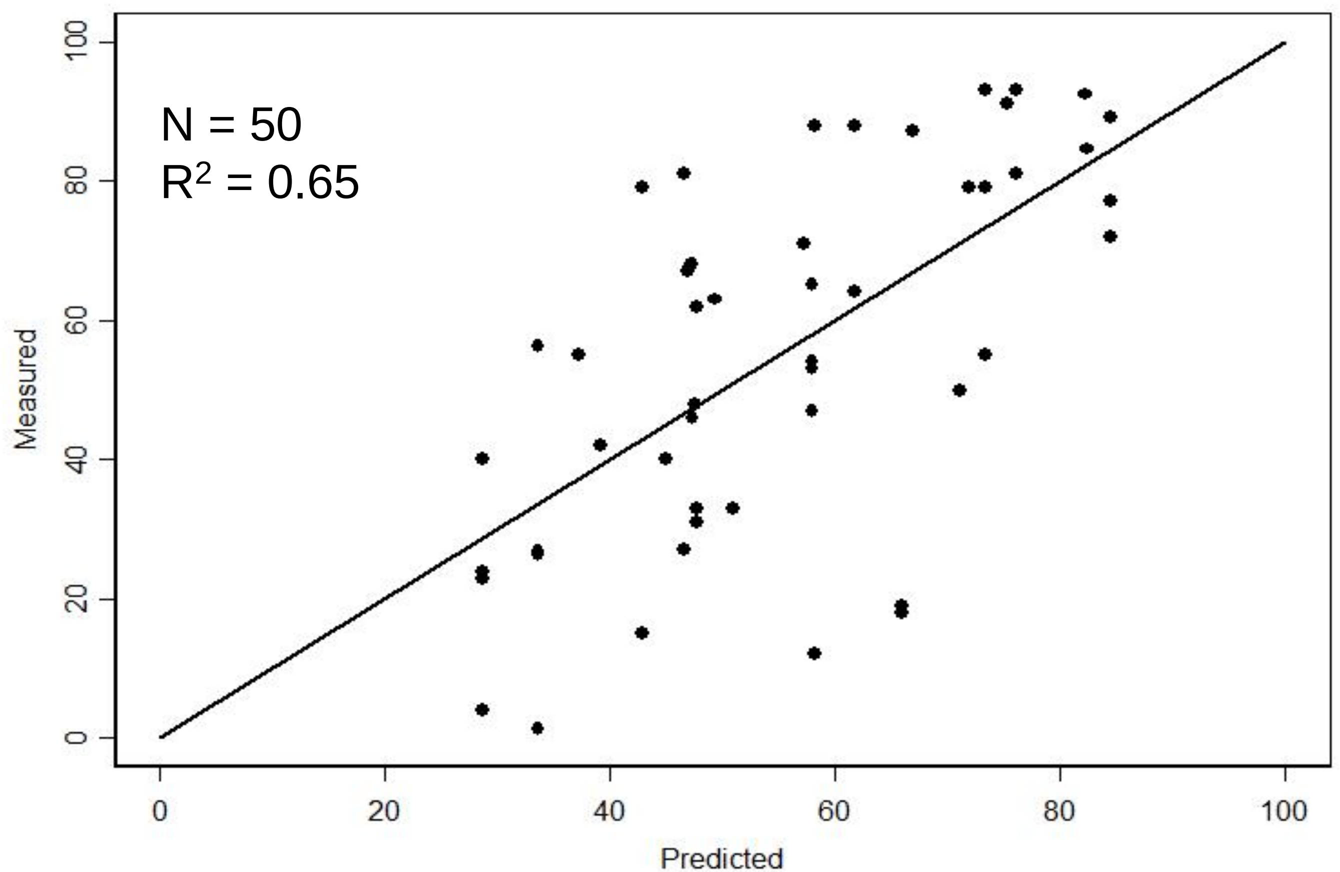
Kronvang og Rubæk. 2005: DJF rapport, Husdyrbrug Nr. 68.

Buffer strips - Their efficiency for total phosphorus retention

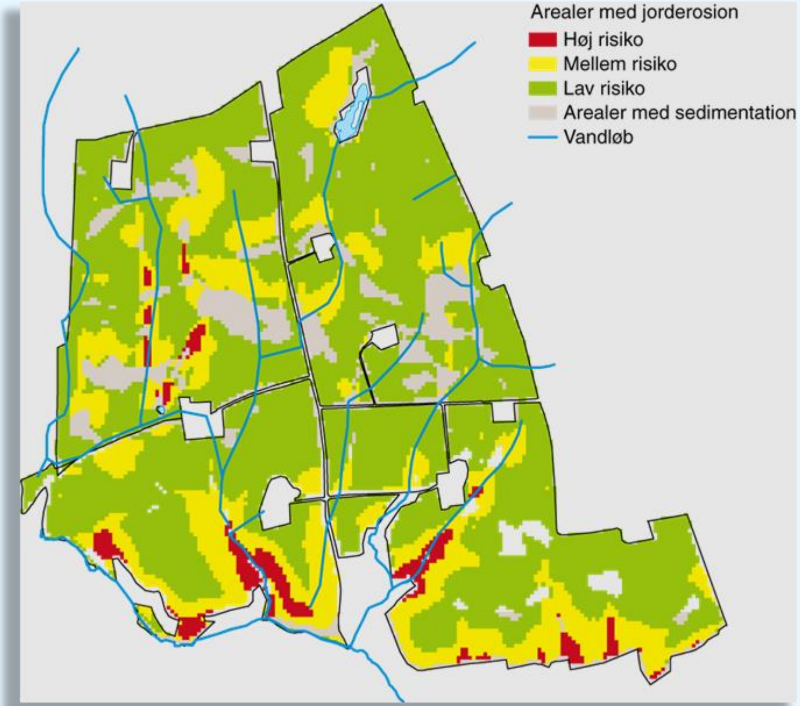


Model of the efficiency of Buffer Strip's for retaining total P from soil erosion and surface runoff

$$F(BS_{width}, BS_{clay}, BS_{slope}) = \frac{1}{1+1.109 \cdot e^{-0.138 \cdot BSw + 0.0297 \cdot BSs + 0.0246 \cdot BSc}}$$



Buffer Strip width should be calculated based on knowledge on erosion risk on adjacent fields – but how wide should they be?

