Impact of selected agricultural management scenarios on the reduction of nitrogen loads in meso scale catchments in Central Germany

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Outline

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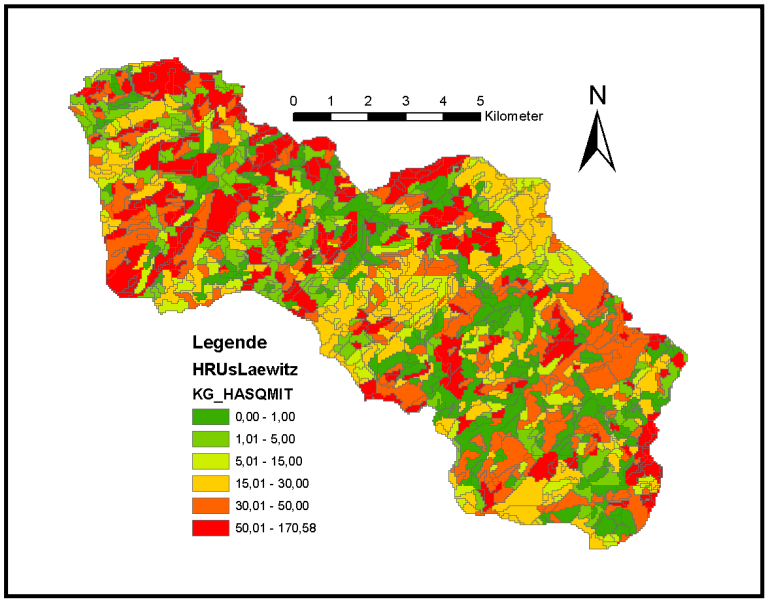
Modelling approach

Comparative catchment study

Scenario results

Conclusion



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Introduction

- What are the controlling factors for nitrogen loads in surface waters?

  - Emission losses from source areas

  - Transformation and storage processes during lateral transport

- What impact does subsurface retention have on the effectiveness of management measures to reduce nitrogen input to surface water ?

  - Impact of catchment characteristics

  - Management implications

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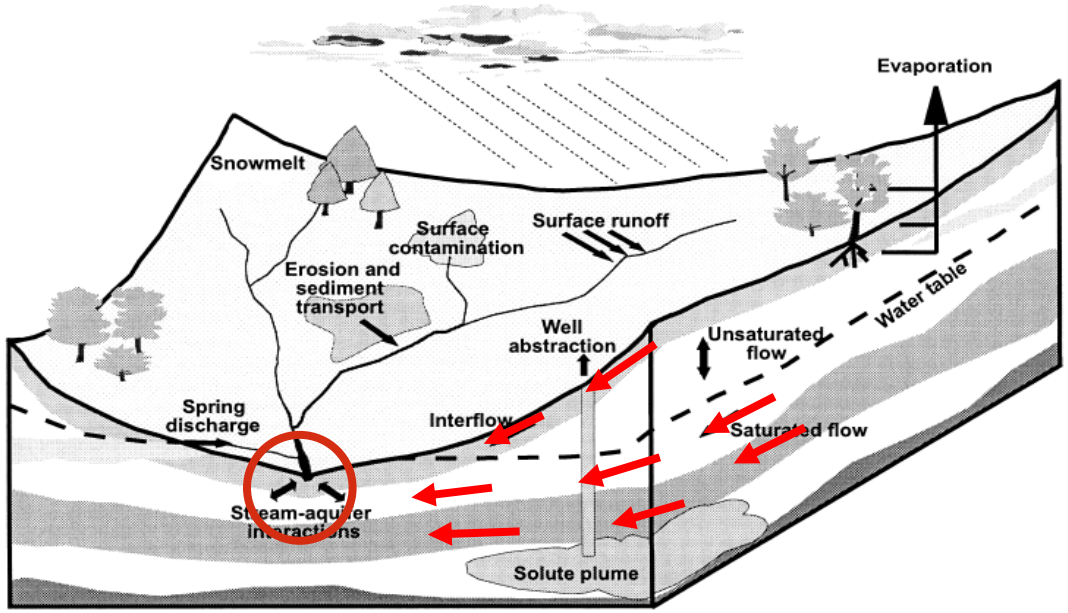
Importance of lateral subsurface flows on nitrogen transport



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Objectives

- Introduce a new integrated modelling approach for spatially distributed N-transport
- Assess the effect of selected agricultural management measures on nitrogen leaching
- Analyze the effect of subsurface retention processes in catchments with differing site characteristics

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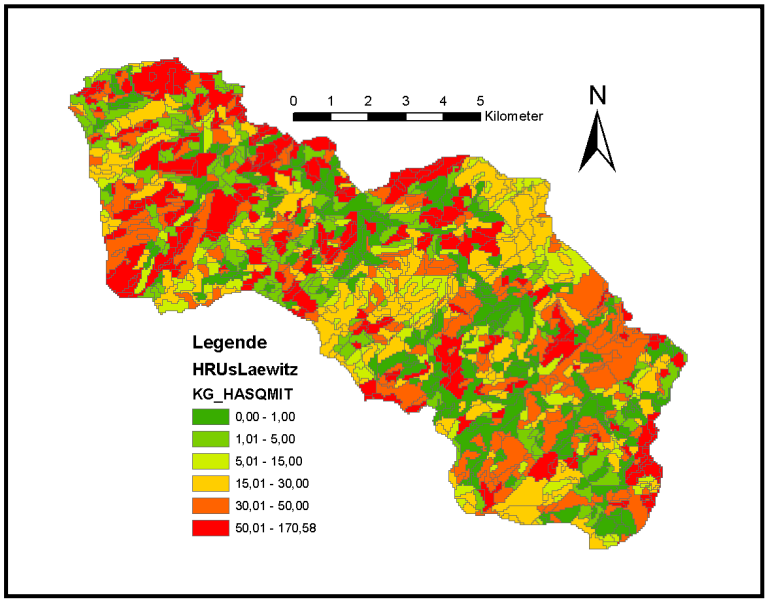

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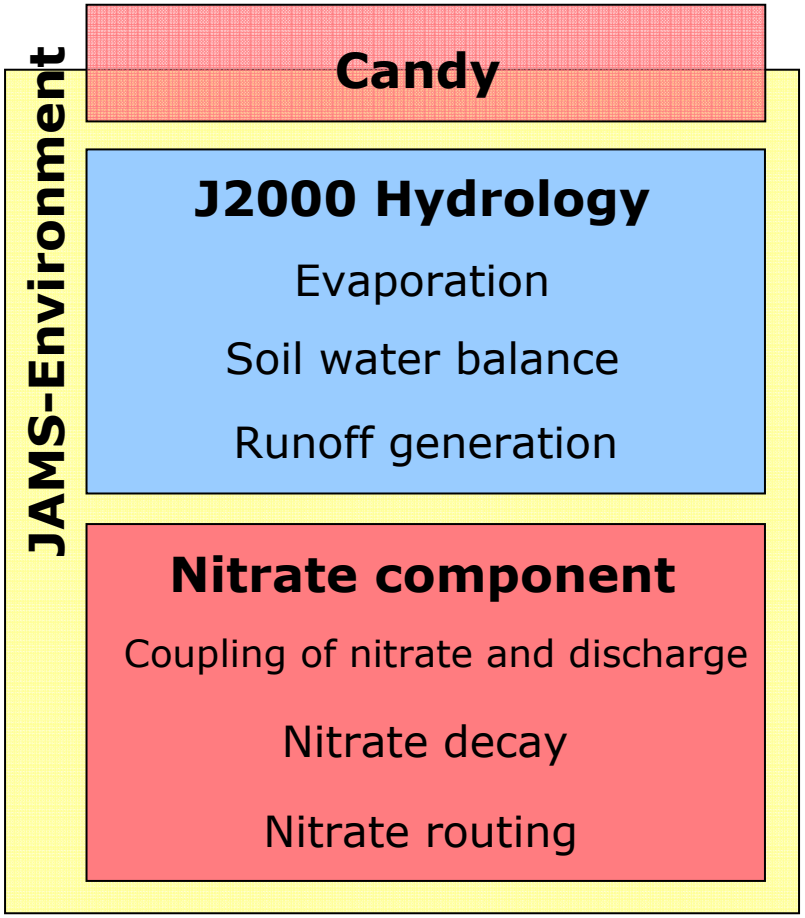
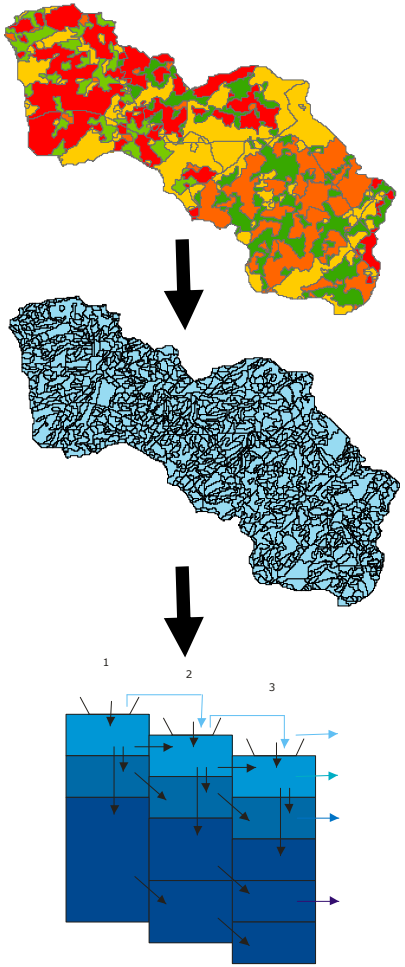
Integrated modelling system JAMS





Nitrogen Response Units (NRU)

Hydrological Response Units (HRU)

