Modelling the impact of emission reduction measures with SWAT: a tool to set up river basin restoration plans

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Towards river basin management plans (RBMP)

- RBMP is essential to reach targets of EU Water Framework Directive (WFD)
- ‘Good’ water status to be reached by 2015
  - Set of pollution abatement measures
  - Objectives to be reached at least cost
  - Motivate expected impact

- Need for cost and impact assessment of emission abatement

Research objectives

- To assess impact of emission abatement on water quality
- To link environmental cost model to SWAT
- To assess relationship between water quality target, potential measures and cost
- To propose a methodology which is easy-to-use and which generates results rapidly

- Focus on **nitrogen** emissions

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Methodology

SWAT

Stepwise emission reduction for nitrogen (point & diffuse)

Impact of emission reduction on in-stream concentration

Required emission reduction to reach target

Environmental cost model

Tool to support a least-cost river basin management

Database of measures incl. abatement potential and cost

Downscale measures to study area

Results:

- Least-cost set of measures
- Cumulative cost of measures

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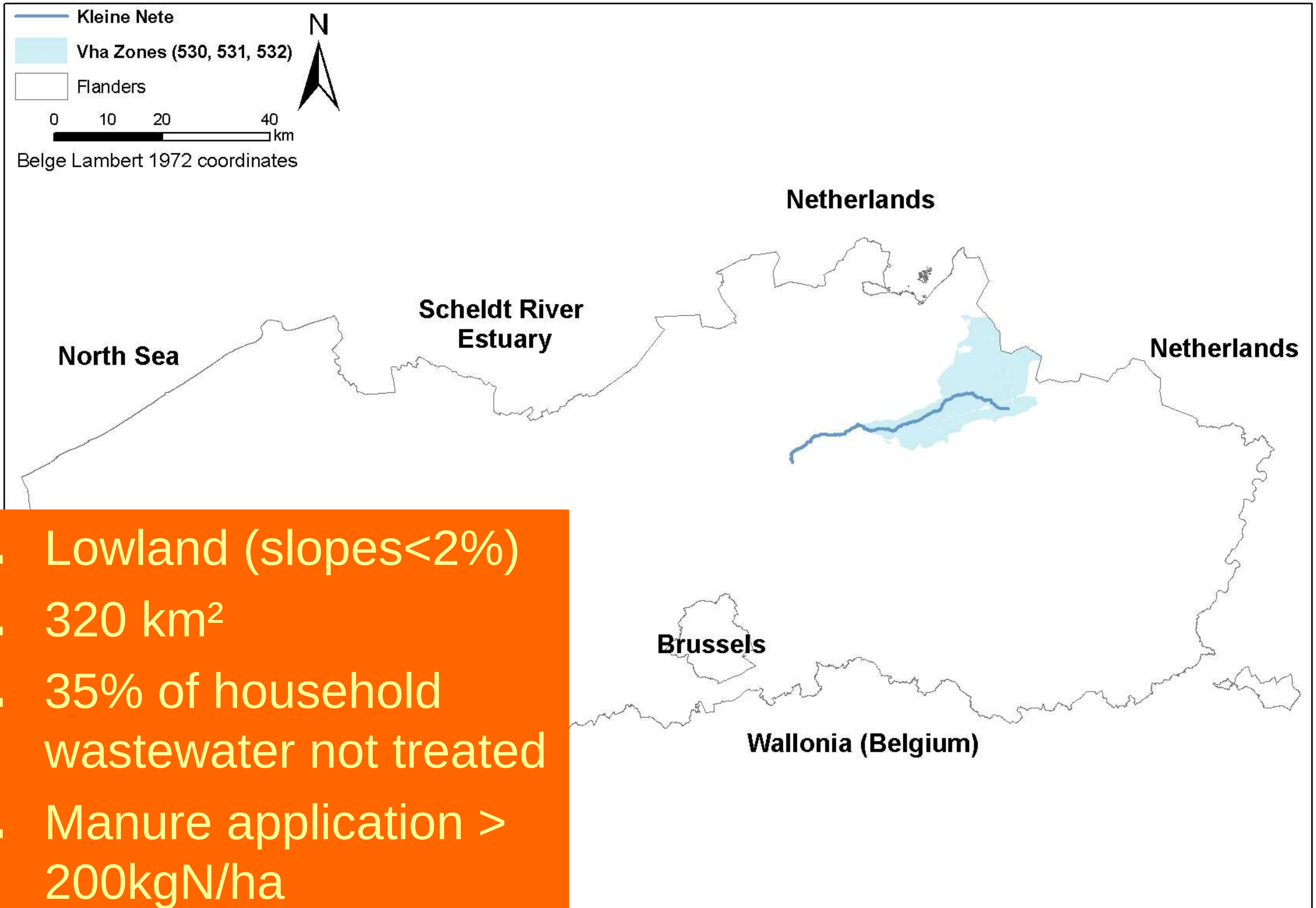
Case study: Kleine Nete river basin in Belgium



