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Modelling of long-term nutrient retention in surface waters in Saxony

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GALF
GESELLSCHAFT FÜR ANGEWANDTE LANDSCHAFTSFORSCHUNG bR

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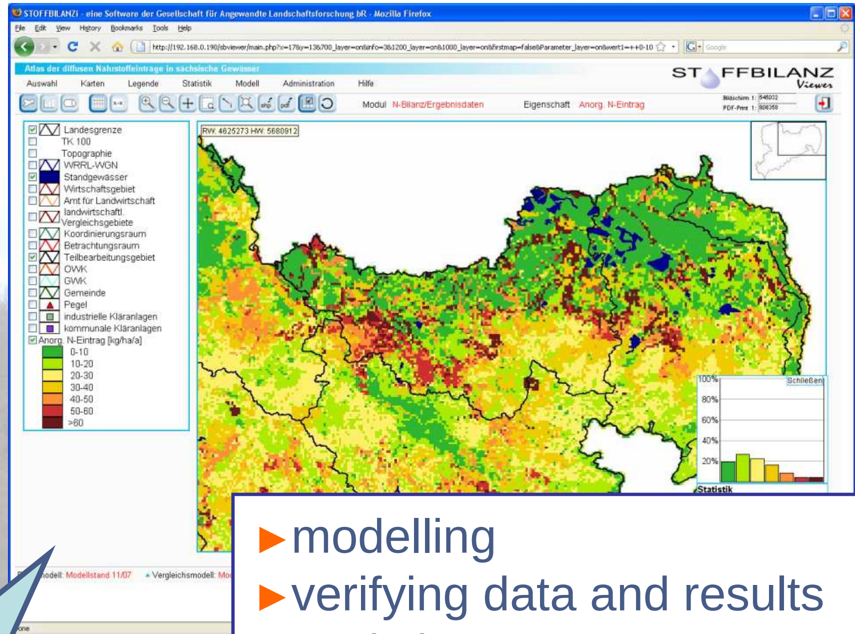
Web GIS based modelling

Mapserver / geo-db / C++

regional scale (watershed)