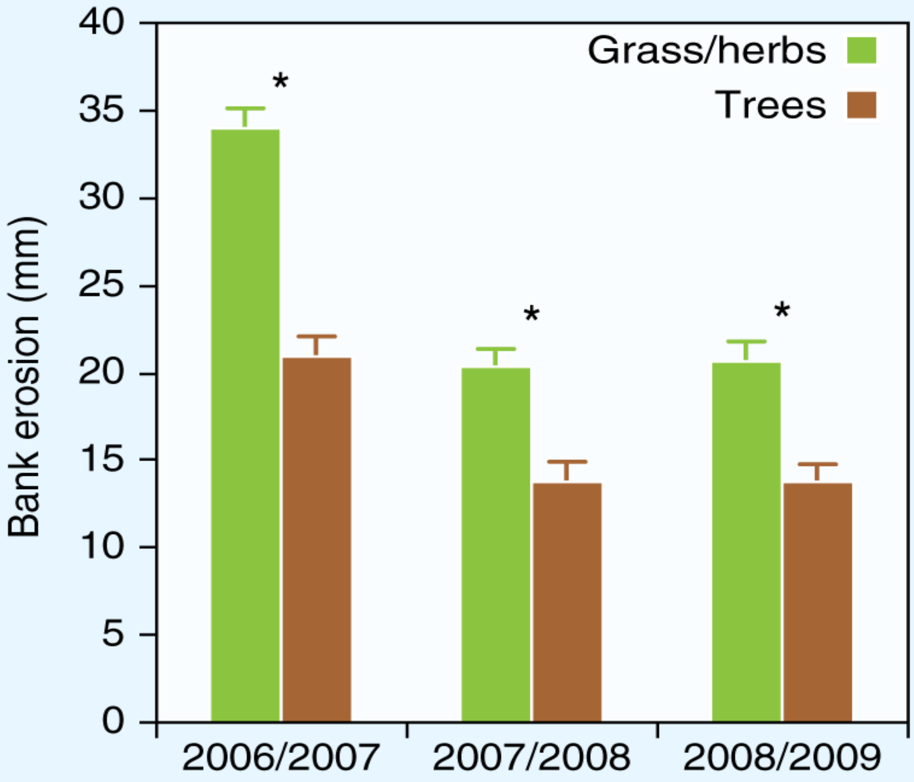


P-risk models can assist in mapping high erosion risk areas on fields for targeted BS implementation

Buffer strip width	Sediment retention	Total P retention
2 m	63%	47%
4 m	70%	54%
10 m	85%	73%
20 m	96%	91%
30 m	99%	98%

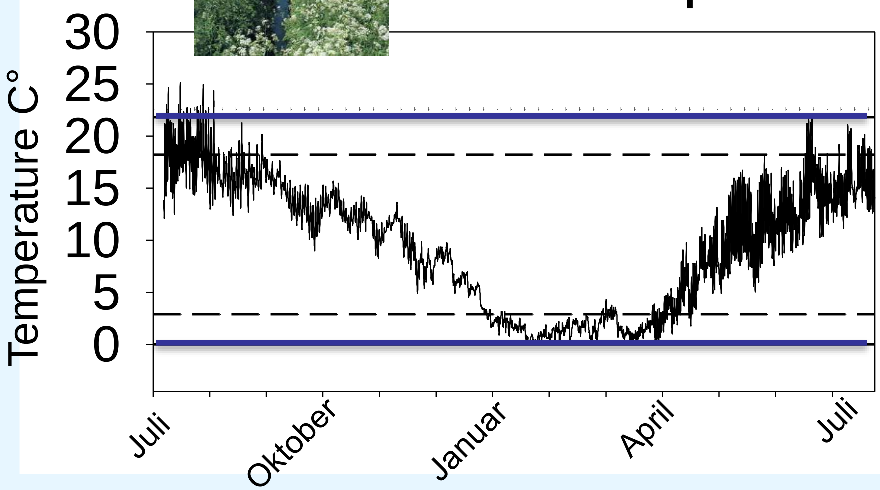
Slope = 2^{o} ; clay = 10%

In situ studies of bank erosion related to vegetation type in buffer strips have shown a significant higher bank erosion and hence particulate P loss in streams having low vegetation (grass and herbs) in the buffer strip as compared to streams having high vegetation (trees) in the buffer strip (Kronvang et al., 2009: JEQ, 41. 304-313).

