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Institute for the Conservation of Natural Resources

Effect of best management practices on water quality in a lowland catchment

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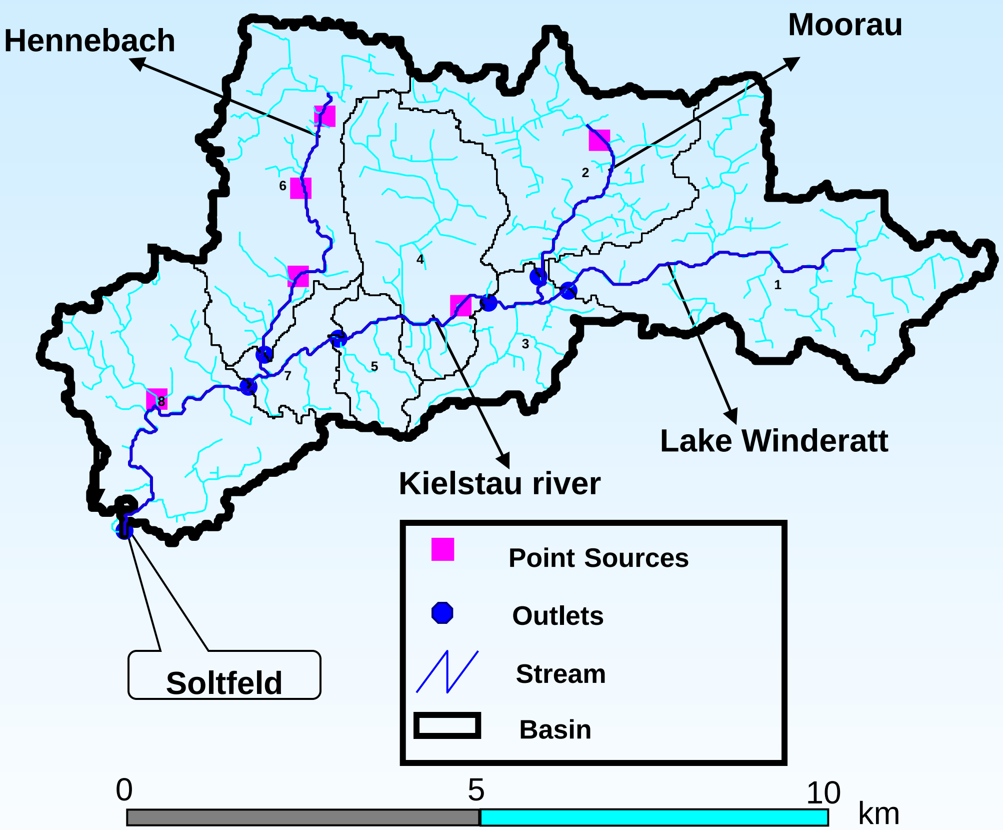
Research area – Kielstau catchment

Precipitation
870 mm/a

Mean annual temperature
8.2° C

North German lowland

Research area – Kielstau catchment



- Area: 50 km^2
- River length: 17 km
- Max. elevation: 79.9 m
- 2 main tributaries
- Rural area
- Population: 4.500 people
- UNESCO Demosite (IHP Ecohydrology Program)

Environmental problems in the Kielstau catchment

Problems

- High nutrient concentrations
- Eutrophication

Pollution sources

- Agricultural non-point sources pollution
- Wastewater treatment plants (WWTPs)

Objectives

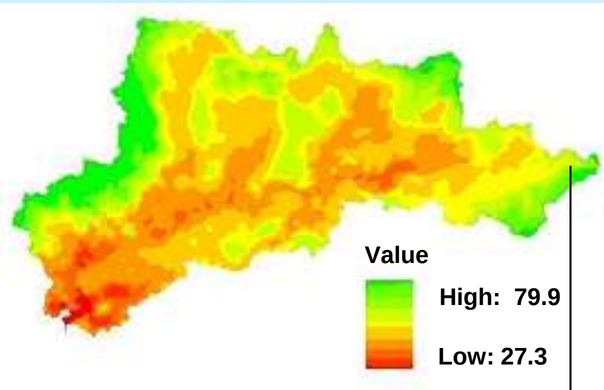
1. to evaluate the long-term impact of point and diffuse source pollution on nutrient loads in lowland catchments using the SWAT model

2. to identify the impacts of different land use management scenarios on diffuse source nutrients as well as to select appropriate management scenarios based on the trade-off relationship between the cost-effectiveness of Best Management Practices (BMPs)

3. to identify crucial areas which provide great nutrient loads based on the spatial distribution maps of nutrient loads

