

# Addressing Phosphorus Reduction in Interconnected Danish Lakes: A Spatial Environmental-Economic Approach

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Raphael Filippelli – IFRO/KU

Berit Hasler – IFRO/KU

Hans Estrup Andersen – EcoScience/AU

Gregor Levin – Env. Science/AU

Goswin Heckrath – Agroecology/AU

KØBENHAVNS UNIVERSITET

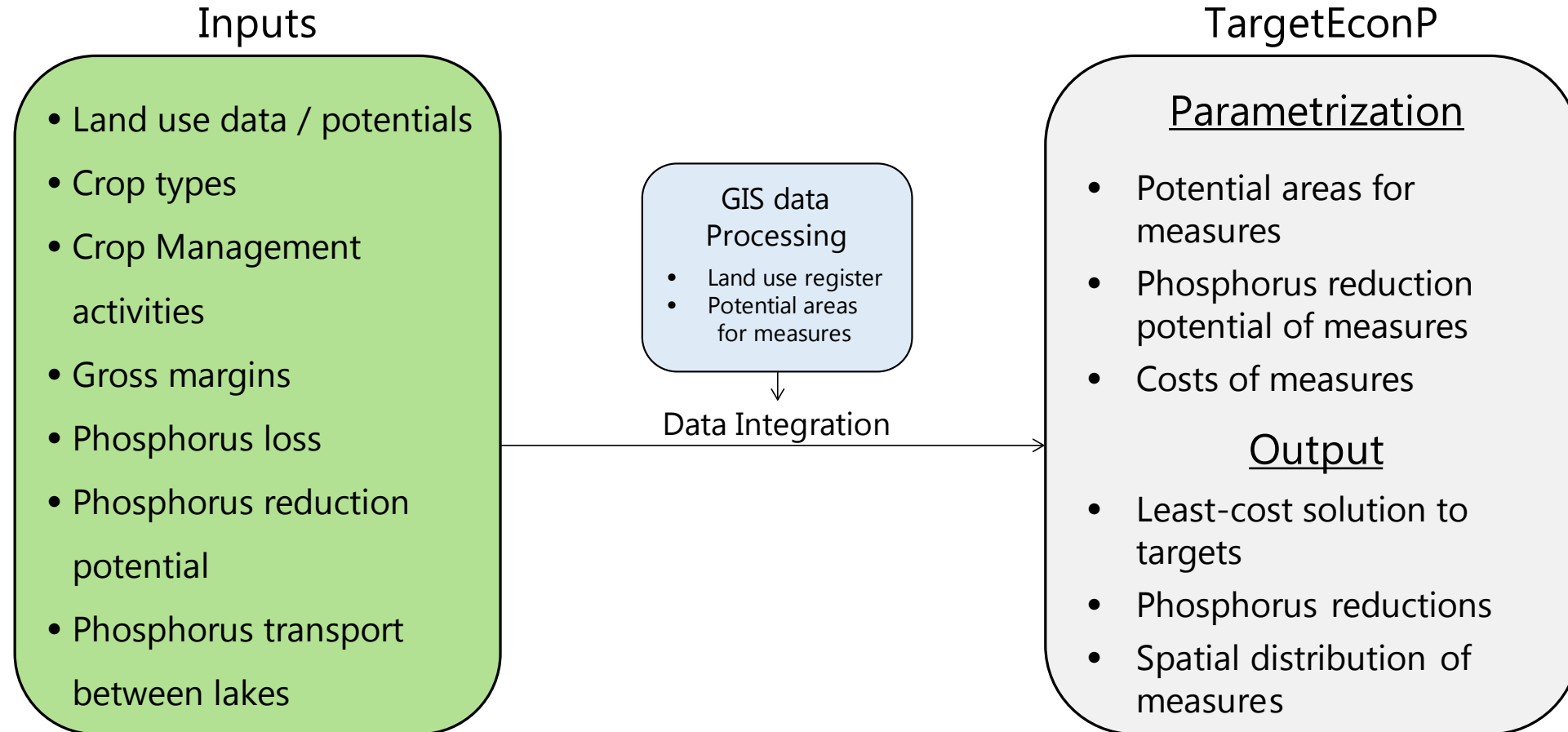


# TargetEcon Model Versions (environmental-economic models)

- TargetEconN – cost-effective solutions to policy targets on N loads to coastal areas.
- **TargetEconP** – cost-effective solutions to policy targets on Phosphorus loads to lakes.
- TargetEconBES – Multiple targets - N, P, climate, biodiversity, and recreation.