annual balancing

runoff, soil erosion, N, P



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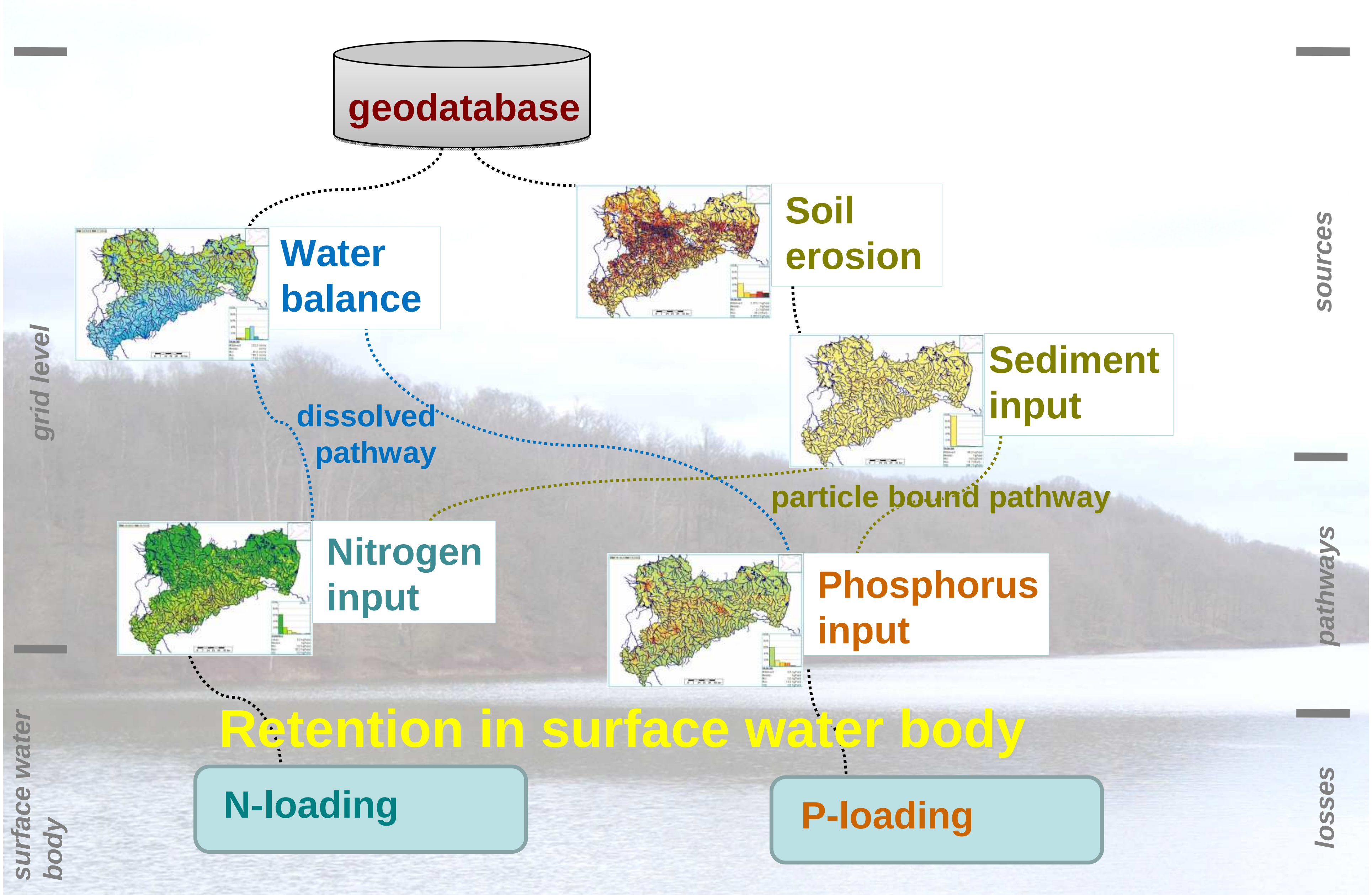
PostgreSQL / POSTGIS-database

model (C++)

- modelling
- verifying data and results
- statistics
- maps / visualization
- scenarios
- decision support


geodatabase
Water balance
Soil erosion
Sediment input
dissolved pathway
particle bound pathway
Nitrogen input
Phosphorus input
Retention in surface water body
N-loading
P-loading
grid level
surface water body
sources
pathways
losses

Retention in surface water body

→ P- and N-fluxes in waters are determined by spatial and temporal dynamic (nutrient spiraling).

Dealing with the nutrient retention phenomenon on regional scale we should attend, that many effects are
→ short-time related, esp. controlled by hydrological variability (flood, low water).

→ A long-lasting retention for P especially exists in flooding areas and reservoirs (Walling u. He 1994, Guhr u. Meissner 2000, Venterink et al. 2003, Withers & Jarvie 2008).

→ The most important long-lasting N-removal is caused by denitrification in river bed (z.B. Donner et al. 2004).

→Average long-time related river basin modeling needs a computation of an average long-lasting retention !
→Derivation of nutrient retention should be process-orientated !
→It should be based on generally available data !

Nitrogen retention in rivers / streams

(Nutrient Spiralling – concept, Stream Solute Workshop, 1990)

$$v = k_{ST} \cdot \left(\frac{Q}{(k_{ST} \cdot w \cdot \sqrt{I})} \right)^{\left(\frac{2}{5}\right)} \cdot \sqrt{I}$$

hydraulic gradient ***I*** → GIS-technologies

discharge ***Q*** → including upstream residents

river section width ***w*** → mapping of river structures (water authorities)

Manning-Strickler coefficient k_{ST} (Mischke et al. 2005) → LAWA river-types

average flow velocity ***v***

river section length ***l*** → GIS-technologies

$$\tau = \frac{l}{v}$$

water residence time ***τ***

time-specific N-uptake rate k_t → Function of discharge ***Q*** acc. to literature data (Wollheim et al. 2006)

retention r_{riv} of a river section

$$r_{riv} = 1 - \exp(-k_t \cdot \tau)$$

Phosphorus retention in rivers / streams

flooding area of river section → GIS-technologies

bulk density of soil → 1,5 g/cm³ (estimated)