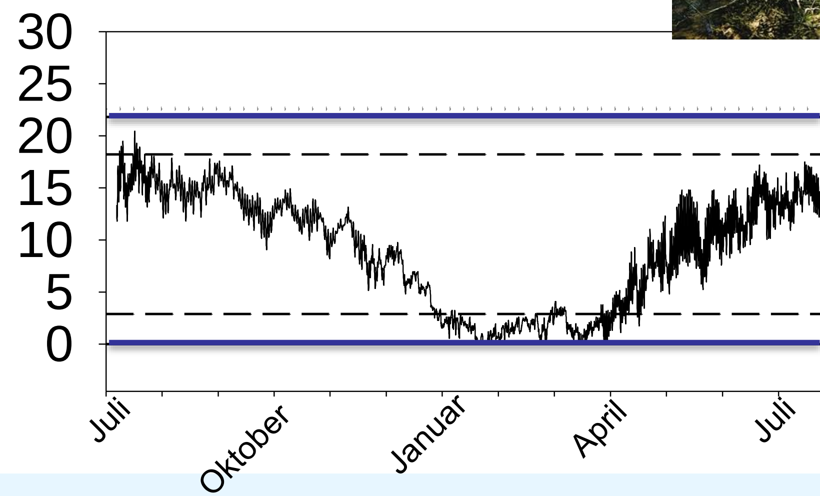


Buffer strips and water temperature – importance for biota in streams

Low vegetation buffer strip



Trees in Buffer strip

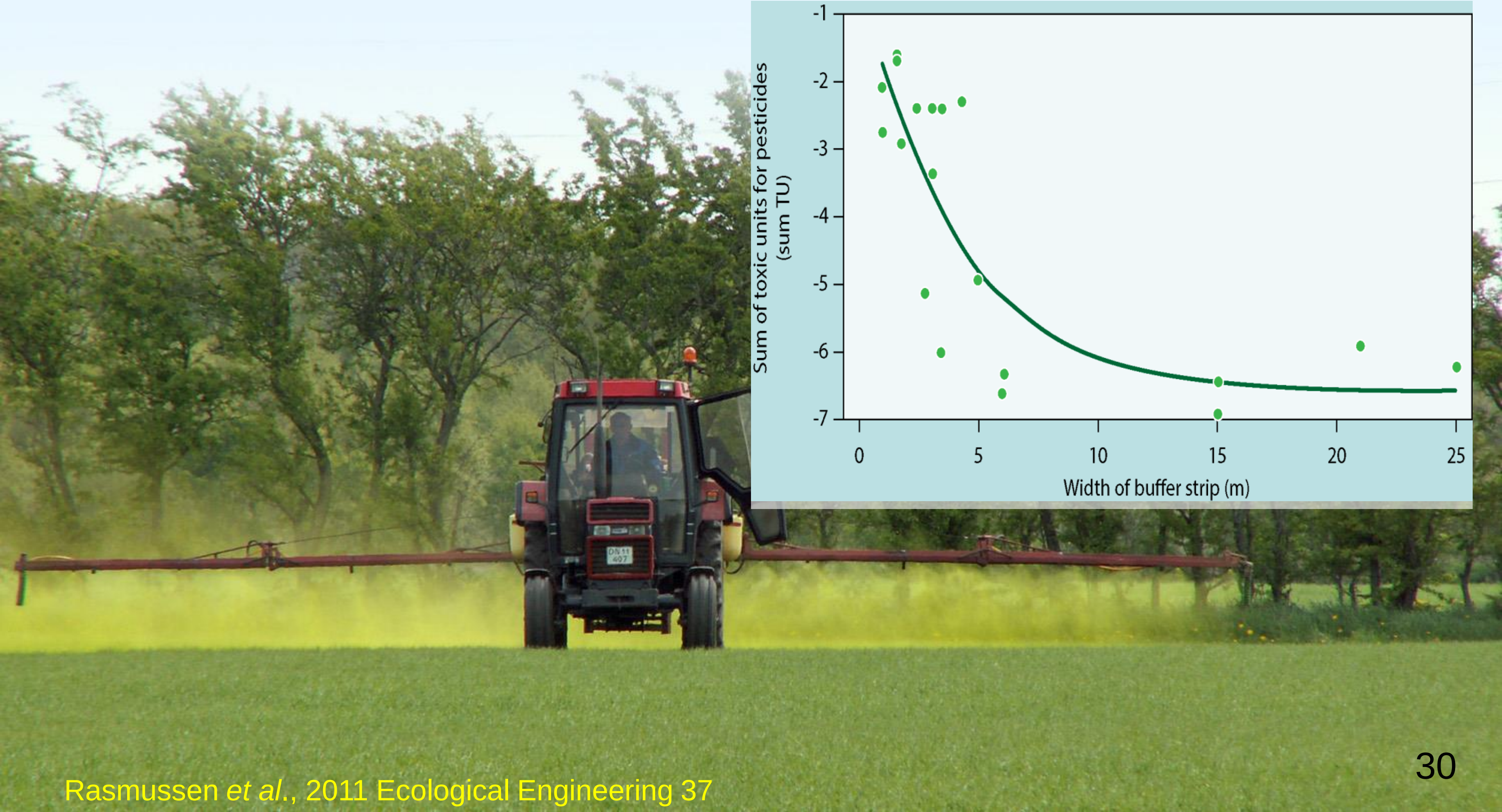


Upper and lower tolerance (LT50) –trout

Upper tolerance threshold for hatching of B.rhodani eeg

Upper and lower threshold for optimum growth of trout ----------

BSs also provide ecosystem services for reducing pesticide loss and resulting toxicity in streams



Rasmussen *et al.*, 2011 Ecological Engineering 37

What kind of nature do we have in existing buffer strips in DK?