Groundwater and Nitrogen Transport

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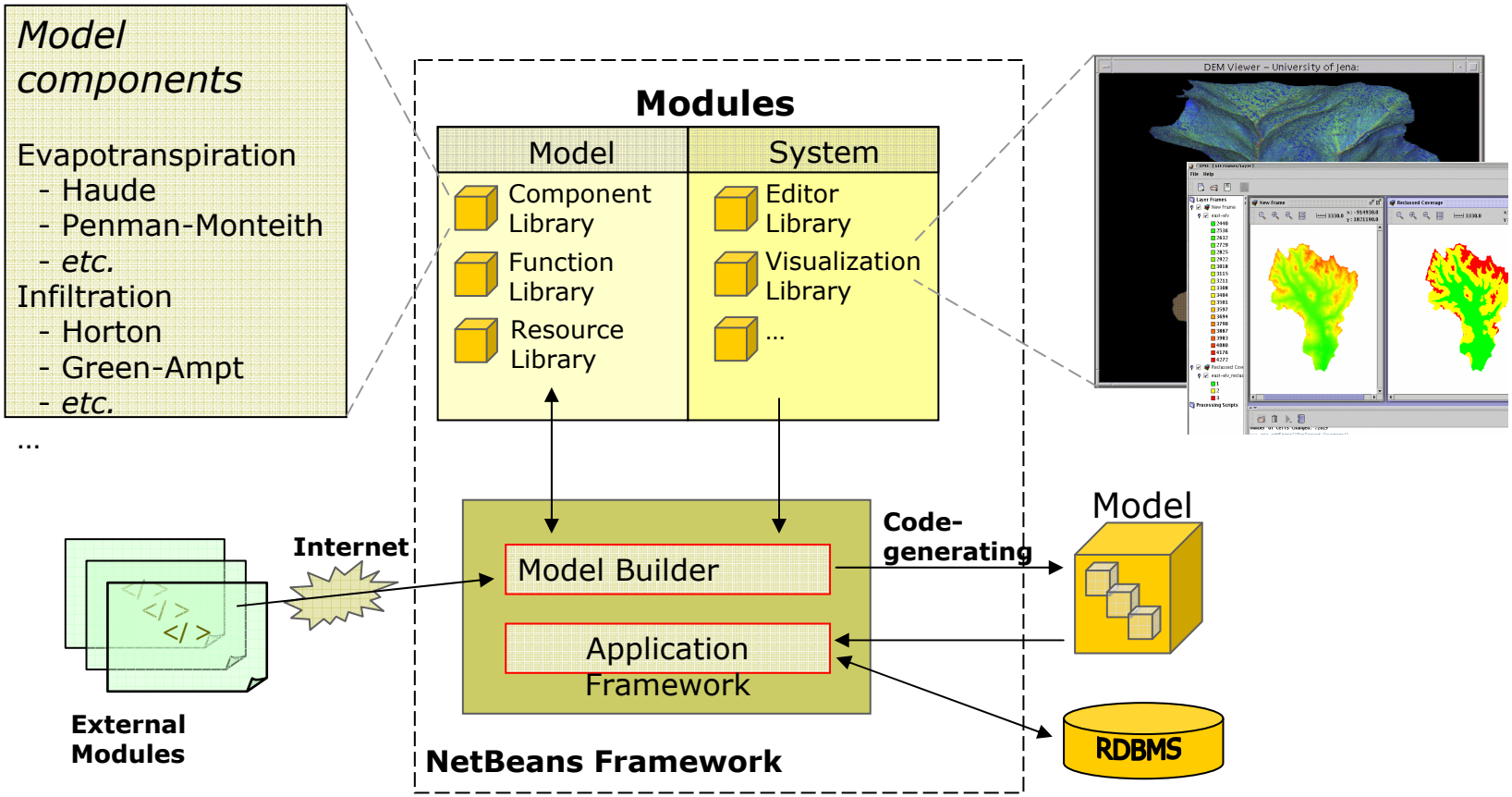
Object Modeling System JAMS



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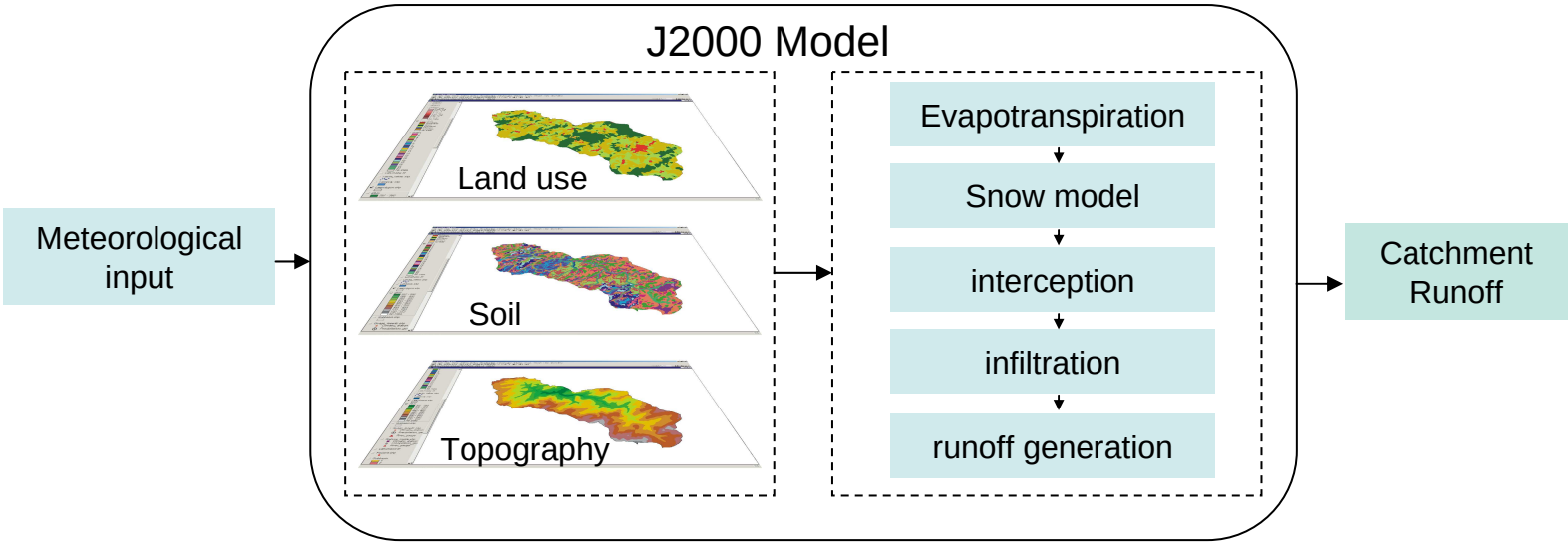
Water balance model

- Spatially distributed J2000 model (Krause, 2002) based on the Hydrological Response Units concept
- Conceptual approach with four runoff components and linear storage concept



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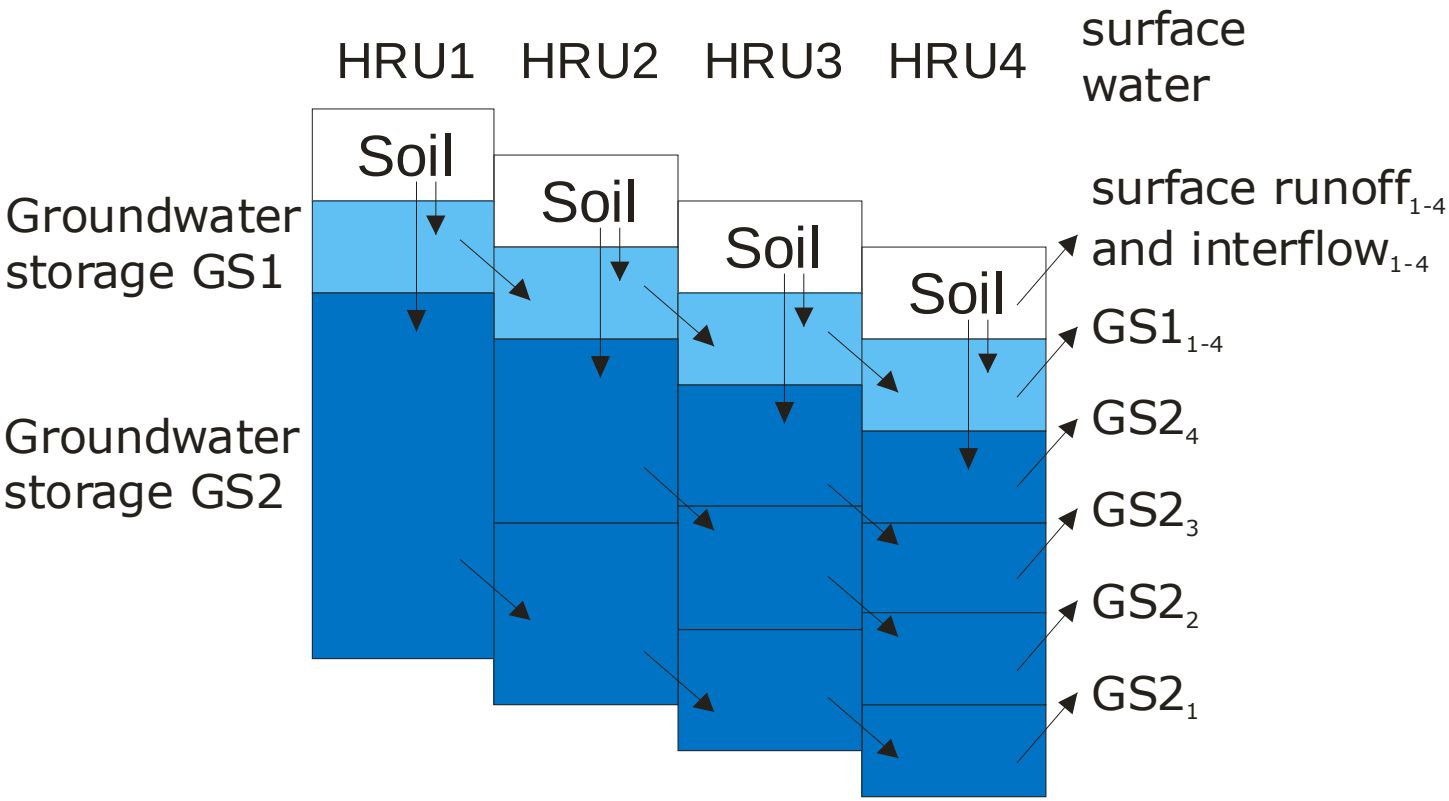
Lateral routing of runoff components