Mean long term sedimentation rate in flooding area → LAWA river-types

maximum mean long-term sedimentation in flooding area

P concentration in surface waters / suspended matter → Sediment discharge and P emission of river section and upstream residents

retention r_{riv} of a river section

Retention in reservoirs (according to Maniak 2005)

coefficient of N/P net-transfer s_N

hydraulic residence time τ

average depth of water body z

→ data from Landestalsperrenverwaltung Sachsen

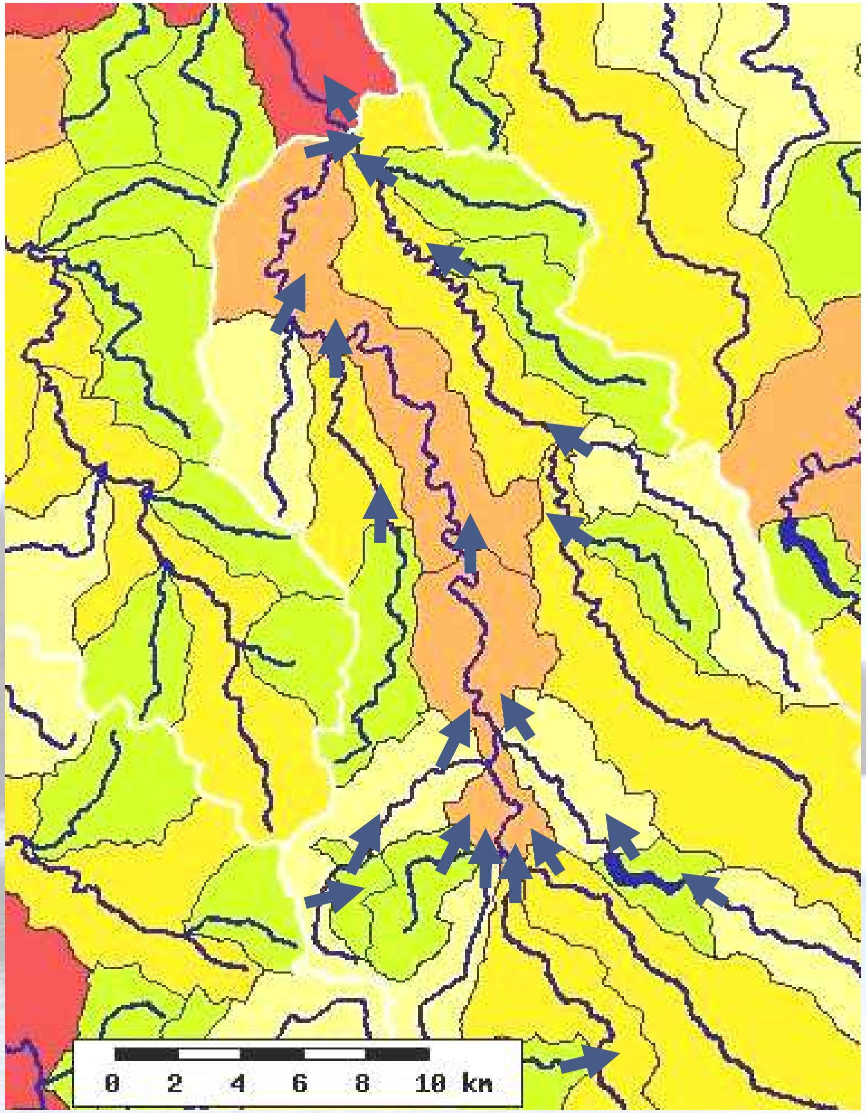
retention r_{res} of a river section

$$r_{res} = \frac{s_N}{\left(s_N + \frac{z}{\tau}\right)}$$

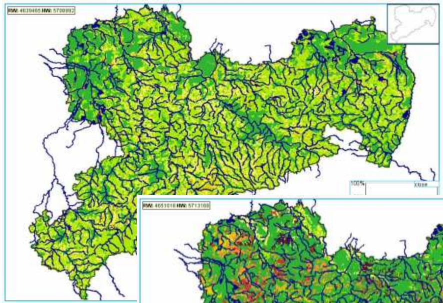
Additional retention for each river section (e.g. nitrogen)