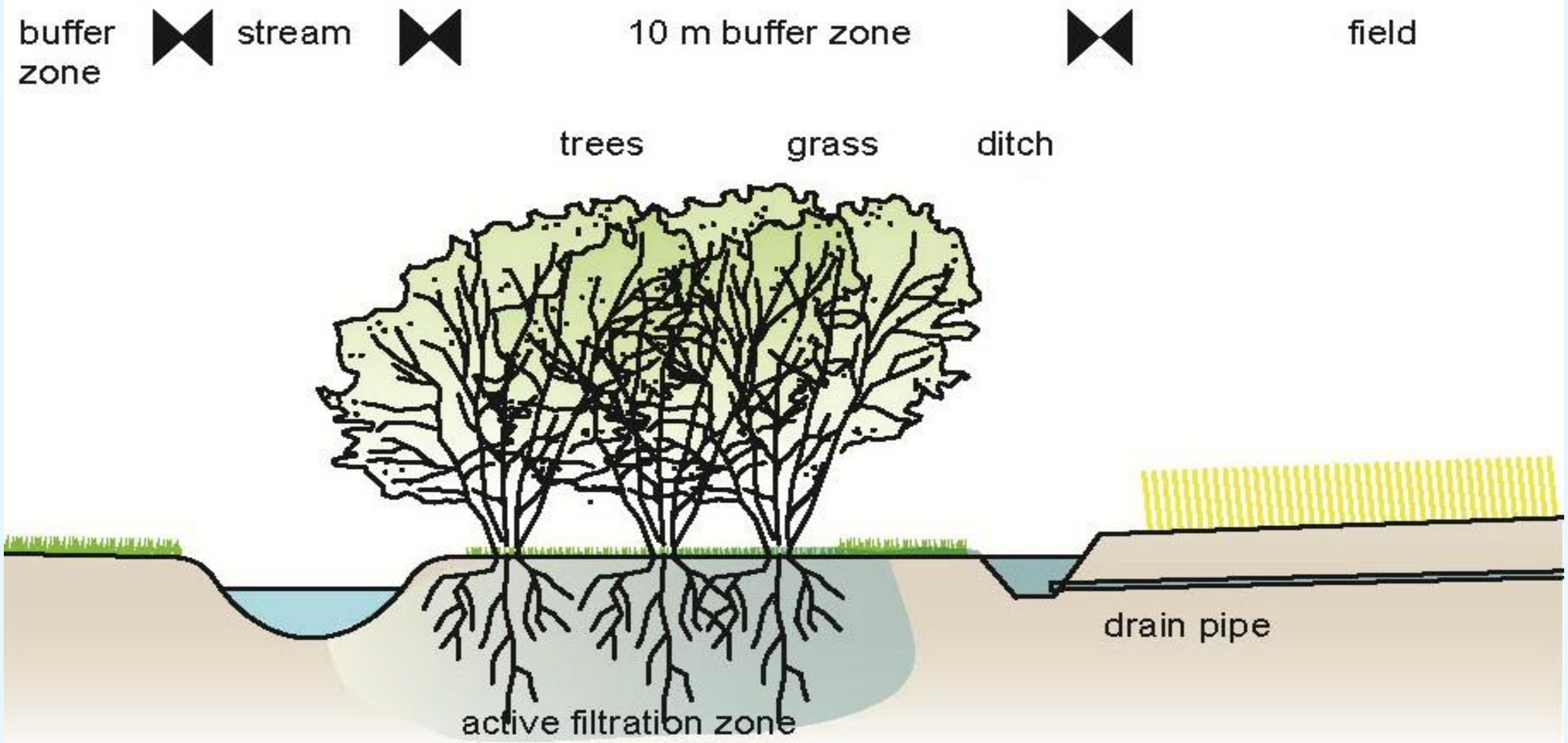
Nature type	Frequency (%)	Vulnerability
Cultured meadow	17	*
Eutrophicated tall perennial	16	*
Wet meadow	12	**
Wet fallow	11	*
Dry fallow	10	*
Herbal Fringe[1] (6430)	9	Unknown
Wet meadow	9	***
Alkaline fens[1] (7230)	8	*****
Marshy fring	3	*
Intermittently wet meadow[1] (6410)	3	****
River mud-flats[1] (3270)	<1	Unknown
Wet heat[1] (4010)	<1	****
Quaking[1] (7140)	<1	****
Mariscus bog[1] (7210)	<1	****
Fens	<1	****

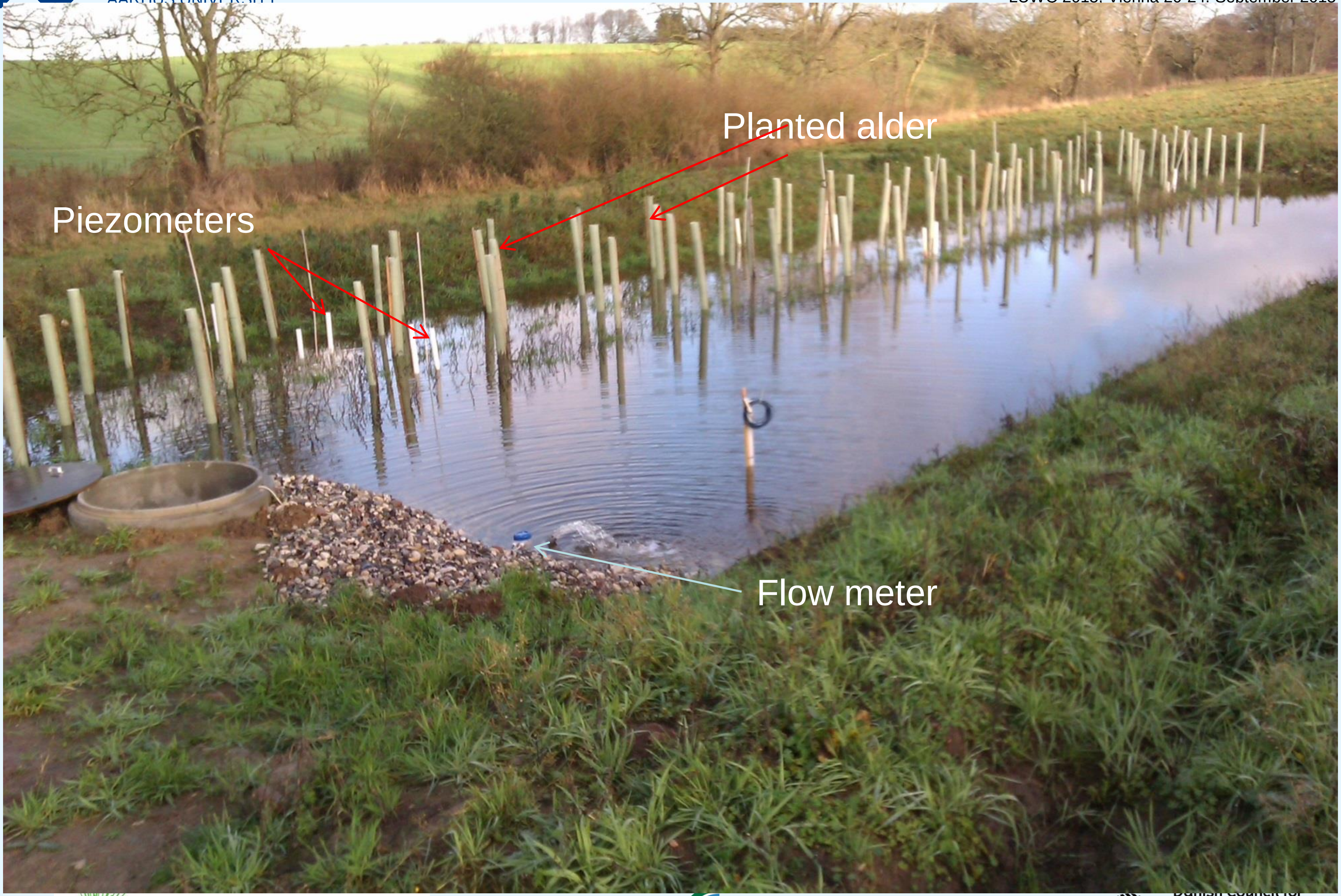
(N=454 areas, 21,000 10 x10 m plots)