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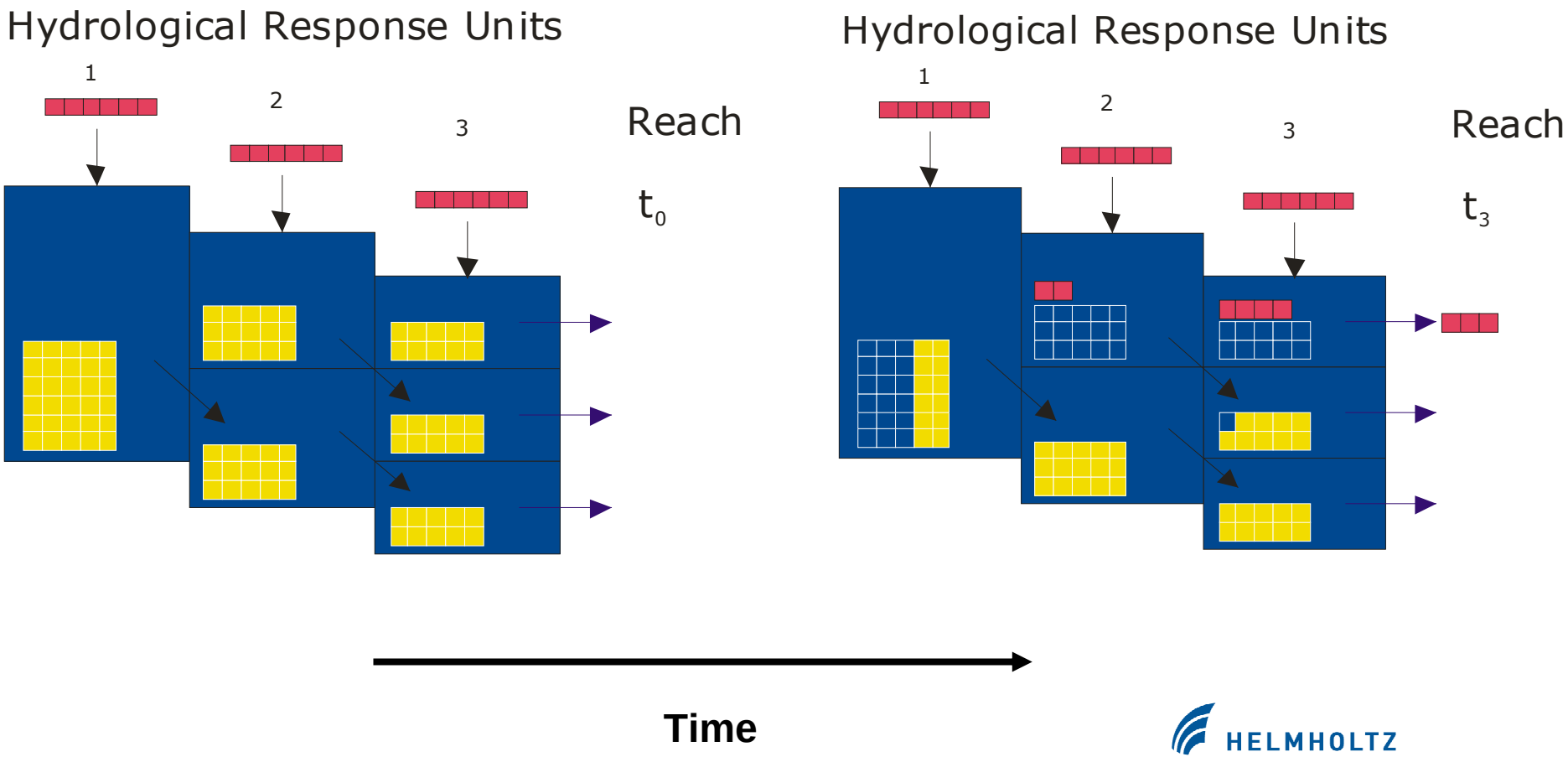
Nitrate transformation processes



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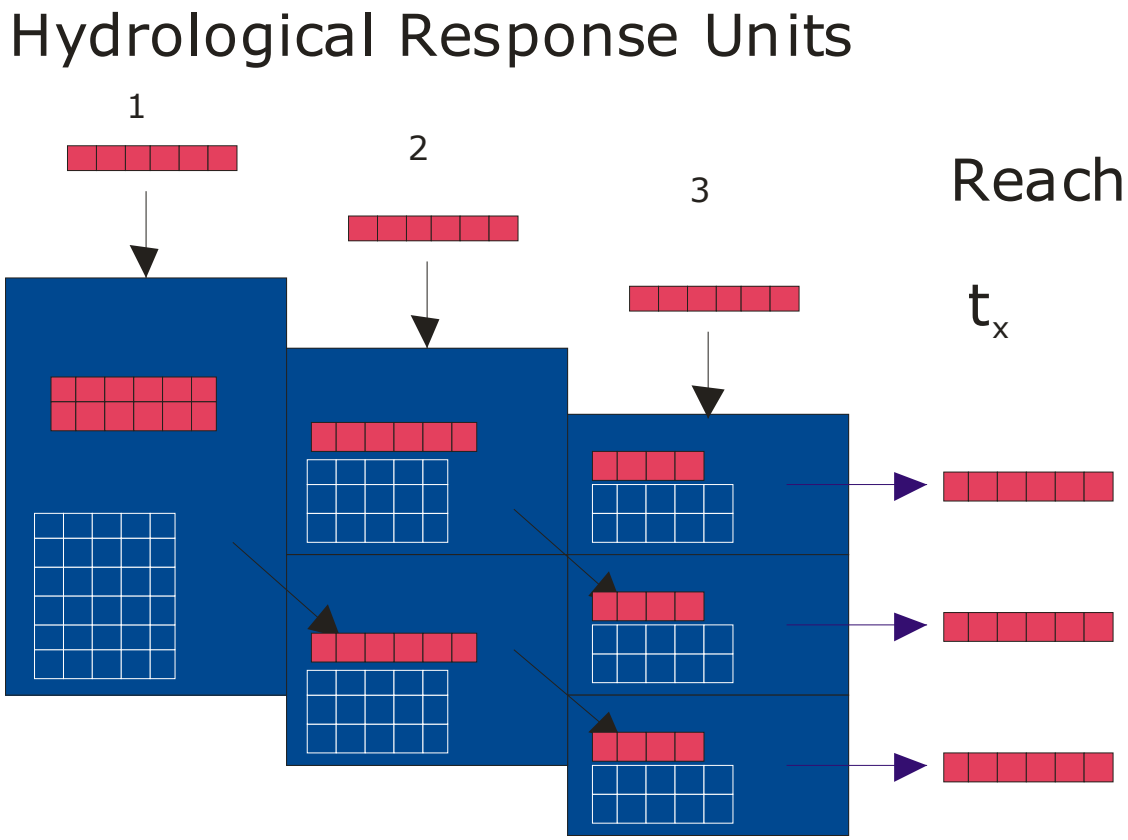
Steady state nitrate transport



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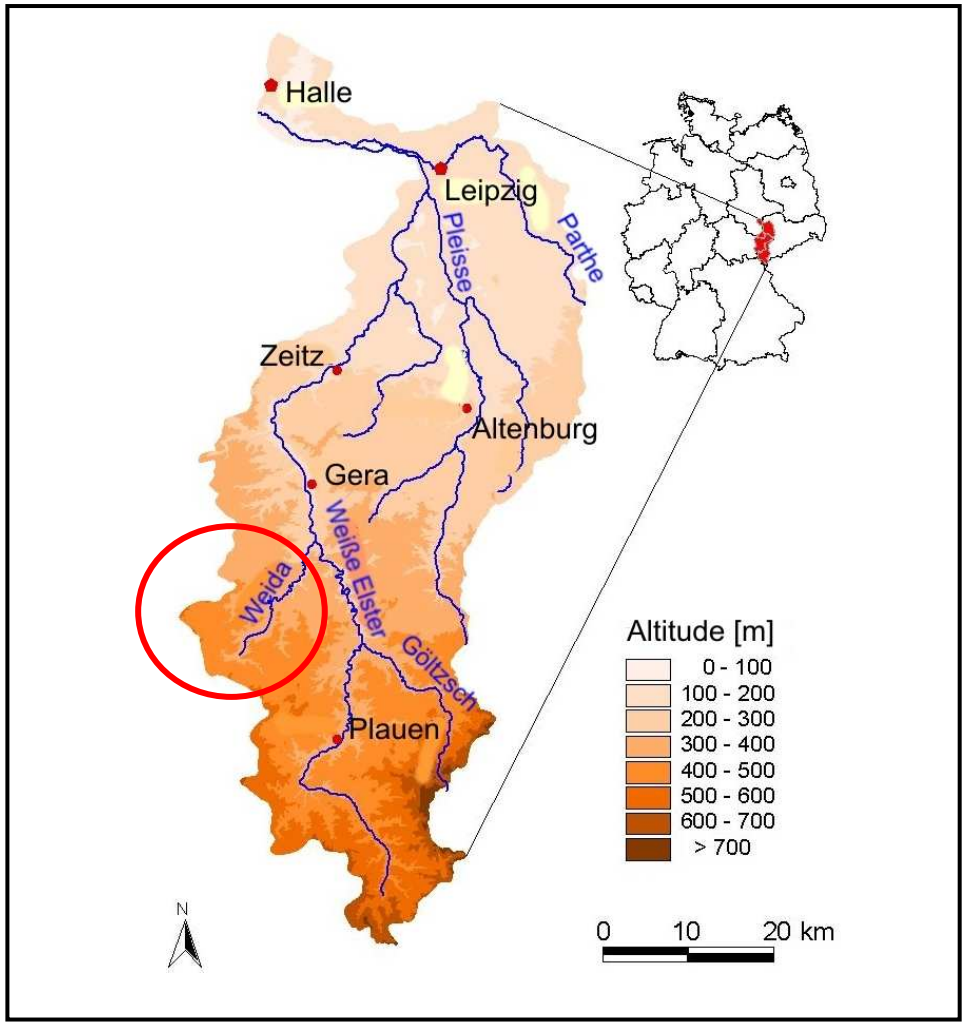
Weida study catchment of the lower mountain range



- Size of the catchment:
  98 km²
- Precipitation:
  640 mm
- Land use:
  65,5% agriculture
- Geology:
  schistous rock, volcanic rock,