We determine a specific retention for each river section. The corresponding load per river section ***L_i*** consists of the catchment related input within the river section area area ***TN_i*** multiplied with the specific coefficient of retention r and the sum of inputs ***L_j*** from the upstream residents multplied with ***r***:

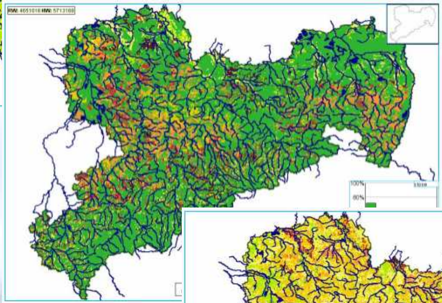
$$L_{i,N} = (TN_{diff,point,i} + \sum L_j) \times (1 - r)$$



Tributaries and upstream residents are joined by a routing.

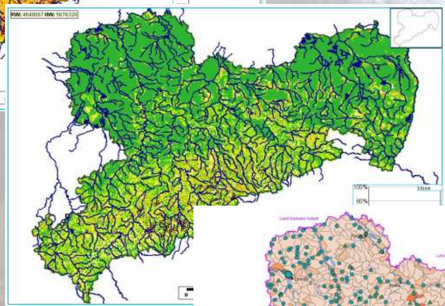


Diffuse N-input via surface runoff

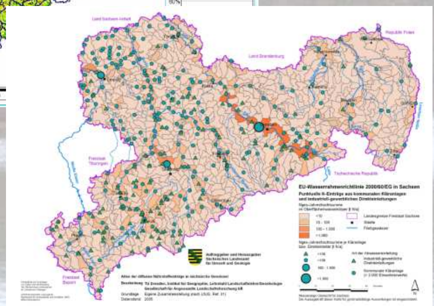


Diffuse N-input via drain discharge

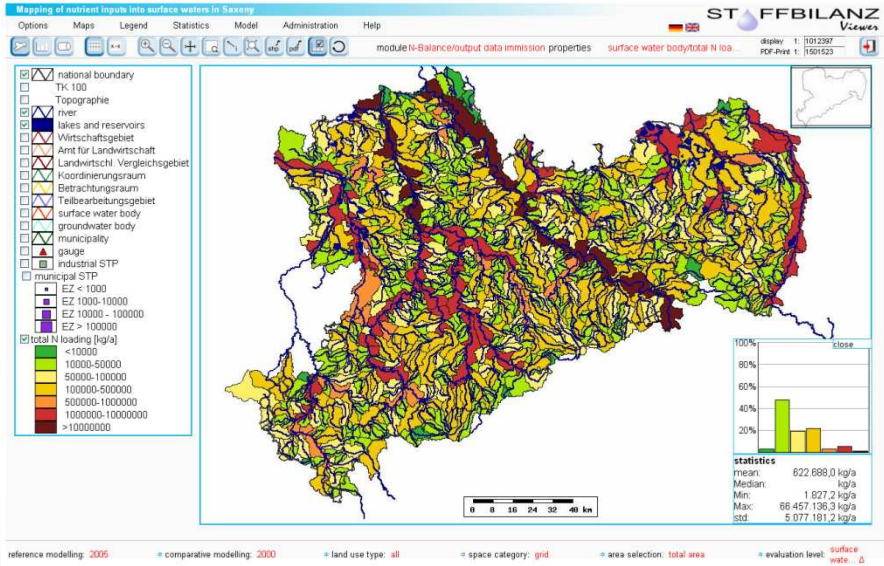
Diffuse N-input via interflow



Diffuse N-input via groundwater runoff



Point related N-input



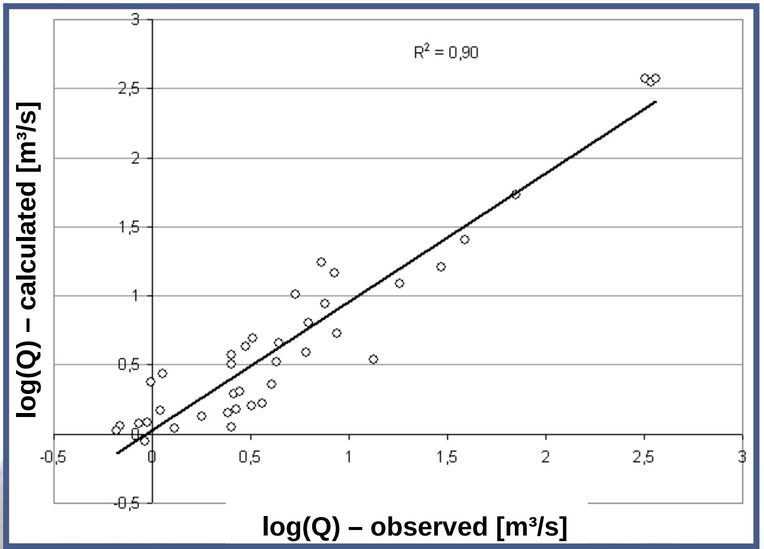
retention per surface water body