New research project ‘BufferTech’ investigate effects of vegetation management for removal of nutrients and biodiversity

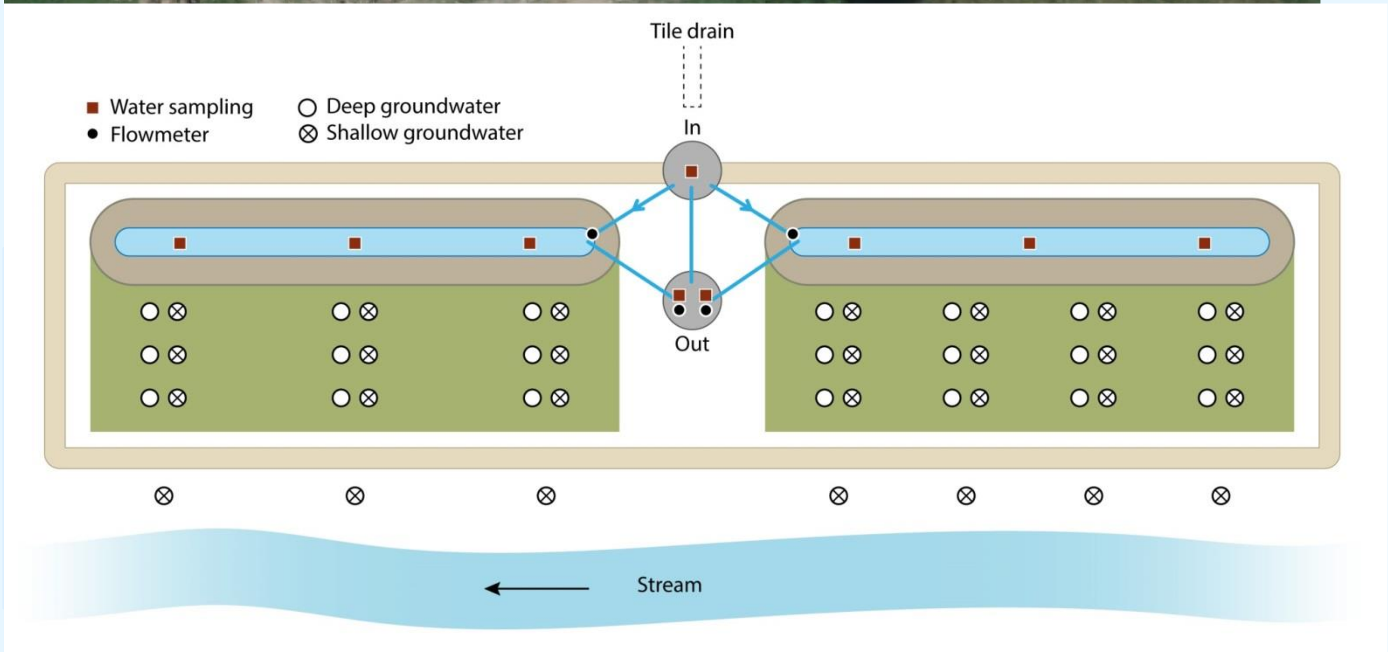
Intelligent Buffer Zone (IBZ)

By introducing Intelligent Buffer Zones (IBZ) the drainage will no longer have a direct passage to the aquatic environment. By cutting the drainpipes and introduce a ditch in connection with an infiltration zone the drainage water can infiltrated a zone made of several components of vegetation. Native tree species such as alder could transform even heavy clay soil to an active infiltration zone.