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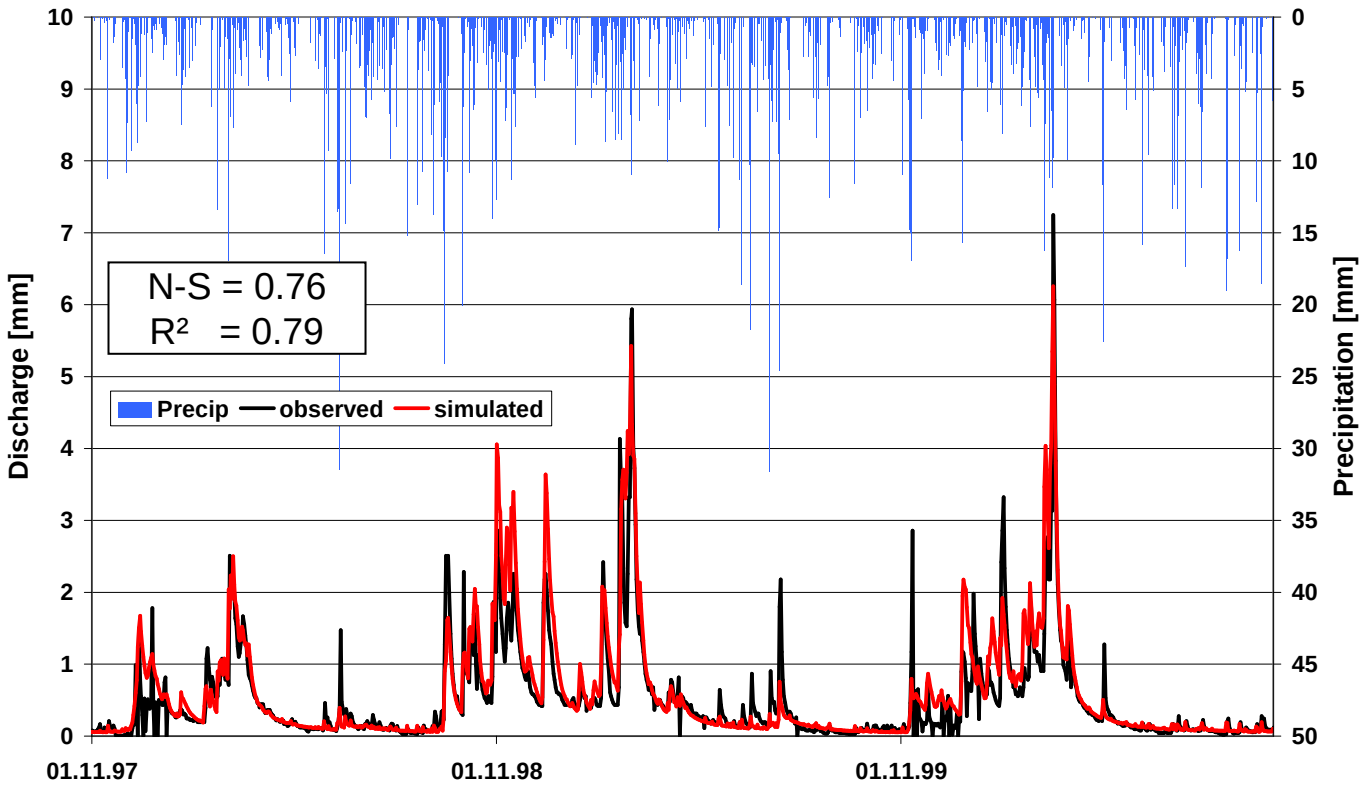
Calibration of discharge



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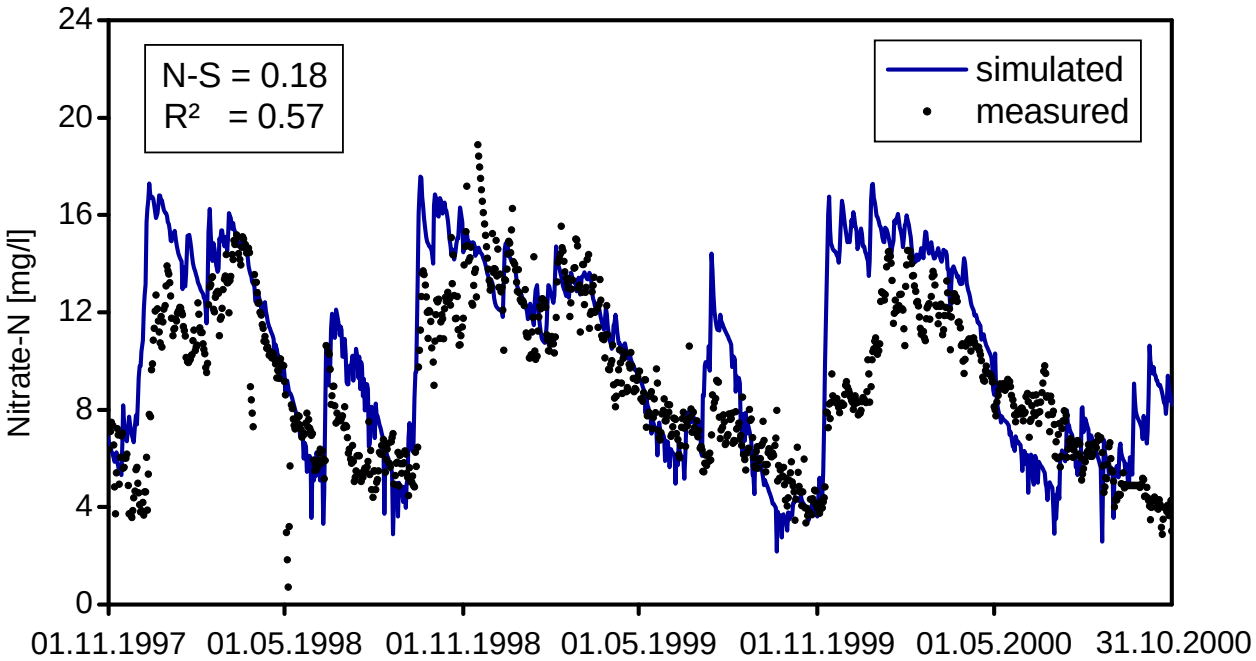
Calibration of nitrate-N concentration



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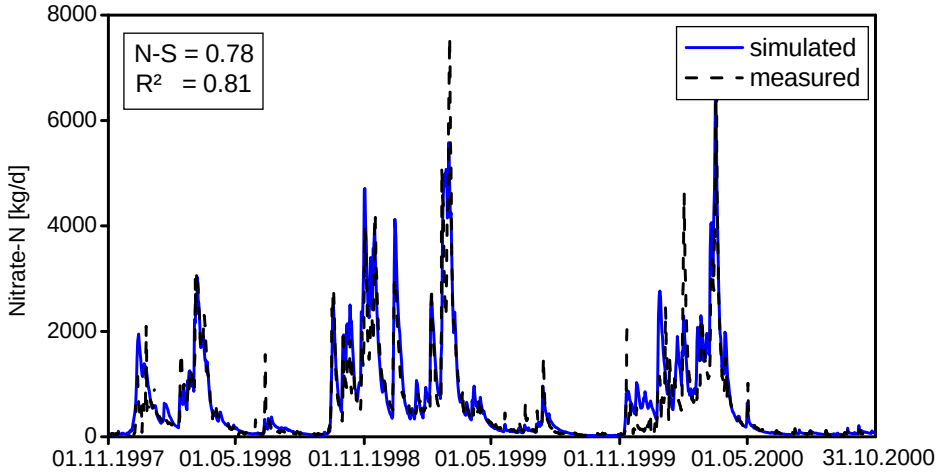
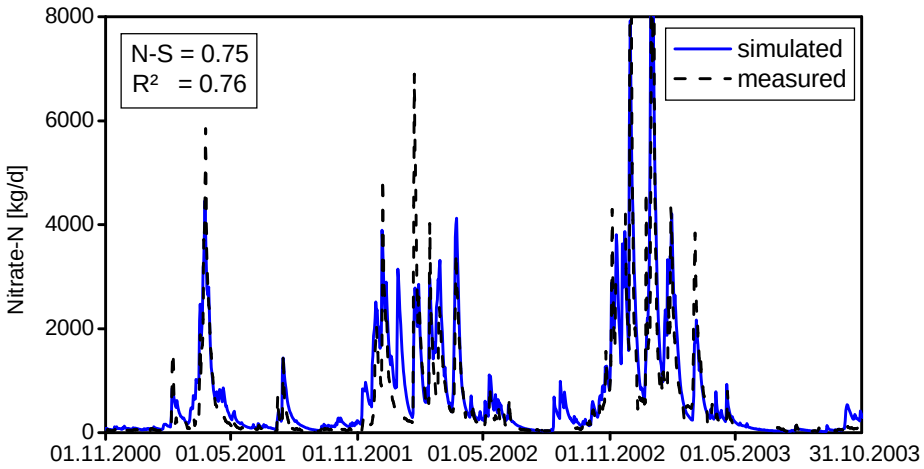
Nitrate-N load calculations

Calibration





Validation

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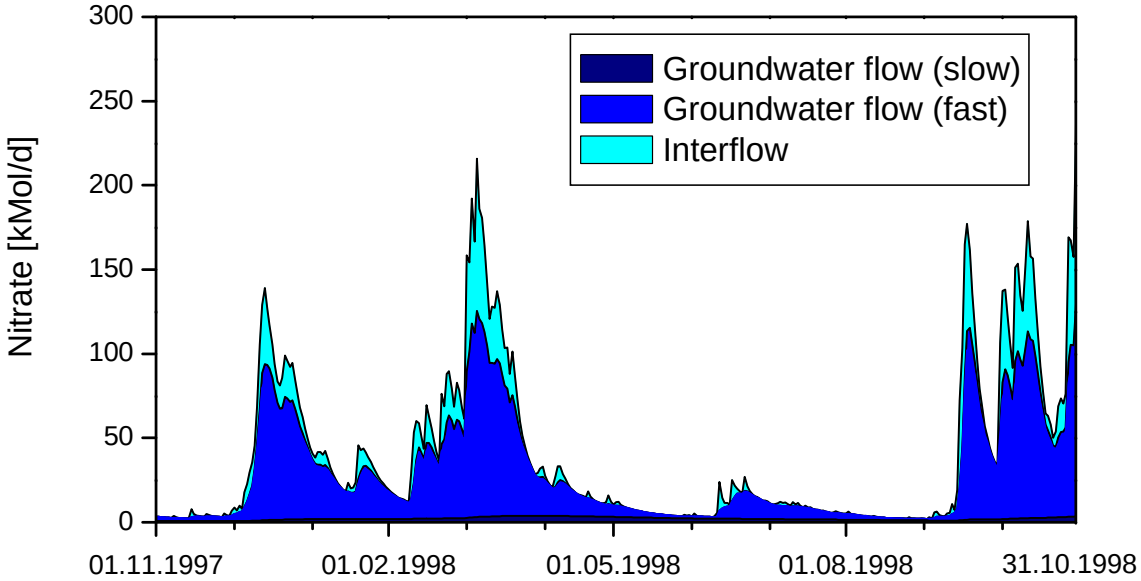
Simulated nitrate-N loads of subsurface flow components