Mapping of nutrient inputs into surface waters in Saxony: ordered by LfULG Sachsen

Table 1: Emissions into surface water and loadings at river basin outlet of phosphorus and nitrogen in saxonian parts of FGE Elbe and FGE Oder (reference year 2005)

	Emissions into surface water		loading at river basin outlet		retention	
	N [t/yr]	**P [t/yr]**	**N [t/yr]**	**P [t/yr]**	**N [%]**	**P [%]**
Mulde	15.983	465	12.784	417	20	10
Elbe	9.190	240	8.148	156	11	35
Weiße Elster*	6.660	206	5.596	119	16	42
Spree	3.331	72	2.636	58	21	19
Schwarze Elster	3.959	76	3.615	68	9	11
FGE Elbe	**39.123**	**1.057**	**32.778**	**817**	**16**	**23**
Lausitzer Neiße**	1.379	34	1.098	32	20	6
FGE Oder	**1.379**	**34**	**1.098**	**32**	**20**	**6**
Sachsen	**40.501**	**1.091**	**33.876**	**849**	**16**	**23**

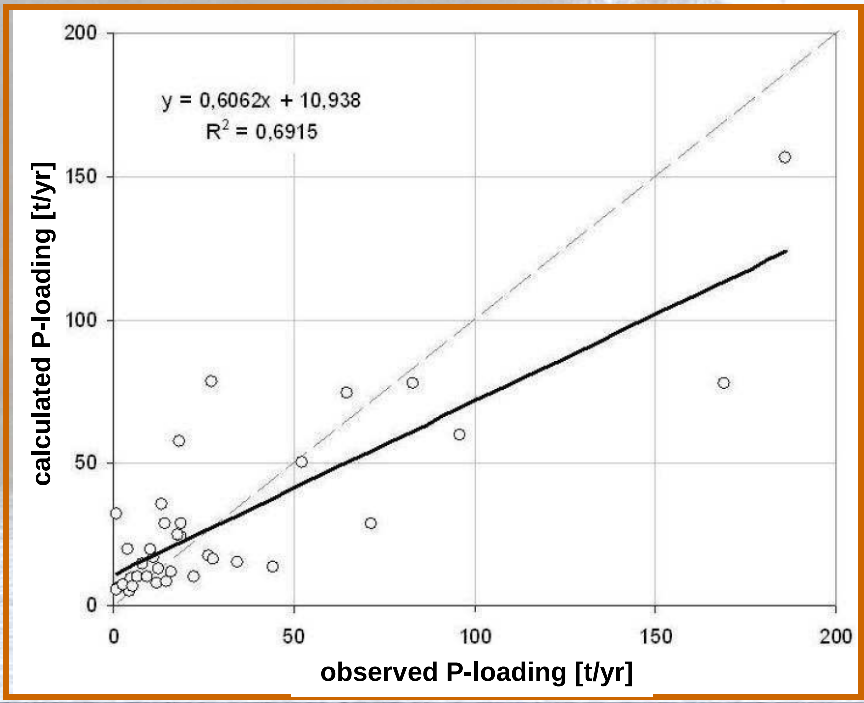
* excluding thuringian emissions, exluding P-retention in Thuringia
** excluding polish inundation zone of river Neiße