- Lowland (slopes<2%)
- 320 km²
- 35% of household wastewater not treated
- Manure application > 200kgN/ha

Impact of emission reduction on water quality

Steps followed:

- Calibrate SWAT2005 water quality model
- Reduction of nitrogen emission in steps of 10% for 3 scenarios:
  - Point sources only
  - Manure and fertilizer application only
  - Point and diffuse sources together

- Derive relationship of nitrogen emission reduction and in-stream concentration
- Specific focus on validity of linear relationship

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Origin of nitrogen sources

N component	symbol	point	fertilizer	plant residues
Nitrate	NO3	x	x	
Ammonia	NH4	x		
Organic nitrogen	ORGN	x		x

NO3 = 46% of total nitrogen
ORGN = 34% of total nitrogen
NH4 only from point sources;
NH4 in fertilizer automatic to NO3

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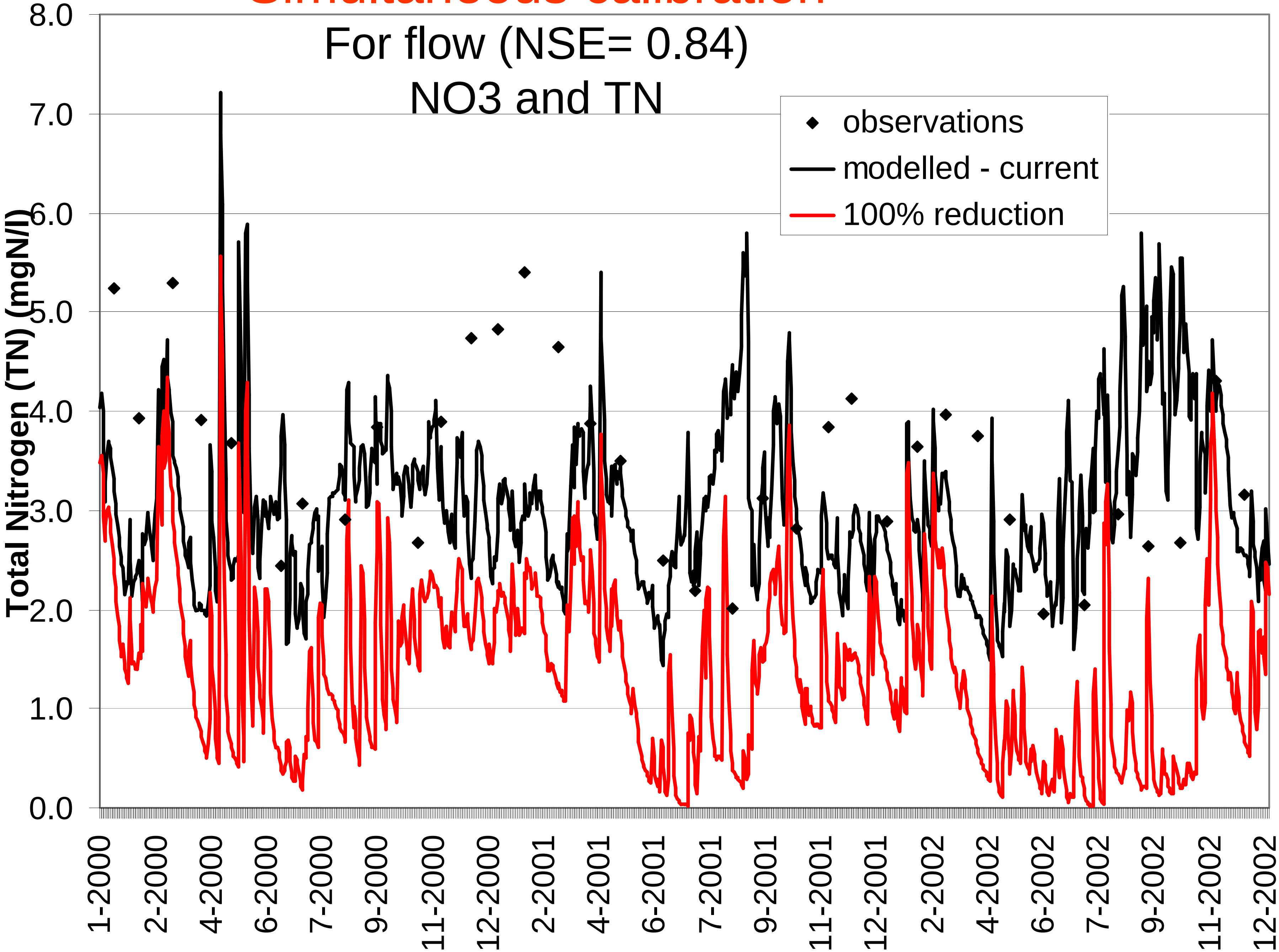
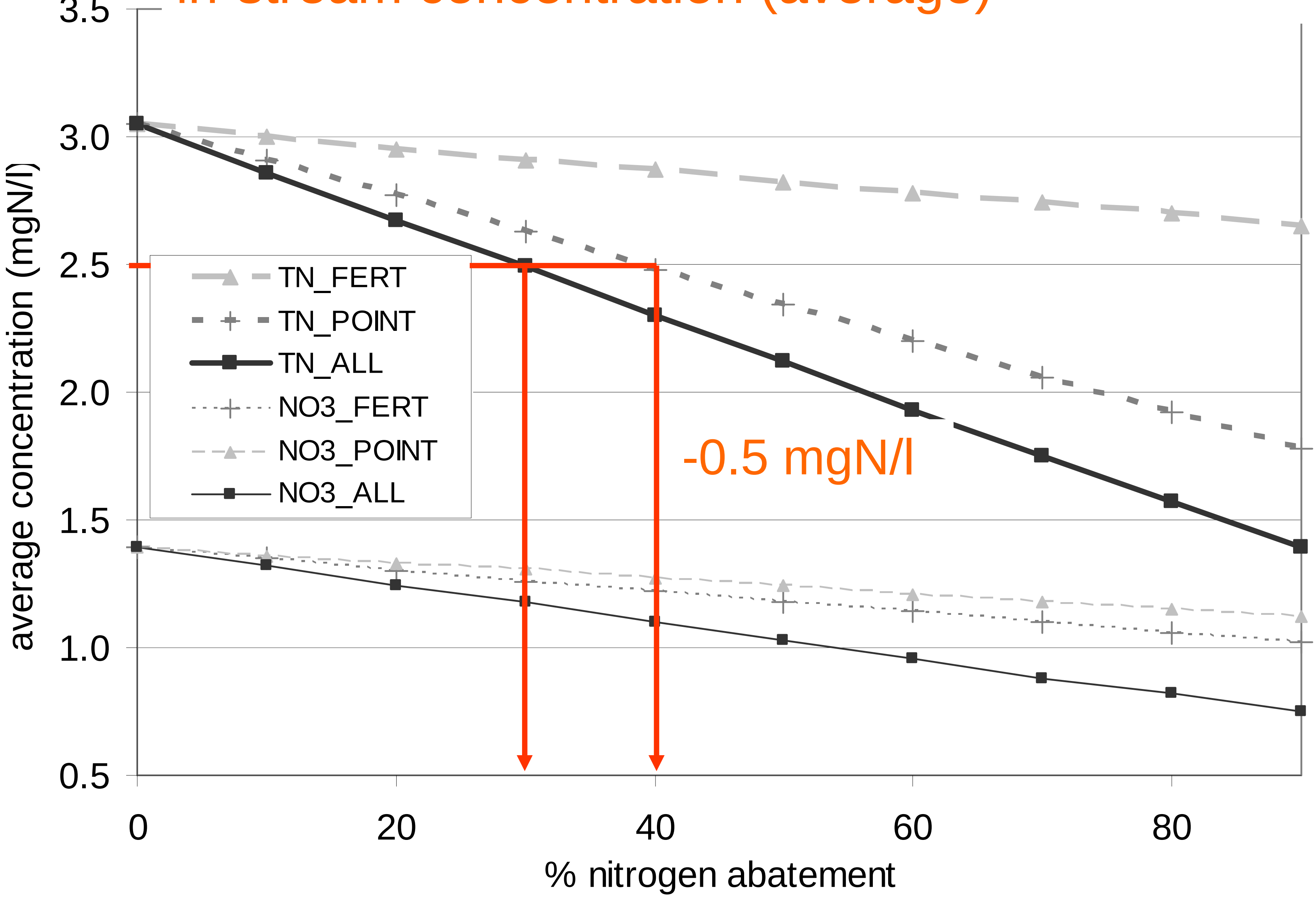
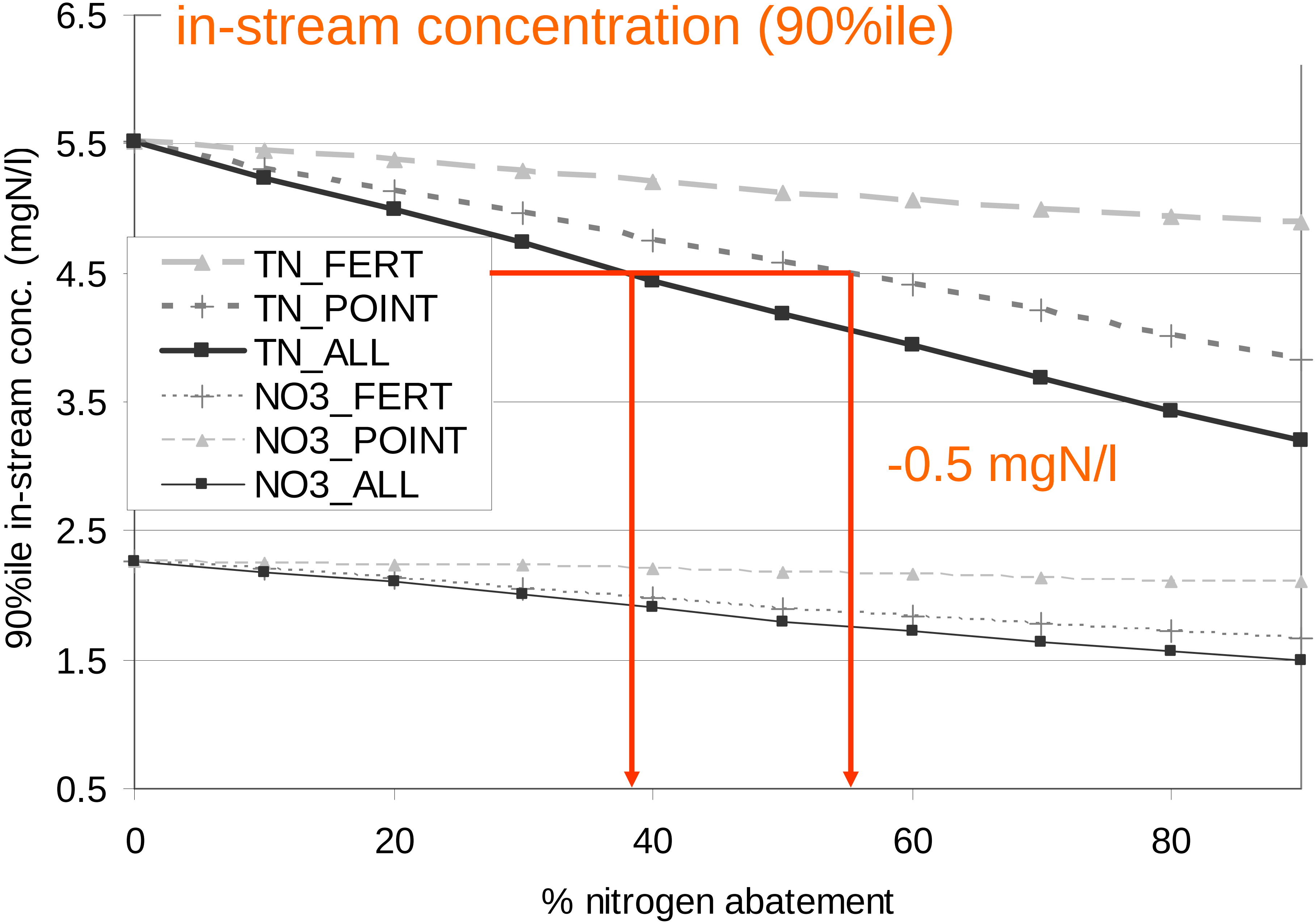
Simultaneous calibration