# Modelling Framework



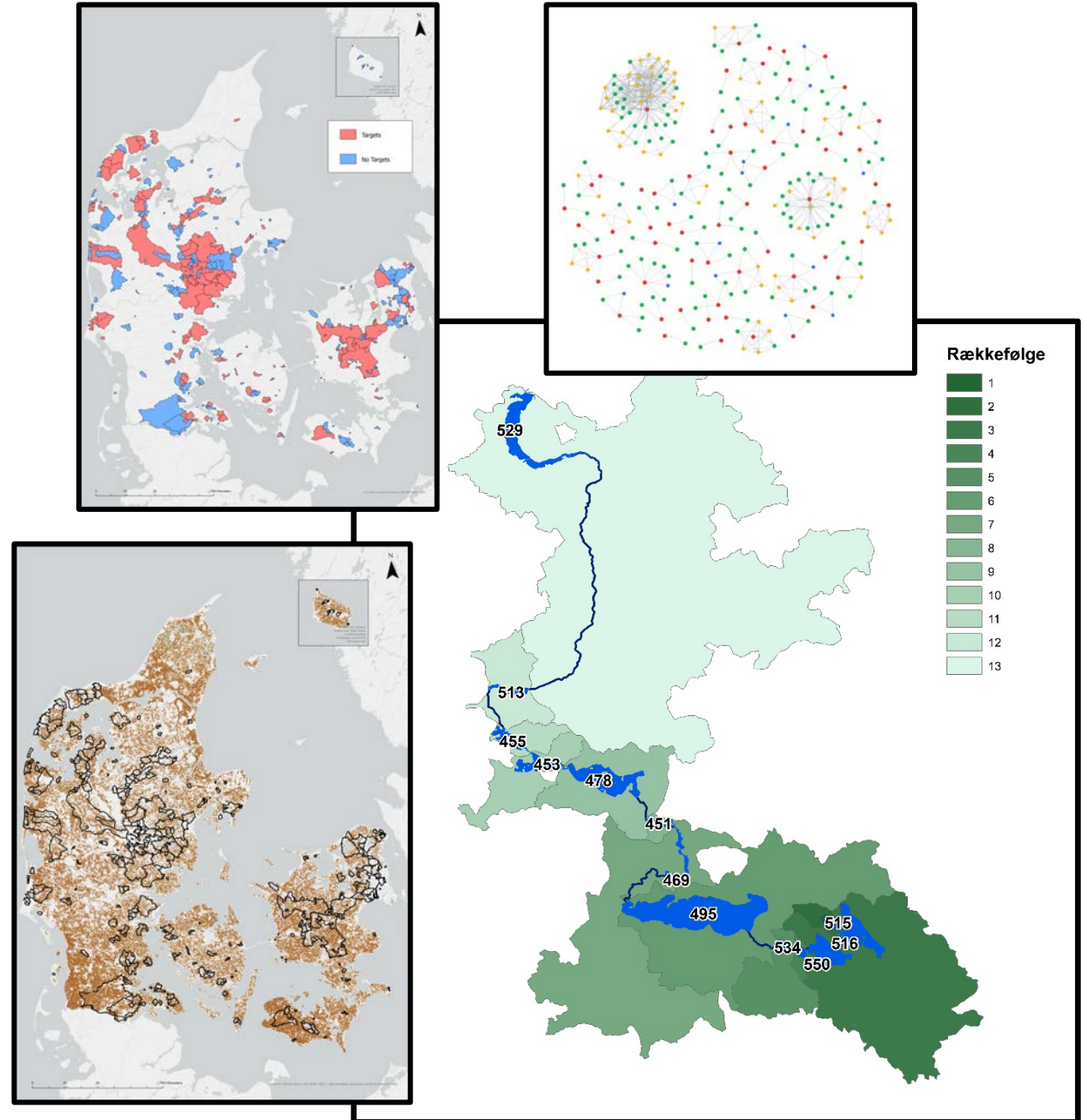
# Phosphorus modelling

- Minimize costs in all lake catchments
- Variable phosphorus transport
- Multiple phosphorus loss pathways: (Hans Estrup Andersen & Goswin Heckrath)
  - Erosion (incl. brink erosion)
  - Macropore
  - Matrix

$$PL_i = PL_{local_i} + \sum (PL_j \times Peff_{j,i})$$

where:

- $PL_i$  - total phosphorus load at lake  $i$ ,
- $PL_{local_i}$  - local phosphorus inputs to lake  $i$ ,
- $PL_j$  - phosphorus load from upstream lake  $j$ ,
- $Peff_{j,i}$  - transport efficiency coefficient between lakes  $j$  and  $i$ .



# Measures

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**Land retirement of Agricultural Land**

**Targeted Buffer Zones**

**Integrated Buffer Zones (IBZ)**

**Afforestation**

**Wastewater Treatment**

**Constructed wetlands**

**Phosphorus Wetlands**

**Negative Phosphorus Balance**

**Permanent Plant Cover**

**Reduced/Optimized Tillage**

**Rainwater Overflow Management**

**Streambank Stabilization with Trees**

**Sand Traps**

**Ochre Plants**

**Remaindering of watercourses**

**Streambed Raising**

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# Manuscript: Spatially Optimized Phosphorus Reduction Strategies: A Lake-Chain Approach for Cost-Effective Management in Danish Lakes

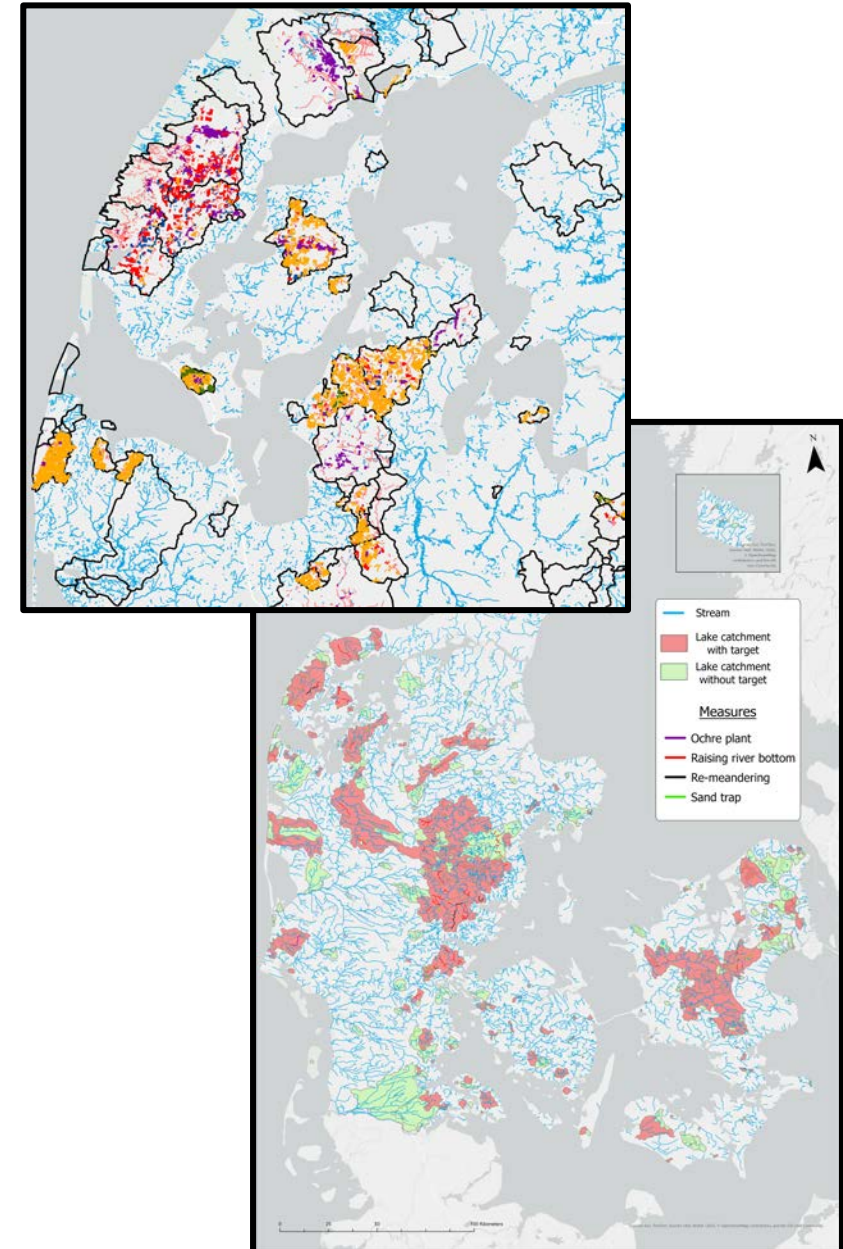
| Scenario                             | Key Assumption/Change   | Baseline Comparison                          | Purpose/Rationale   |
|--------------------------------------|---|--|---|
| <b>Baseline</b>                      | Cost-optimized phosphorus reduction measures; phosphorus wetlands reduce 15 kg P/ha | Reference scenario                           | Reference scenario for evaluating other scenario impacts  |
| <b>Nature-based Solutions</b>        | Restricts available measures to nature-based solutions                              | Baseline includes all measures               | Assesses whether NBS alone can meet WFD targets cost-effectively and identifies potential implementation gaps |
| <b>Phosphorus Wetland Efficiency</b> | Reduces P removal efficiency to <b>5 kg P/ha</b>                                    | Baseline assumes <b>15 kg P/ha</b> reduction | Tests impact of lower-than-expected phosphorus reduction  |
| <b>Lake Transport Coefficient</b>    | Transport efficiency varies $\pm$ <b>30%</b> from baseline value                    | Baseline uses default transport coefficients | Evaluates impacts of transport efficiency uncertainty   |