- Nitrogen mainly retained in slow groundwater flow
- Slow groundwater flow 16% of total runoff
- Total nitrogen-N retention 11%

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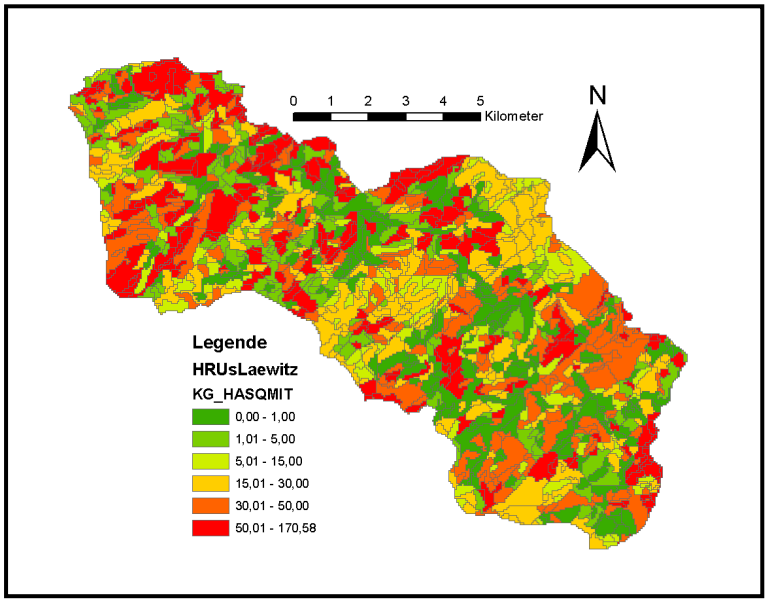

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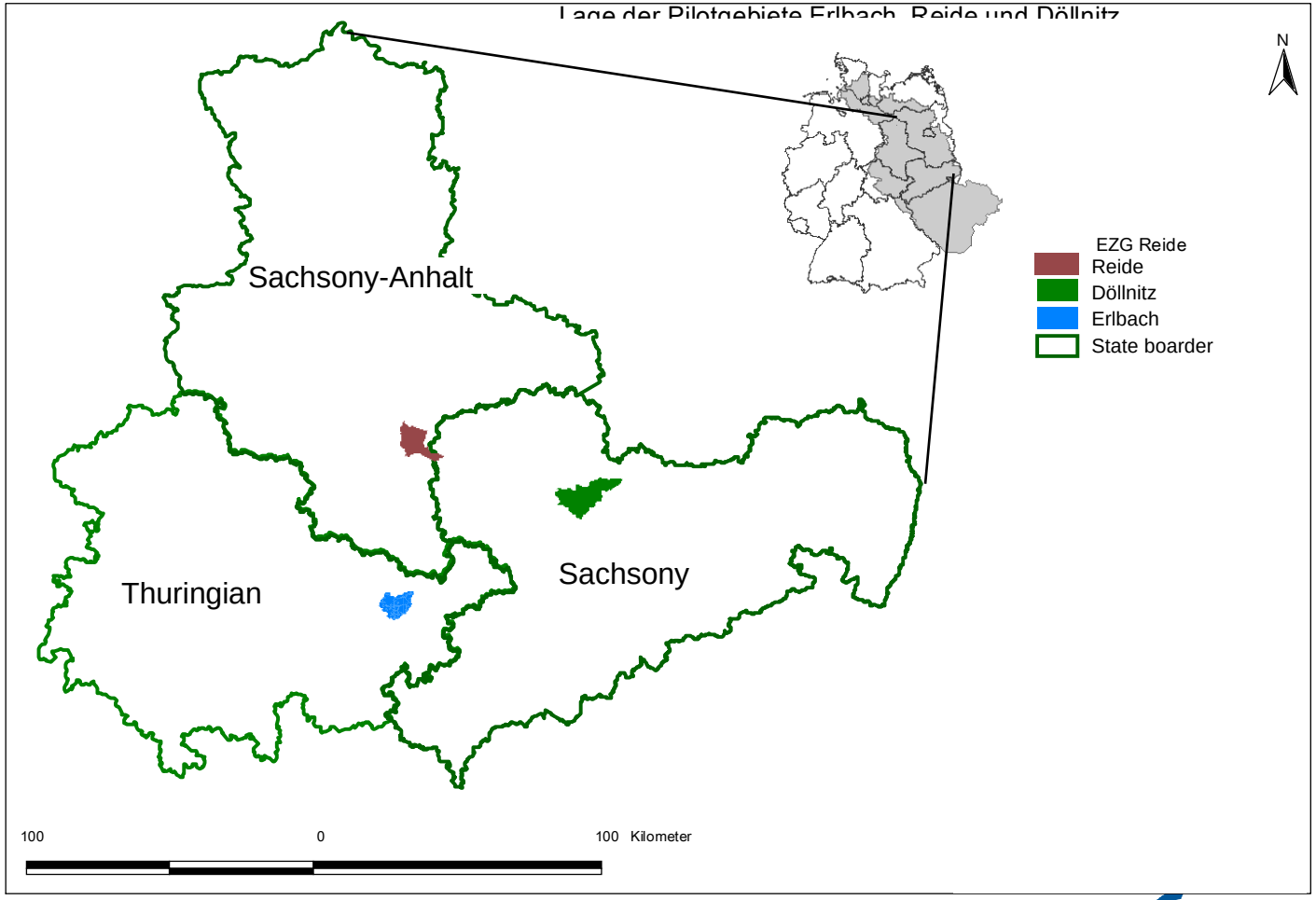
Study catchments: Erlbach, Döllnitz and Reide



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Hydrological characteristics of the study catchments Erlbach, Reide and Döllnitz

Catchment characteristic	Unit	Erlbach	Döllnitz	Reide
Area	km²	105	215	132
Elevation	m a. NN	280-360	98-312	105-115
Mean precipitation*	mm	751	677	606
Mean discharge*	mm	160	120	72.3
Mean temperature*	°C	8.4	9.4	9.6
Mean nitrogen concentrations	mgN/l	12.3	6.5	5.8

*1995-2005

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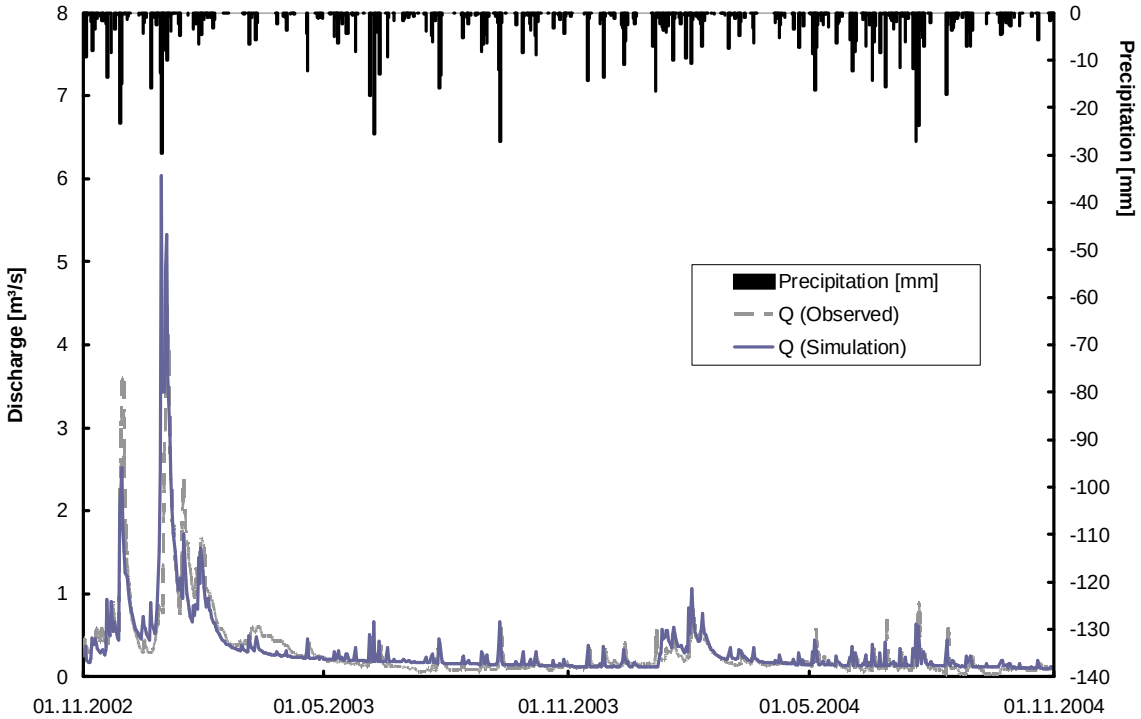
Observed and simulated discharge in the Reide catchment (calibration period)