Linear relationship: N-emission reduction and in-stream concentration (average)



Linear relationship: N-emission reduction and in-stream concentration (90%ile)



Linearity can be explained

- In-stream processes insignificant
  - Travel time lower than 1 day

- Linearity of land phase processes
  - Discharge = mainly baseflow
  - Low buffer capacity of soil (sandy, low org C)

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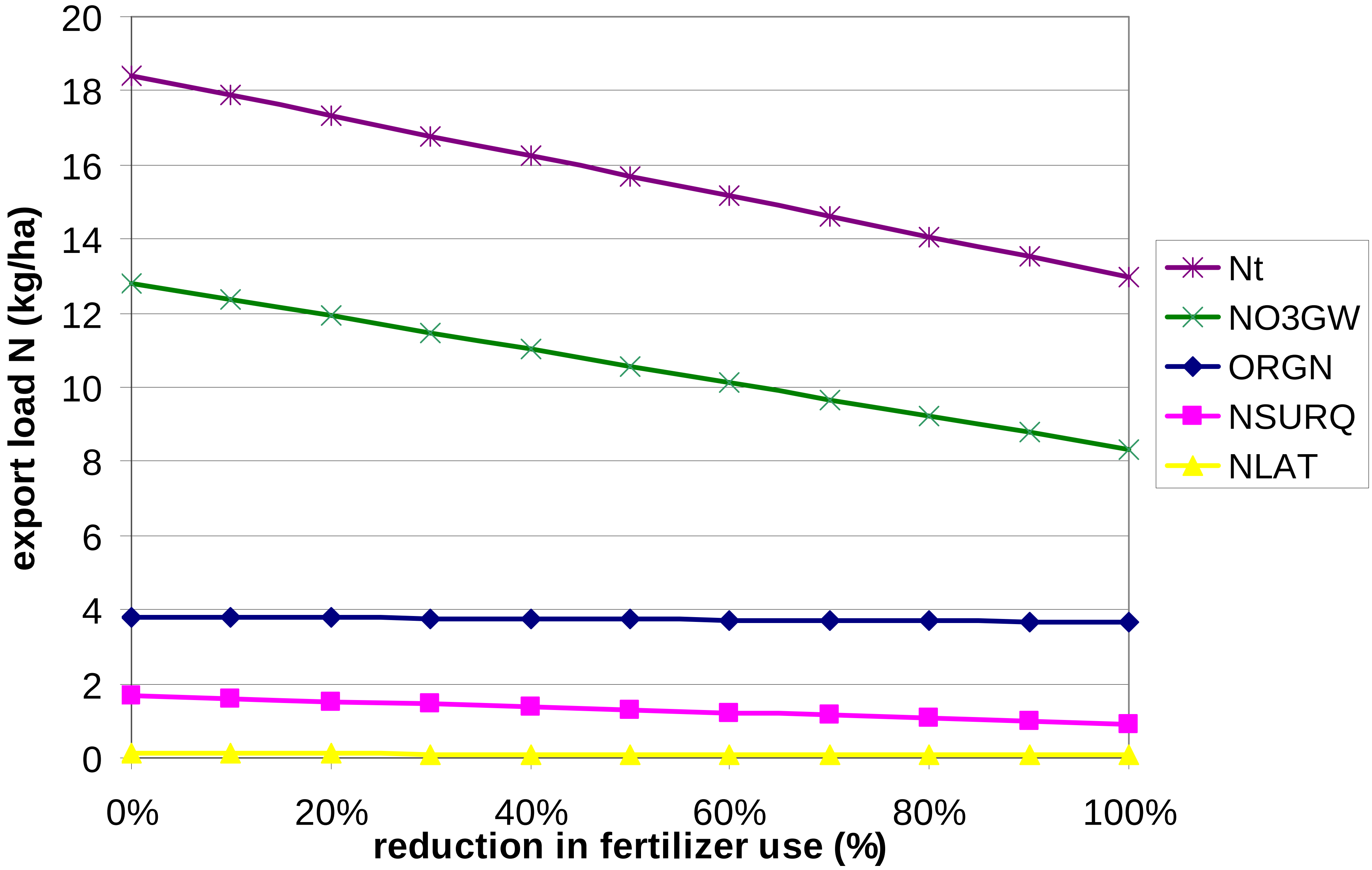
Impact of emission reduction on water quality



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Environmental cost model

- Tool to support river basin management specifically on cost-effectiveness analysis (CEA)
- Database of measures developed for N, P and COD by VITO and Resource Analysis (2006)
- Estimates of costs and abatement potential
  - For industry/WWTP: cost functions
  - For agriculture:
    - Socio-economic model SELES
    - Diffuse emission model SENTWA
  - Applied for Nete river basin

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Cost-effectiveness analysis

- Cost-effectiveness (CE) = Cost / Effect
  (in € /kgN removed)