Input / output data for Kielstau catchment

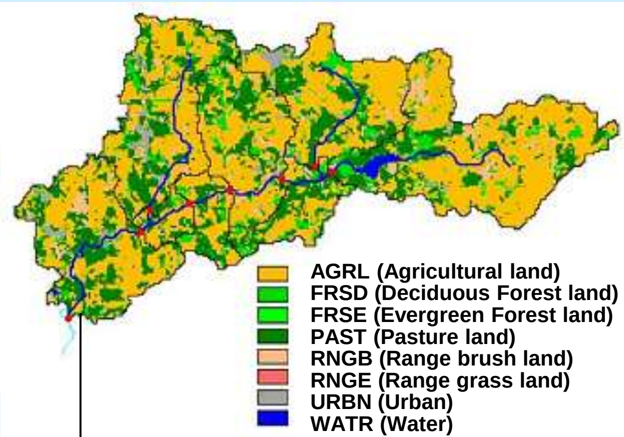
DEM (LVermA, 1995)



27 - 79 m ASL

2% mean slope

Land use (DLR, 1995)

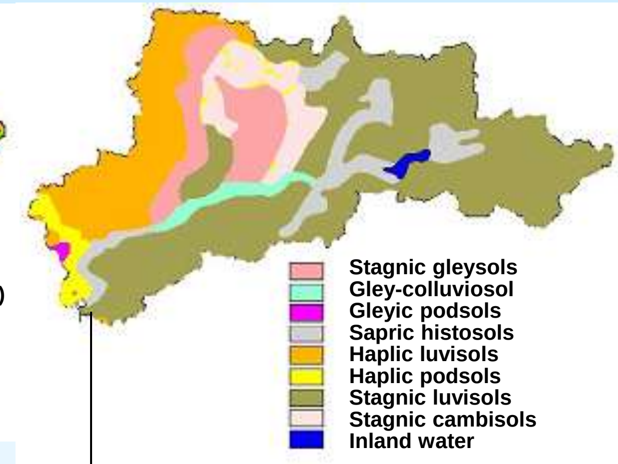


56% arable land

26% pasture

9% forest

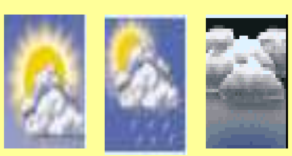
Soil map (BGR, 1999)



50% Stagnic Luvisols

20% Haplic Luvisols

Climate data (DWD, 2009)



SWAT

Agricultural practices

- Crop rotations
- Fertilizer applications (LWKSH, 2006)

Output

Discharge

Nitrogen

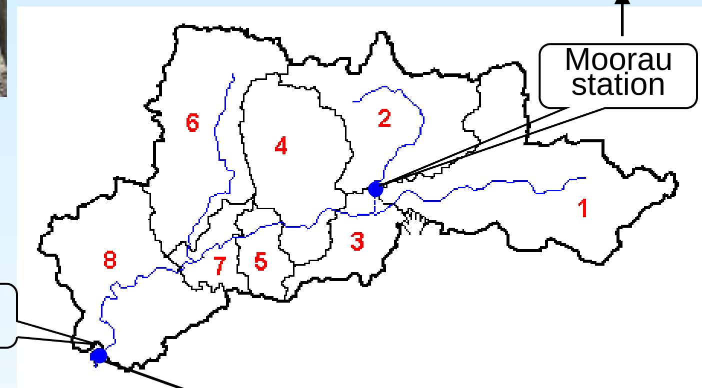
Measured data and model setup

- SWAT version 2005
- 8 subbasins
- 154 HRUs
- Measured water quality parameters:

  -Susp. Sediment
  -NO_3-N, NH_4-N, TN
  -PO_4-P, TP

Measured data Moorau

- Discharge: Jul. 2007 – Jun. 2009
- Water quality: Nov. 2007 – Mar. 2009 (CAU Kiel)