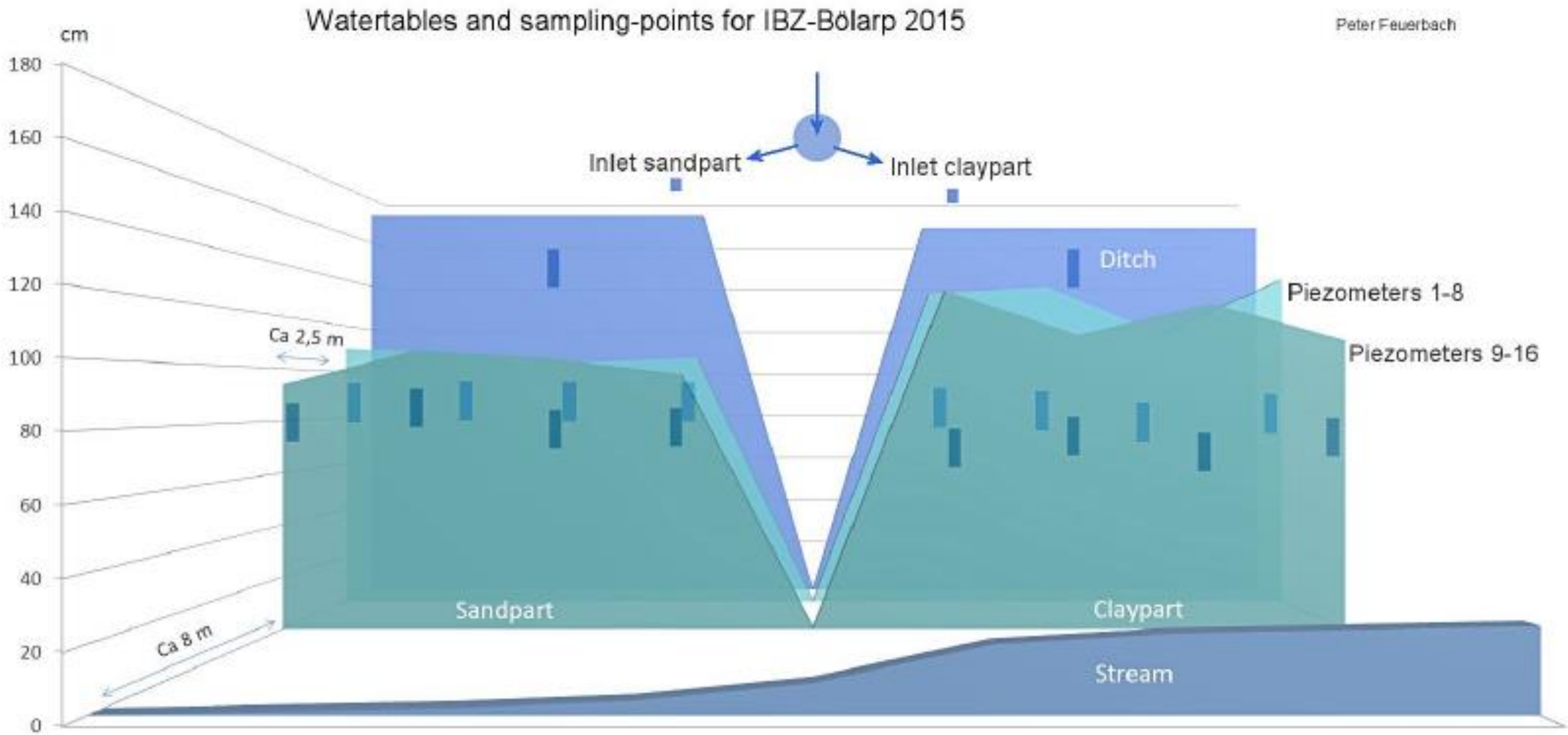



Planted alder
Piezometers
Flow meter


IBZ at Fillerup, Constructed July 2014

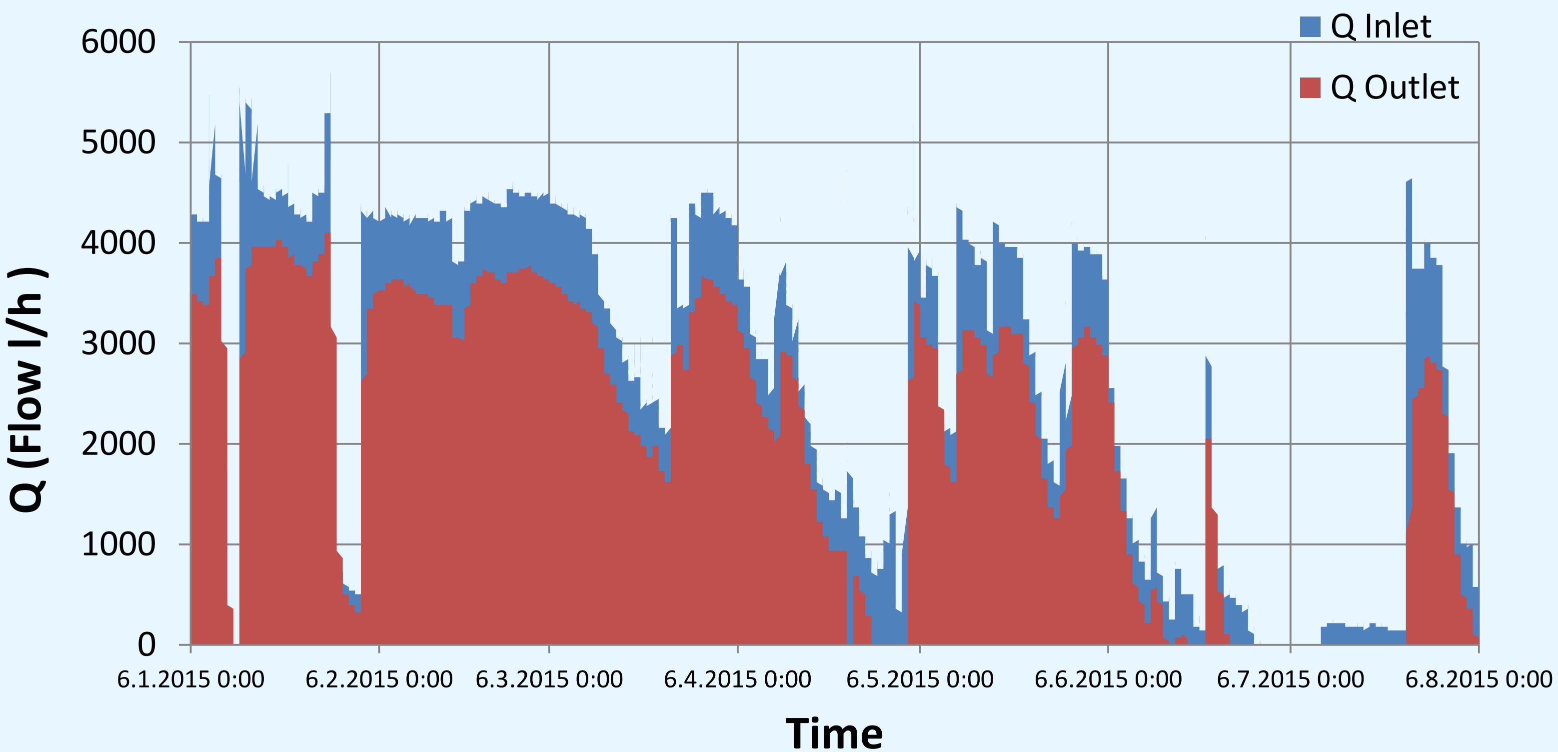

Tile drain
Water sampling
Flowmeter
Deep groundwater
Shallow groundwater
In
Out
Stream

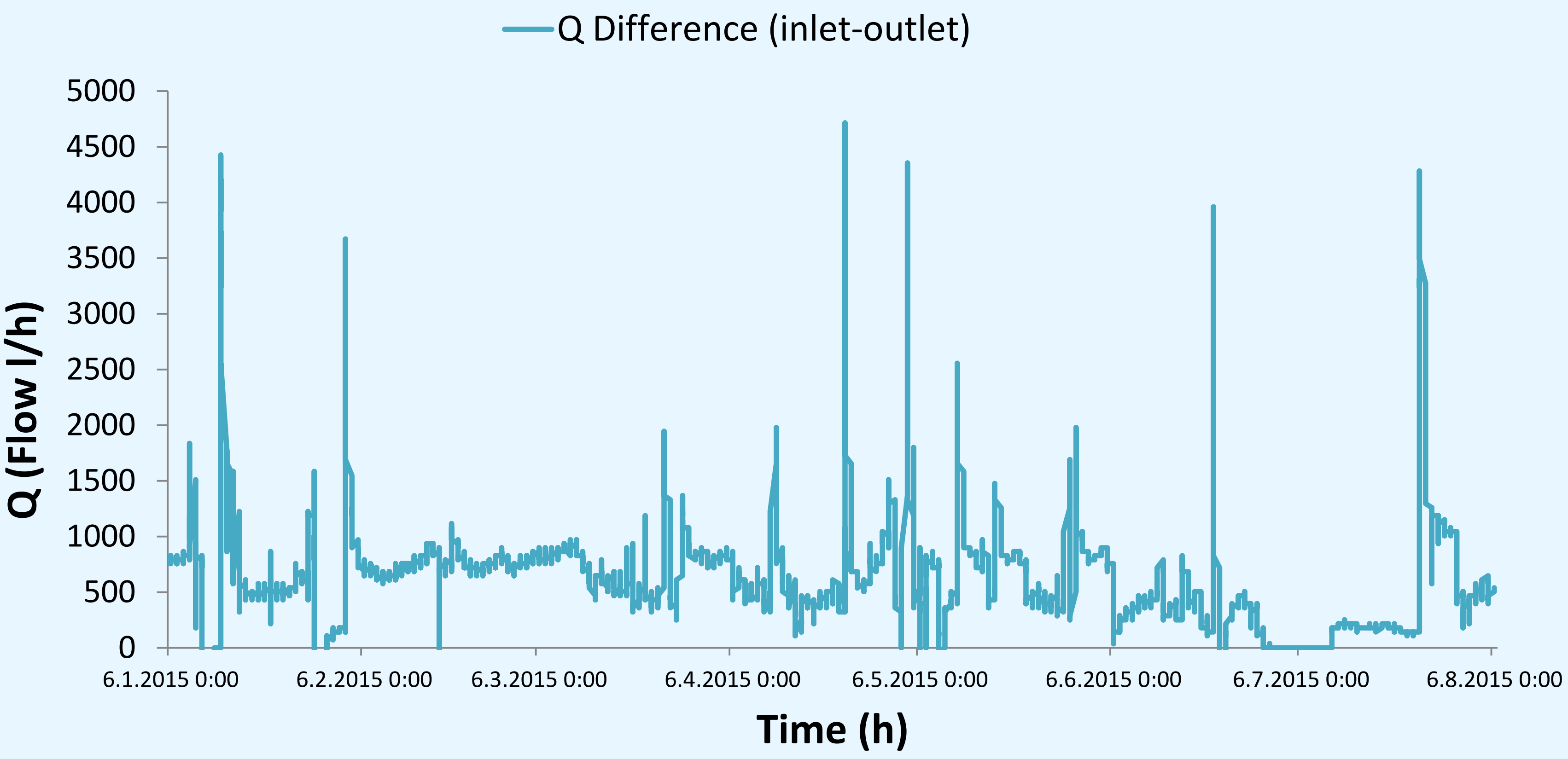

30 m
BalticSea2020
IBZ-Bölarp trials 2015
Hushållnings
sällskapet


Watertables and sampling-points for IBZ-Bölarp 2015
Peter Feuerbach
cm
180
160
140
120
100
80
60
40
20
0
Inlet sandpart
Inlet claypart
Ditch
Piezometers 1-8
Piezometers 9-16
Ca 2,5 m
Ca 8 m
Sandpart
Claypart
Stream