- Cost = annualized cost incl. investment and operational costs

- Effect = Export load N
  Based on:
  - nitrogen removal efficiency (%)
  - modelled export load for nitrogen (kgN/ha)

Modelled N export load

- Export load coefficient

$$= \frac{\text{export load (kgN/ha)}}{\text{manure applied (kgN/ha)}}$$

- Load reduction factor

$$= \frac{\text{export load (\%)}}{\text{reduction in manure applied (10\%)}}$$

- Area-weighted averages

	export load coefficient	**load reduction factor**
CORN	16%	0.22
PAST	1%	0.86
TOTAL	11%	0.44

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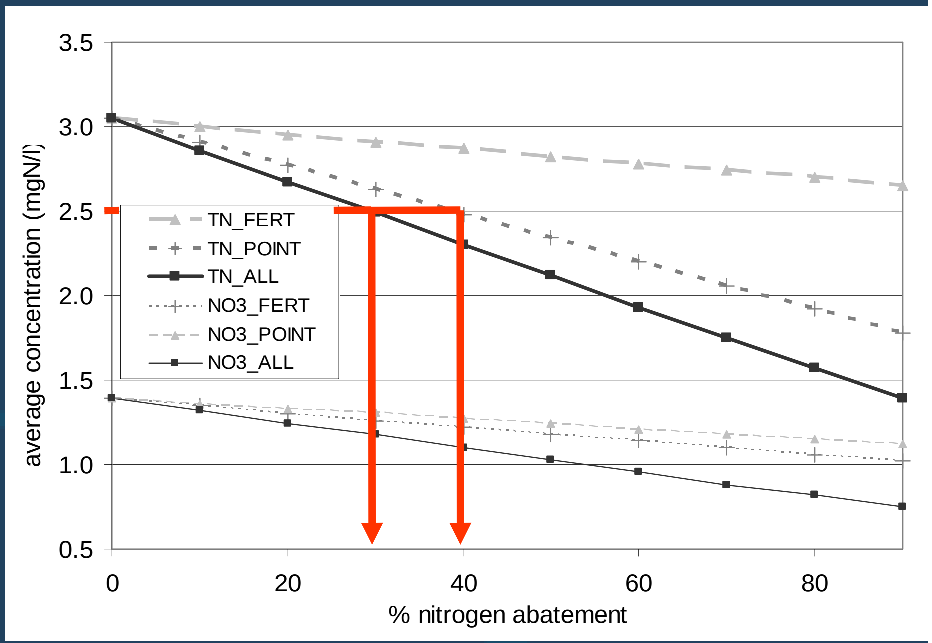
Emission reduction measures

measure	target group	total cost (Eur/year)	N removal efficiency	CE (Euro/kgN removed)
factory closure	industry	0	100%	0
membrane filtration (up to 500m³/day)	industry	$50\text{-}56*10^3$	65%	177-297
connect to WWTP	household wastewater	150-415 Eur/IE.yr	56-75%	55-203
individual treatment	household wastewater	172-326 Eur/IE.yr	20-60%	146-329
riparian buffer zones 5m	diffuse processes	1469 Eur/ha.yr	7%	411-500
riparian buffer zones 10m	diffuse processes	1469 Eur/ha.yr	10%	279-347
green manuring after harvest	diffuse processes	100 Eur/ha.yr	8%	28-30
reduce manure application to 170 kgN/ha	agriculture	653 Eur/ha.yr	32%	115-130

Impact of emission reduction on water quality

Required emission reduction for a reduction in in concentration of Nt of **0.5 mgN/l**

	ALL	point sources only
average	30%	40%
90%ile	40%	55%



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Most cost-effective measures

Ranked for diffuse sources

1. Green manuring after harvest
2. Riparian buffer zones
3. Reduction of manure application

Ranked for point sources

1. Closure most cost-effective
2. WWTP or IBA depends on population density

Estimated cumulative cost (-0,5mgN/l)

Average : 9 million Euro/year
90%ile : 14 million Euro/year

Depends largely on ‘export load coefficient used’

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Conclusion

- Linear relationship for impact of emission reduction is valid:
  - For sandy lowlands
  - For small river basins
  - In modelled range of concentrations

- Large uncertainty on costs and effects, though valid for:
  - First assessment of required emission reduction
  - Comparison of cost-effectiveness of measures across sectors and processes
  - Rough estimate of total cost of measures

- For effective use in water management
  - Acceptance of ‘values’ by stakeholders is essential
  - Comparison of export load coefficients
  - Advance on impact on ecologic quality

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