	Water balance (mm/a)	
	Obs.	Sim.
Calibration	69.6	73.4
Validation	85.3	81.5

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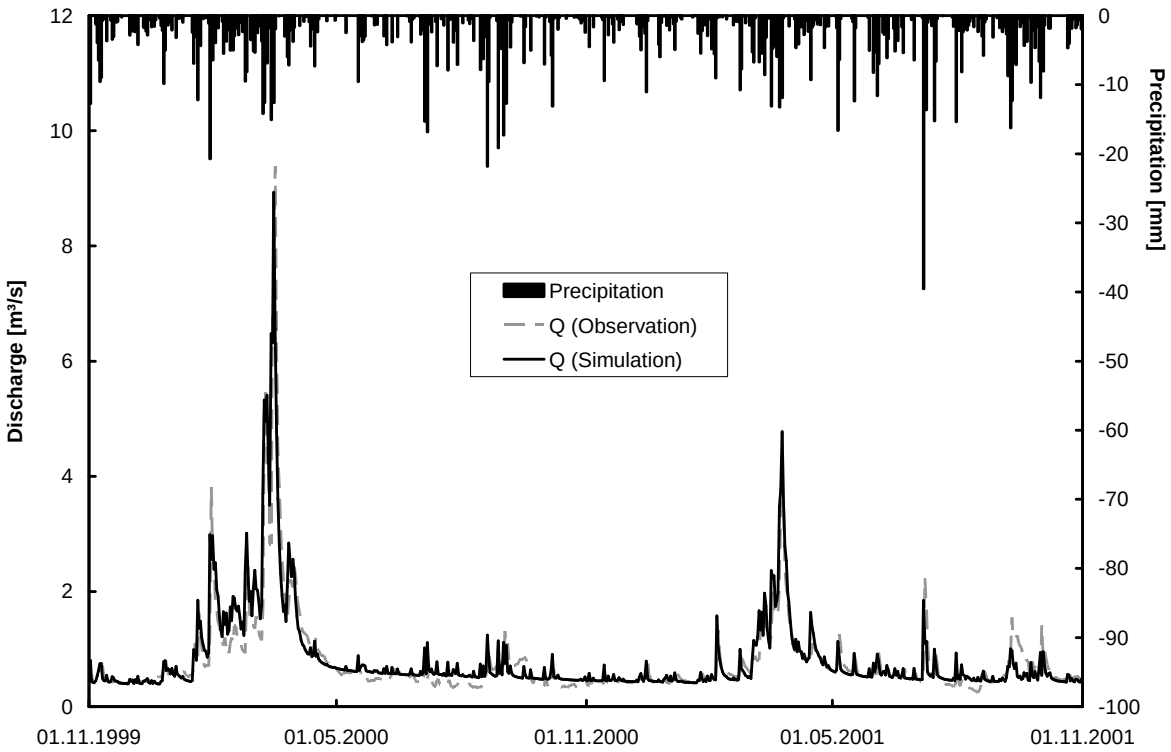
Observed and simulated discharge in the Döllnitz catchment (calibration period)



	Water balance (mm/a)	
	Obs.	Sim.
Calibration	132.5	136.6
Validation	109.6	104.5

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Simulated regional crop rotations in the study catchments

Catchment	Conventional farming					Organic farming	
Döllnitz	cr 1	cr 2	cr 3	cr 4	cr 5	cr 6	cr 7
	silo maize	maize	sugar beet	winter rape	potato	alfalfa	bean
	winter wheat	winter wheat	winter wheat	winter wheat	winter wheat	alfalfa	winter wheat
	pea	winter barley	spring barley	flax	pea	winter wheat	triticale
	silo maize	maize	winter rape	winter barley	winter barley	oat	clover-grass
	triticale	triticale	winter rye	triticale	set-aside	spelt	winter wheat
Reide	cr 1	cr 2	cr 3	cr 4		cr 5	
	silo maize	maize	sugar beet	winter rape		alfalfa	
	winter wheat	winter wheat	winter wheat	winter wheat		alfalfa	
	pea	winter barley	spring barley	durum wheat		winter wheat	
	winter wheat	winter rape	winter rape	winter barley		spelt	
	winter wheat	winter wheat	winter rye	triticale		clover-grass	
						oat	
Erlbach	cr 1	cr 2	cr 3			cr 4	
	winter wheat	winter wheat	winter wheat			triticale	
	pea	ryegrass	winter rye			clover-grass	
	winter barley	silo maize	spring barley			winter rye	
	winter rape	winter wheat	winter rape			oat	
						clover-grass	
						spring barley	
						clover-grass	

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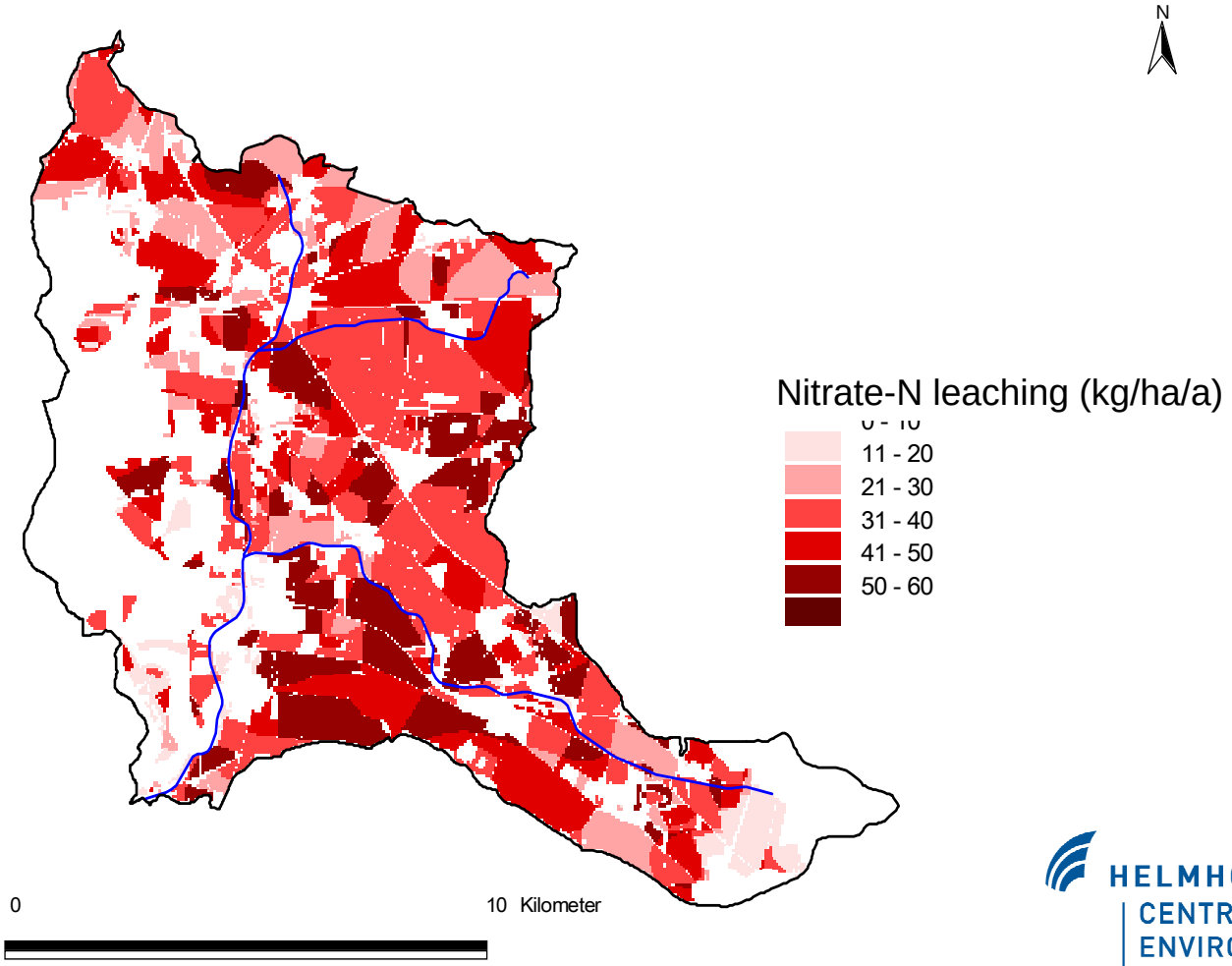
Catchment Reide - average nitrate N leaching form the soil zone (current land use, 1990-2005)



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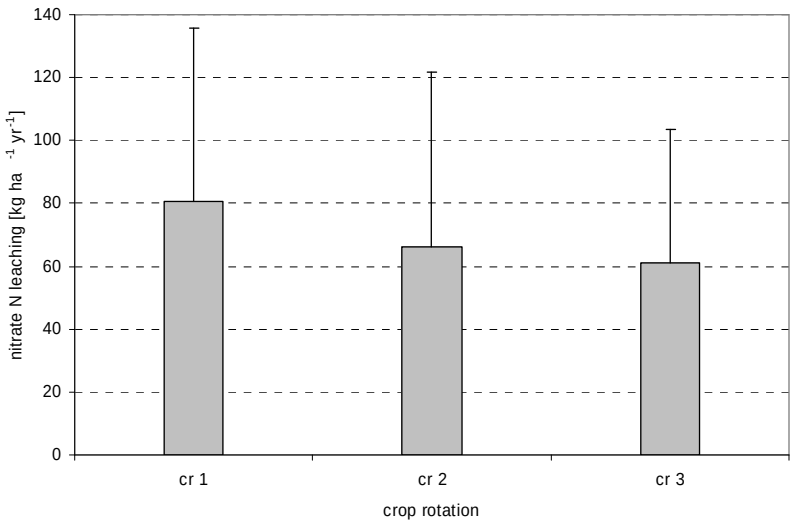
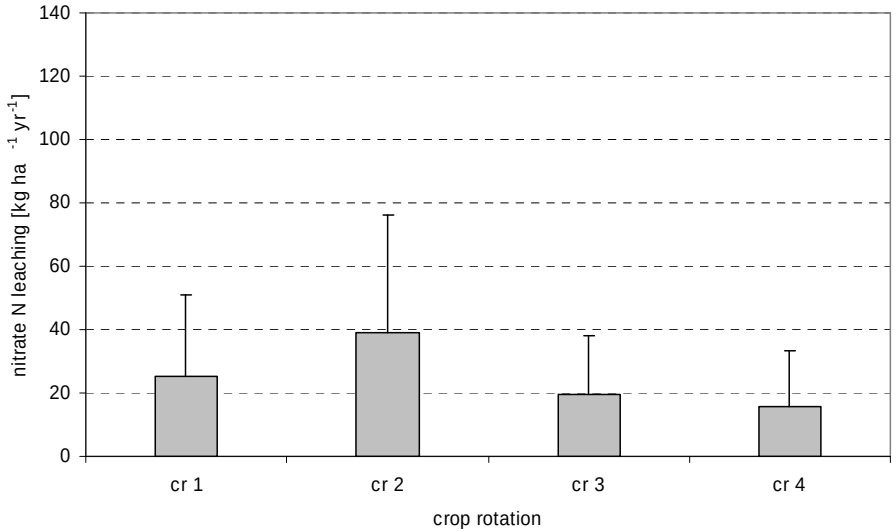
N-leaching of conventional crop rotations for the catchments Erlbach and Reide