# Results

| Scenario     | Cost/year (1000 EUR) | EUR/KgP     | Area Used (ha)   | Gap to Target (KgP) |
|--------------|----------------------|-------------|------------------|---------------------|
| Baseline     | 40,164               | 408         | 227,424          | 18,693              |
| NBS Scenario | 45,775 (14.0%)       | 519 (27.2%) | 143,658 (-36.8%) | 28,972 (55.0%)      |

Total P target: 117,089 KgP

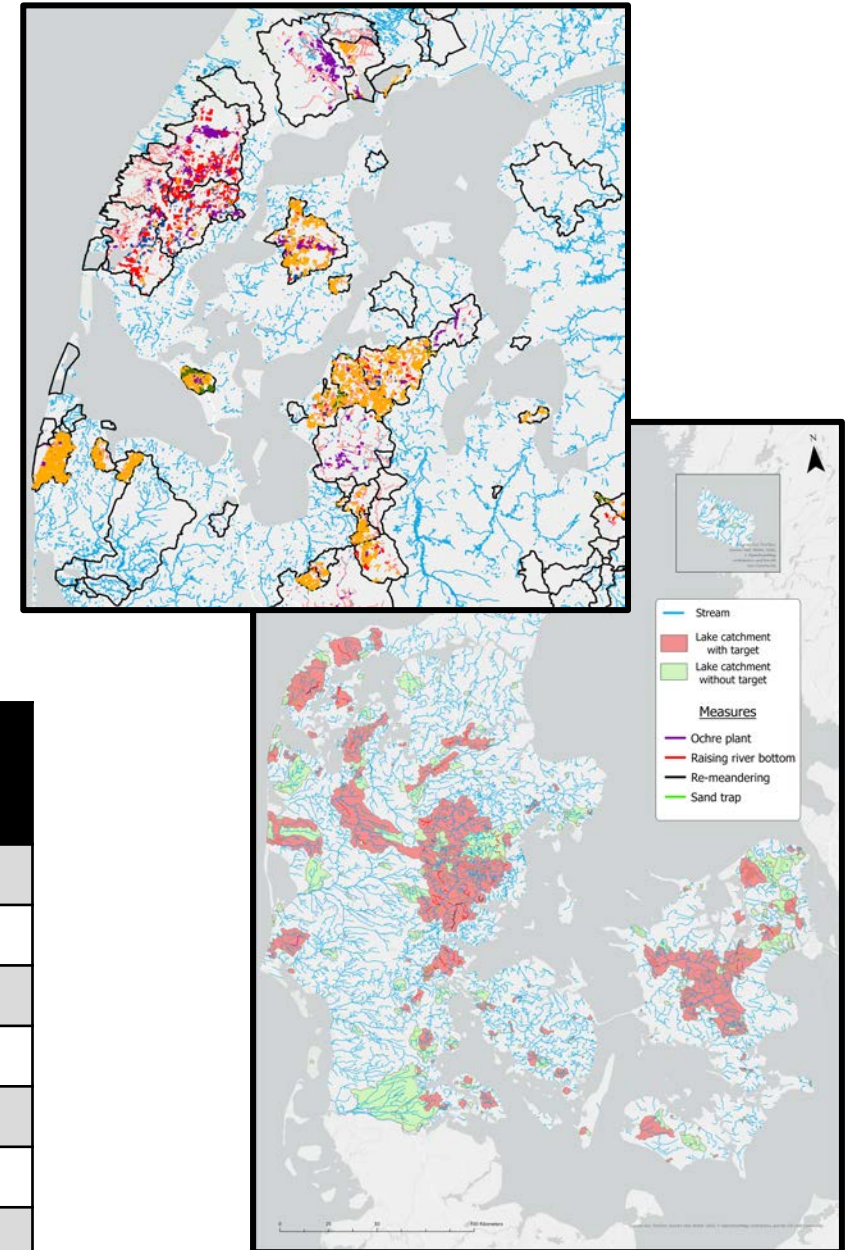
| Scenario                            | Cost/year (1000 EUR) | EUR/KgP      | Area Used (ha)   | Gap to Target (KgP) |
|-------------------------------------|----------------------|--------------|------------------|---------------------|
| Baseline                            | 40,164               | 408          | 227,424          | 18,693              |
| P Wetlands 5 (5 KgP/ha P reduction) | 46,769 (16.45%)      | 504 (23.42%) | 260,073 (14.36%) | 24,253 (29.74%)     |



# Results

| Scenarios     | Costs (1000 DKK) | Difference in Costs | EUR/KgP | % Change |
|---------------|------------------|---------------------|---------|----------|
| Peff -30%     | 47,844           | 19.1%               | 516     | 26.4%    |
| Peff -20%     | 46,832           | 16.6%               | 494     | 20.9%    |
| Peff -10%     | 42,767           | 6.5%                | 442     | 8.4%     |
| Peff original | 40,164           | -                   | 408     | -        |
| Peff +10%     | 35,118           | -12.6%              | 353     | -13.6%   |
| Peff +20%     | 33,943           | -15.5%              | 338     | -17.3%   |
| Peff +30%     | 33,580           | -16.4%              | 332     | -18.6%   |

| Scenarios     | Pred. before transp. (KgP) | Pred. after transp. (KgP) | After - Before | % Change | Gap to target (KgP) | % Change |
|---------------|----------------------------|---------------------------|----------------|----------|---------------------|----------|
| Peff -30%     | 73,385                     | 92,748                    | 19,363         | -35.0%   | 24,340              | 30%      |
| Peff -20%     | 71,728                     | 94,875                    | 23,146         | -22.3%   | 22,214              | 19%      |
| Peff -10%     | 70,086                     | 96,683                    | 26,597         | -10.7%   | 20,406              | 9%       |
| Peff original | 68,614                     | 98,396                    | 29,782         | -        | 18,693              | -        |
| Peff +10%     | 67,047                     | 99,624                    | 32,576         | 9.4%     | 17,465              | -7%      |
| Peff +20%     | 65,531                     | 100,533                   | 35,002         | 17.5%    | 16,556              | -11%     |
| Peff +30%     | 64,577                     | 101,049                   | 36,472         | 22.5%    | 16,040              | -14%     |



# THANK YOU!!!



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