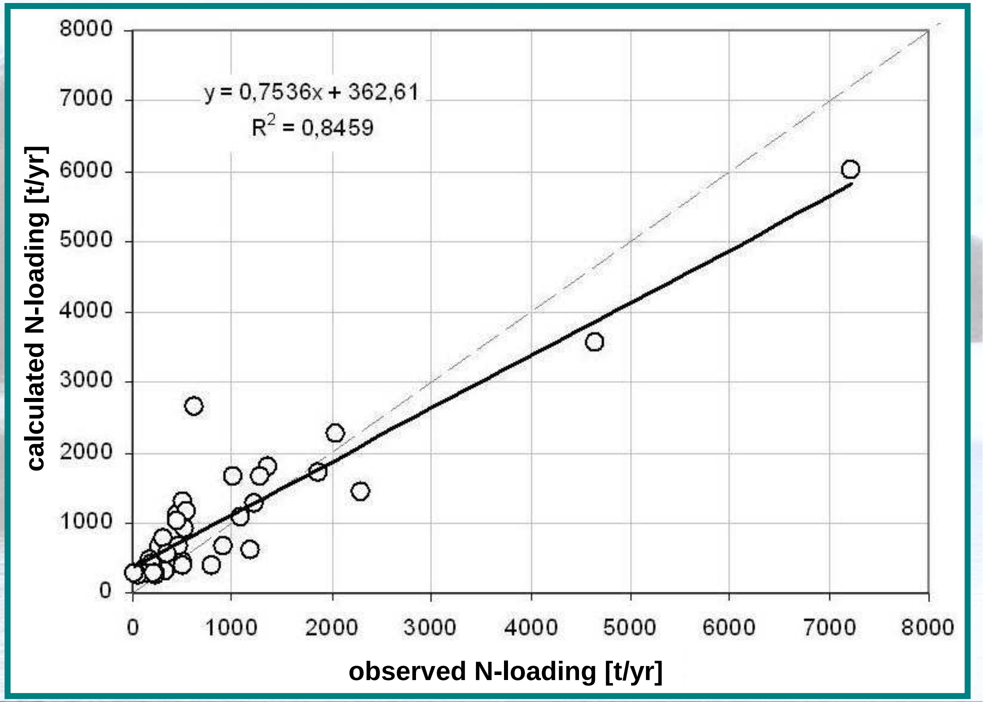


Calculated (y) and measured (x) total runoff (r^2=0,90)

Calculated (y) and measured (x) total nitrogen loadings (r^2=0,69) (Labe, Elbe-1, Elbe-2 and Mulde-7 excluded)

Calculated (y) and measured (x) total nitrogen loadings (r^2=0,85) (Labe, Elbe-1, Elbe-2 and Mulde-7 excluded)





→ Computation of long-lasting retention on regional scale, based on generally available data, is possible in a first approach.

→ we should think about further improvement, for example:

… N-uptake rate is derived from literature, its dependency to nitrate concentration and water temperature is not considered at the moment. The implementation of these parameters should be strived for in order to optimise the retention modelling especially for point-related inputs.

… we need more research to derive average long-lasting sedimentation rates especially in smaller rivers

… the computation of phosphorus retention only considers the long-term sedimentation of suspended loads in the flooding zone of surface waters. A limitation of P-concentration in suspended loads could reduce retention capacity, but is not considered at the moment.

… bank erosion as an important source for suspended loads is not included in the P-retention modelling.


Thank you
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