Erlbach



Reide



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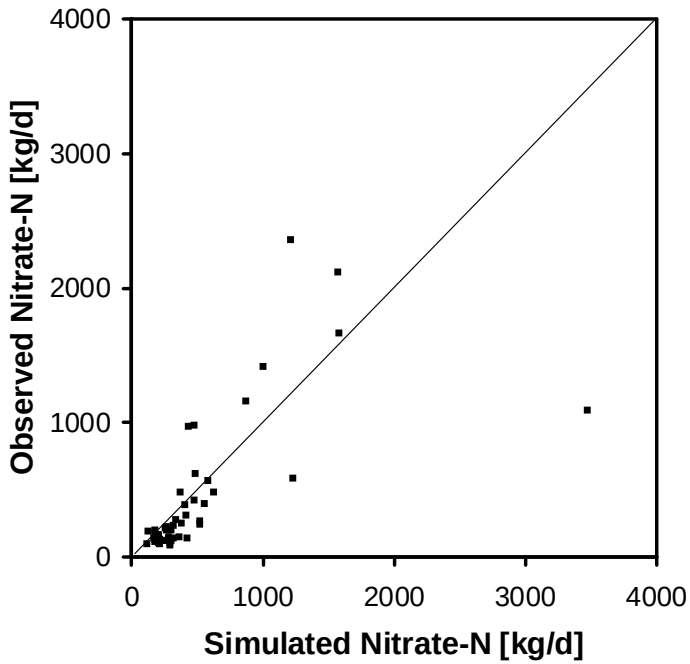
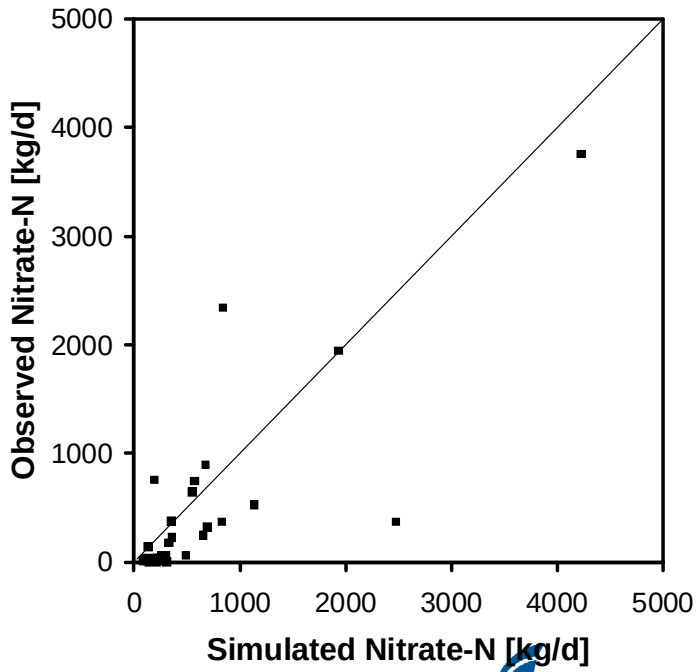
Observed and simulated daily NO_3-N loads in the study catchments

Döllnitz



Reide



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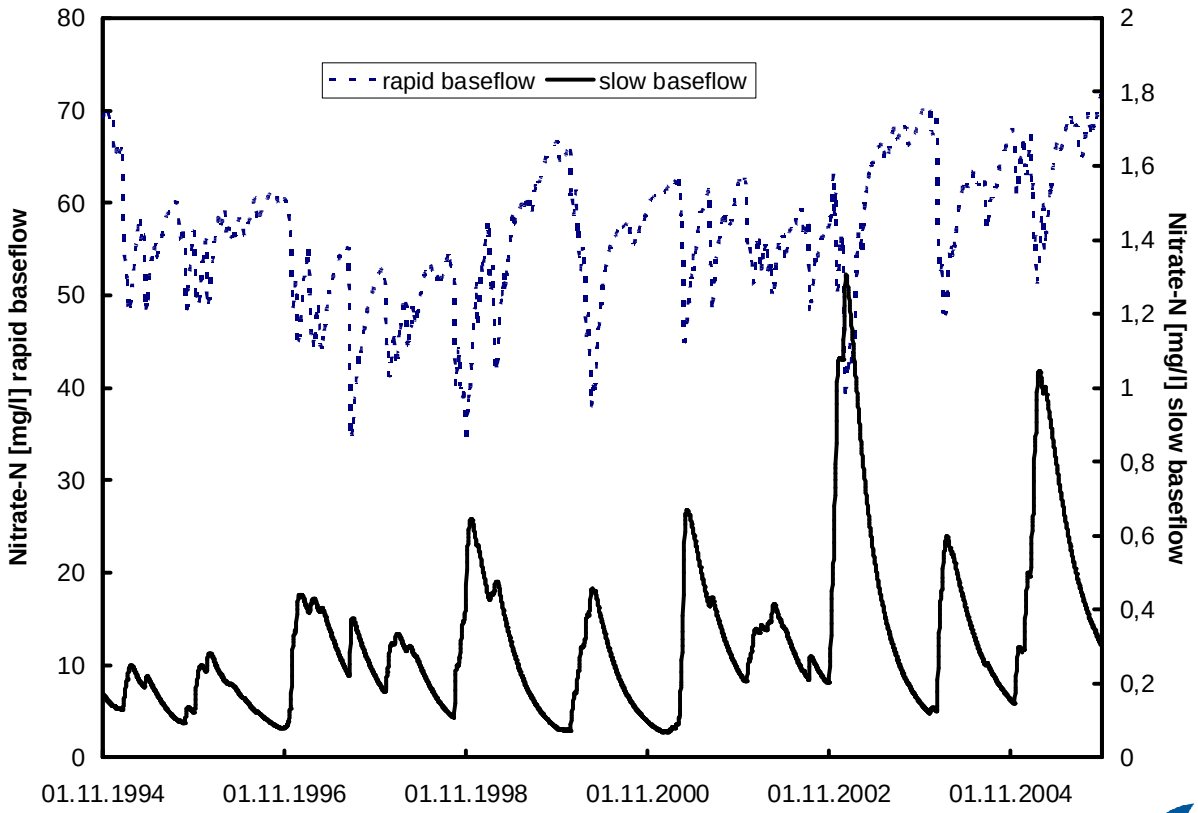
Simulated NO_3-N concentrations in subsurface flow components of the Reide catchment



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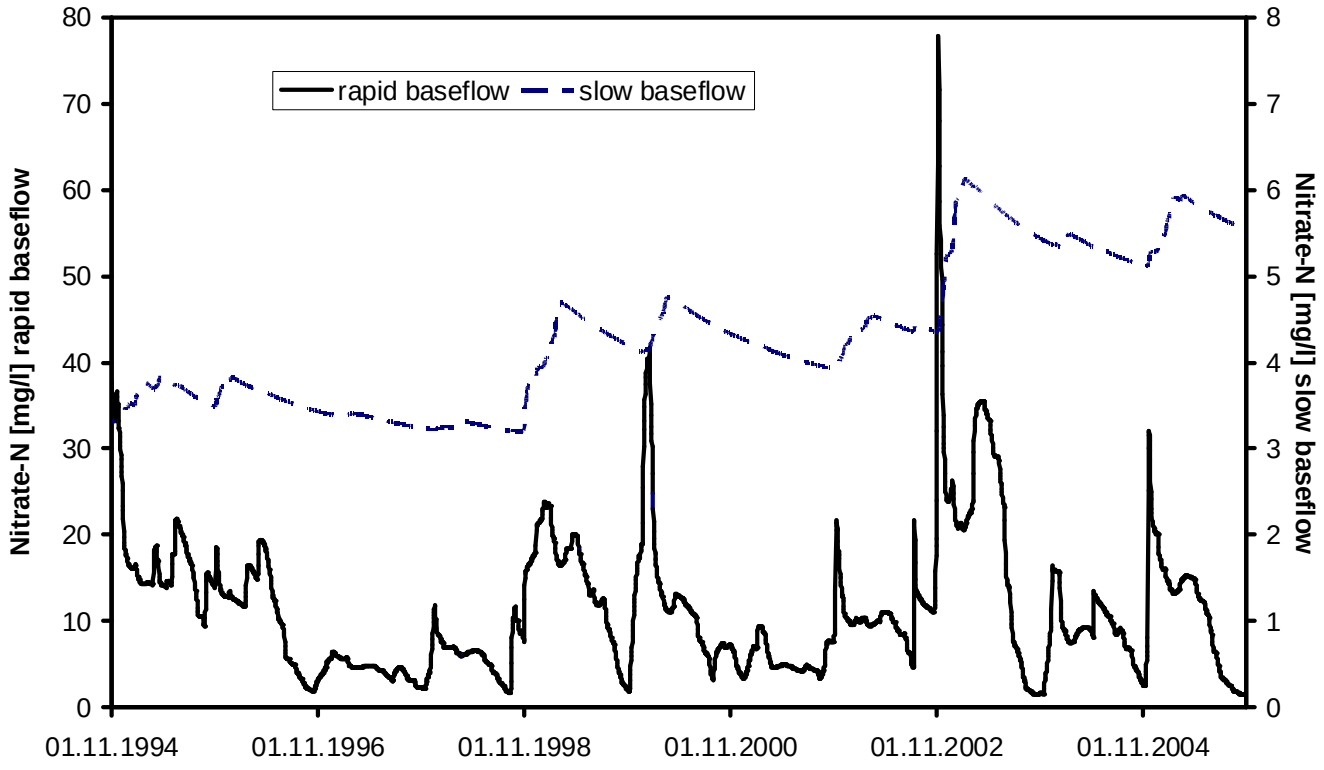
Simulated NO_3-N concentrations in subsurface flow components of the Döllnitz catchment



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Simulated nitrate-N reduction capacity for the baseline scenario

Year	Erlbach (t NO_3-N)	Döllnitz (t NO_3-N)	Reide (t NO_3-N)
1960	2450	13700	50200
1990	1060	9510	47900
2005	759	7750	46000

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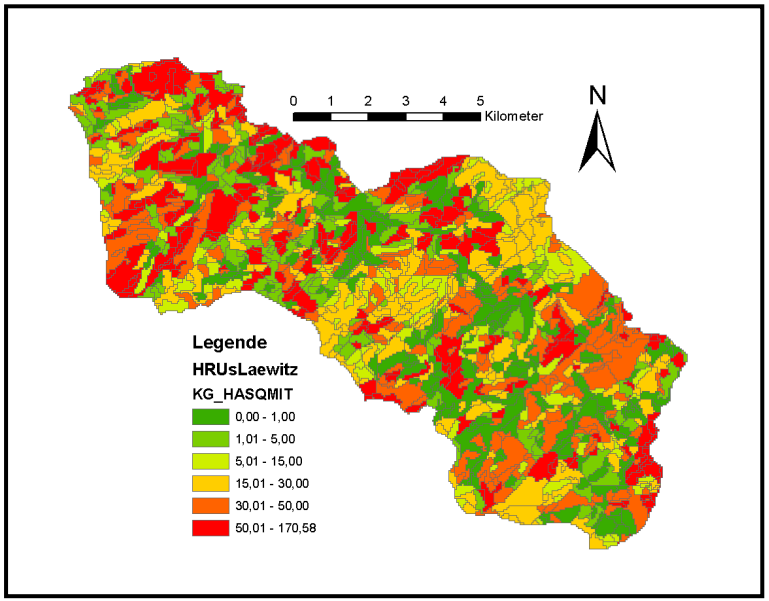