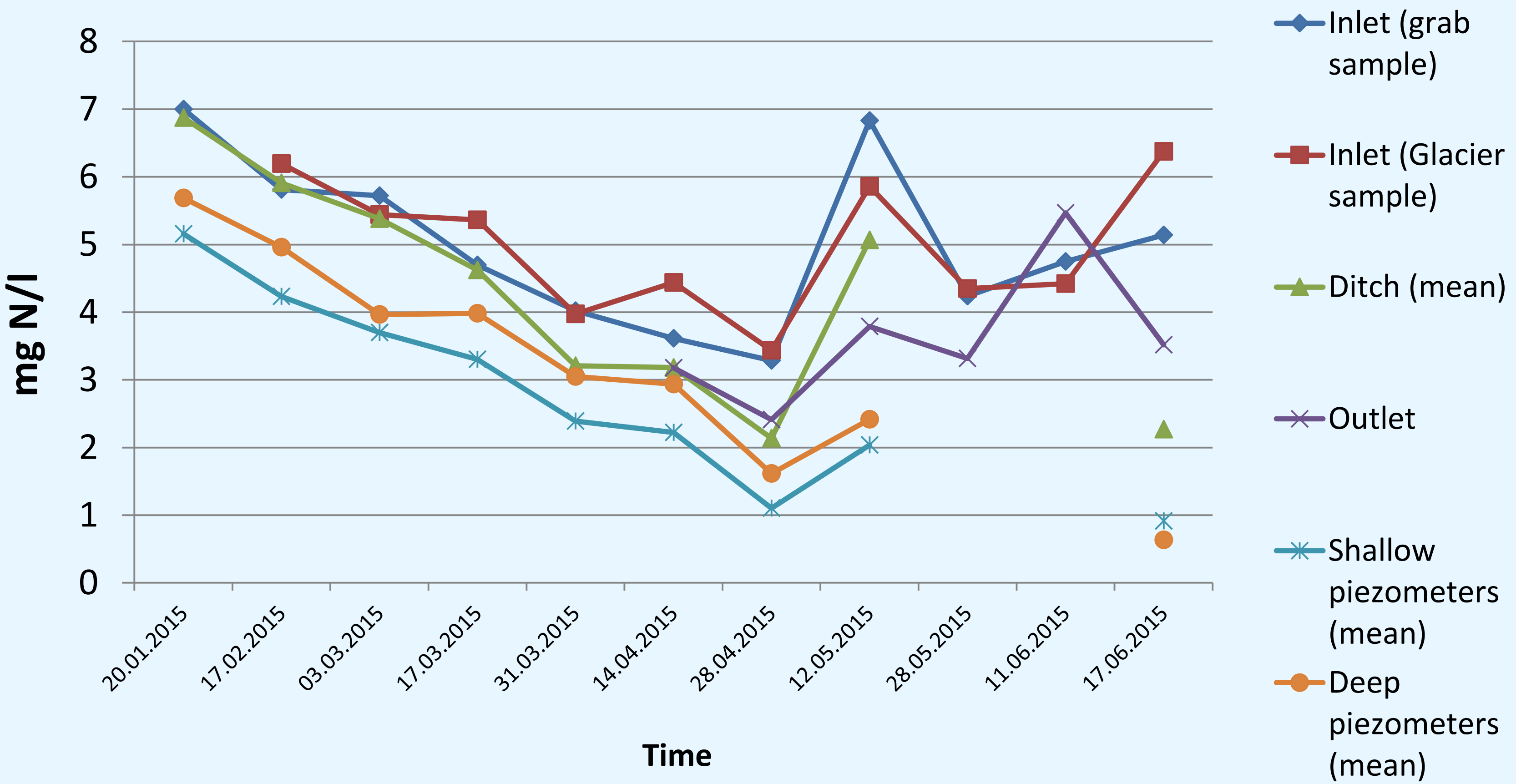
Water Flow

Water flow is measured every minute automatically with flow meters in inlet and outlet from each reservoir




Q Difference (inlet-outlet)
Q (Flow l/h)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
6.1.2015 0:00
6.2.2015 0:00
6.3.2015 0:00
6.4.2015 0:00
6.5.2015 0:00
6.6.2015 0:00
6.7.2015 0:00
6.8.2015 0:00
Time (h)

Measured mean nitrate-N concentrations in inflow, ditch, outlet and seepage water



Efficiency of reservoir part of IBZ for nitrate removal

Time	Inlet flow (kg N)	Removal (kg N)	Removal (%)
14.04.2015 - 28.04.2015	2.3	0.88	38
28.04.2015 - 12-05.2015	4.4	2.46	56
12.05.2015 - 28.05.2015	5.8	1.31	23
28.05.2015 - 11.06.2015	4.2	0.52	12
11.06.2015 - 17.06.2015	0.7	0.38	54
Total	17.4	5.55	32

What happens with nitrate-N during Infiltration of water through the soil ?

Time	% Removal
20.01.2015-17.02.2015	16
17.02.2015-03.03.2015	21
03.03.2015-17.03.2015	20
17.03.2015-31.03.2015	9
31.03.2015-14.04.2015	6
14.04.2015-28.04.2015	16
28.04.2015-12.05.2015	38
12.05.2015-28.05.2015	52
28.05.2015-11.06.2015	62
11.06.2015-17.06.2015	72
Total	30

Conclusions

- Increase the benefits per unit space via effectively spatial targeting of use of riparian zones enhancing natural processes using ecotechnologies – buffer strips, restored wetlands, comstructed wetlands, IBZ's, etc..

- Buffer strips serve multiple ecosystem services but they need to be implemented based on local knowledge and needs.

- They work for both sediment, nitrogen, phosphorus, pesticides and biodiversity – but local management will often be necessary to fully optimize their ecosystem services such as e.g. construction of IBZ's for enhancing

BUFFERtech

Thank you for your attention!

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