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Agricultural management scenarios

Scenario	Code	Acceptance (%)
Baseline	BL	-
Reduced N balance – objective 1	RO1-05	5
	RO1-10	10
Reduced N balance - objective 2	RO2-05	5
	RO2-10	10
Catch crops	CC-05	5
	CC-10	10
Conversion of arable land to pasture	AP-05	5
	AP-10	10
	AP-50	50
Organic farming	OF-05	5
	OF-10	10
	OF-50	50
Mineral fertilizer reduction of 25%, no organic fertilizer	FR-05	5
	FR-10	10
	FR-50	50

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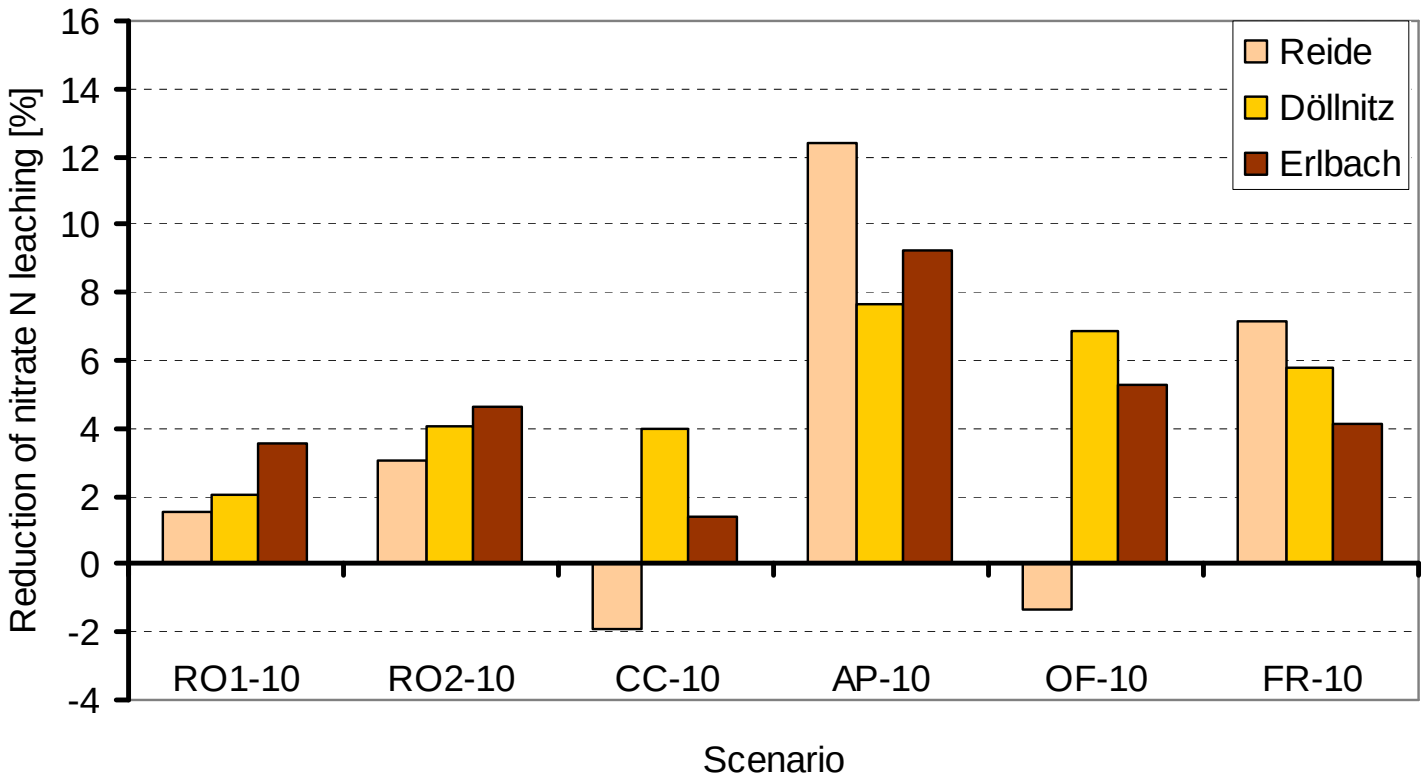
Average effects of the scenarios at 10 % acceptance level compared to the baseline



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Reduction of nitrogen loads compared to the baseline scenario

Scenario/ Catchment	Erlbach (%)	Döllnitz (%)	Reide (%)
RO1-10	2.4	2.0	2.2
RO2-10	3.2	3.9	3.0
CC-10	0.5	4.1	-1,1
AP-10	6.7	8.3	12.5
AP-50	45.2	-	50.3
OF-10	4.5	6.5	-1.2
OF-50	27.1	-	-8.0
FR-10	3.0	5.1	5.5
FR-50	16.2	25.8	23.2

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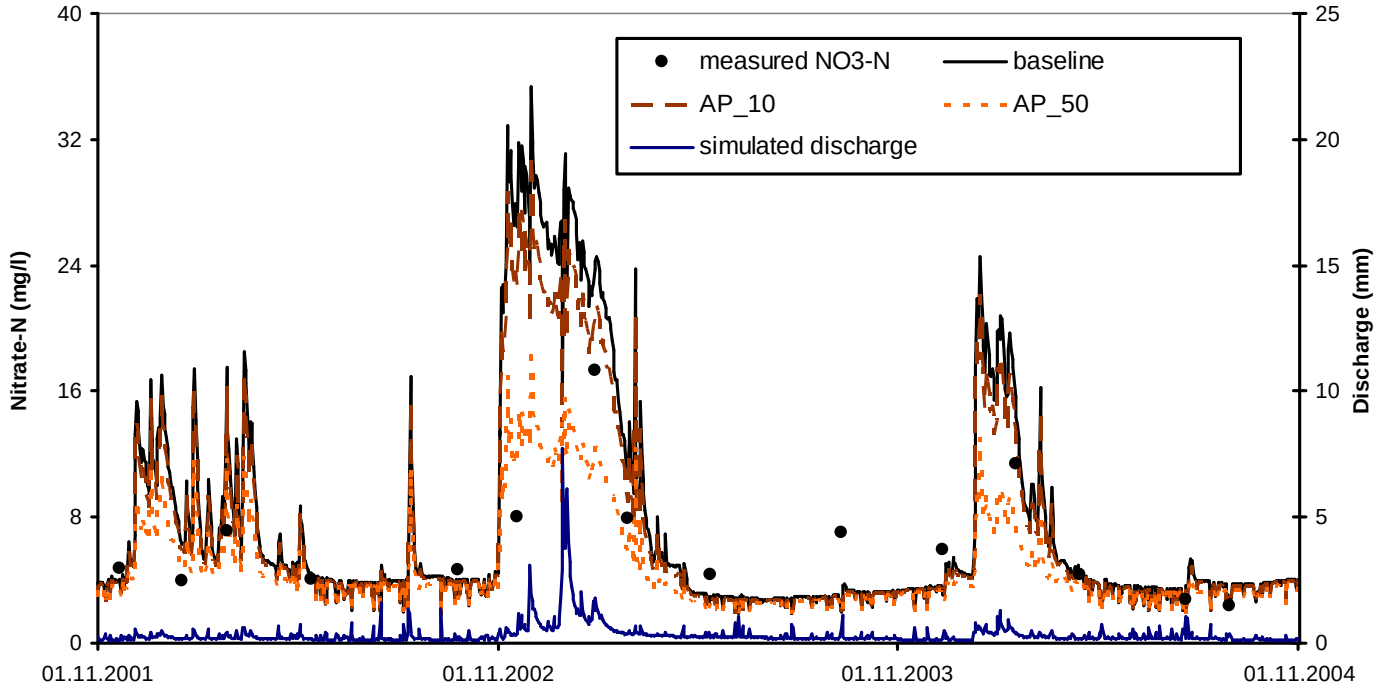
Simulated nitrate concentrations and discharge for baseline conditions and selected management options (Reide catchment)



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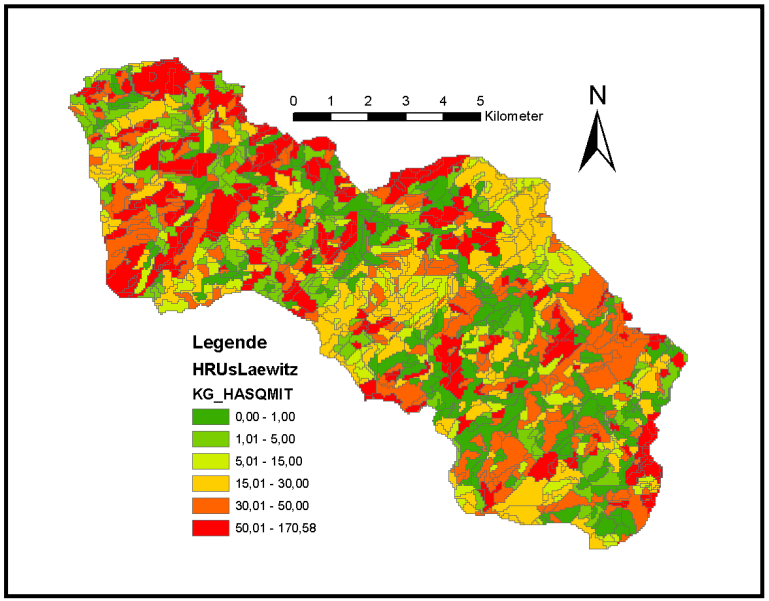

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Conclusions

- The modeling system allows the analysis of spatially distributed nitrate-N transport and denitrification in the subsurface
- Agricultural management options have very site specific partly contrary effects
- Considerable reduction of nitrogen loads can only be achieved through strongly reduced agricultural intensities
- Denitrification processes have no important impact on the ranking of management scenarios
- Nitrate reduction capacities of the subsurface were important for baseflow nitrate concentrations

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