Soltfeld

Measured data Kielstau

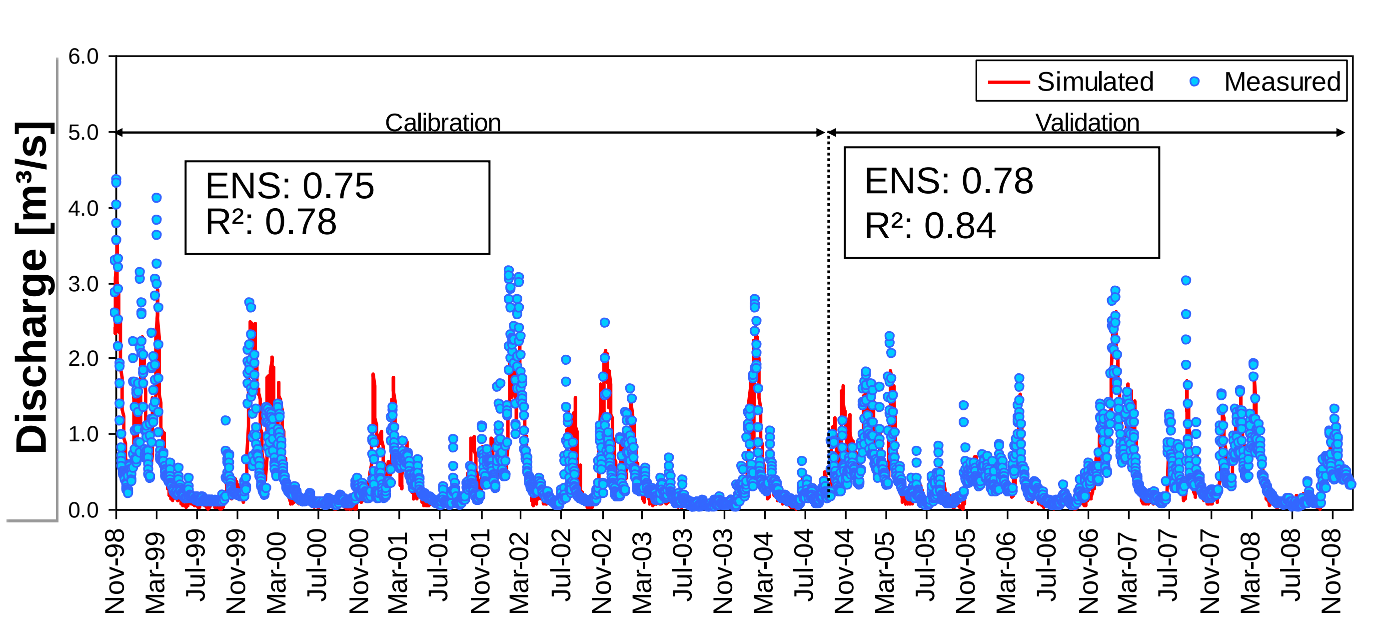
- Discharge: 1998-2008 (StUa Schleswig, 2009)
- Water quality: 2006-2008 (CAU Kiel)

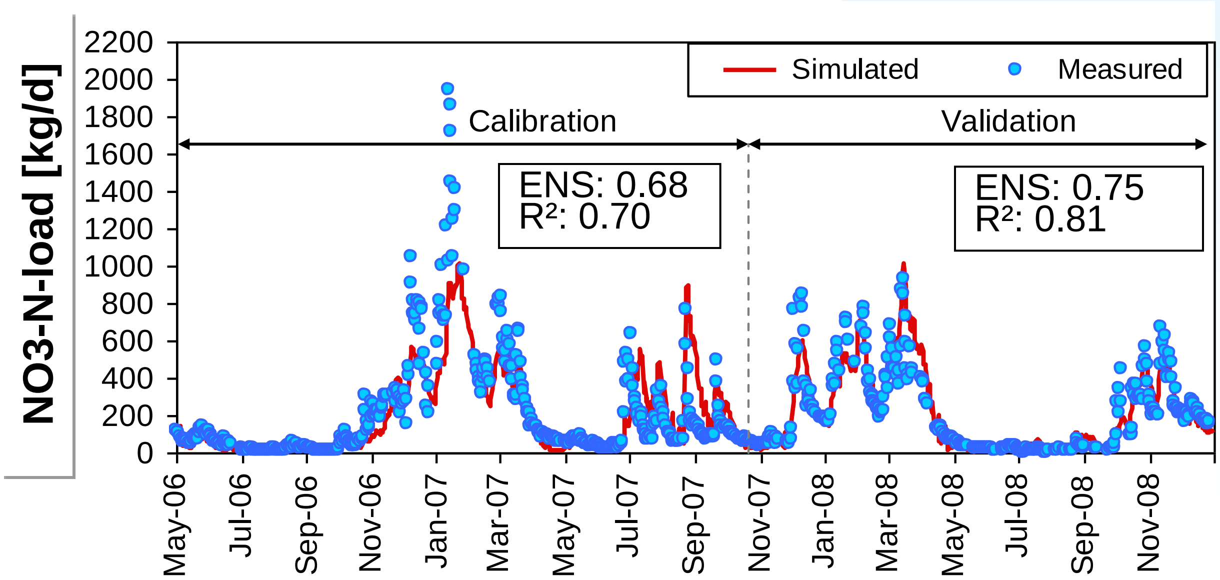
Consti-tuent	Calibration	Validation
Discharge	1998 - 2004 (Auto-calibration)	2004 - 2008
Sediment	Oct. 2006 – Oct. 2007	Nov. 2007 – Dec. 2008
Nutrients	May 2006 – Oct. 2007	Nov. 2007 – Dec. 2008

Baseline model

- ✓ SWAT performed satisfactorily in simulating daily flow, sediment and nutrient loads at the outlets of the Kielstau and Moorau catchment.

Discharge and nitrate load, Kielstau





Baseline model: I Flow

- ✓ Groundwater parameters are found to be most sensitive and they turned out to be the most influential factors on water discharge.
- ✓ Groundwater is found to be the dominant flow component.

Baseline model: II Nutrients

- ✓ Groundwater parameters are found to be most sensitive and they turned out to be the most influential factors on water discharge.
- ✓ Groundwater is found to be the dominant flow component.
- ✓ Diffuse sources are the dominant entry pathways of nitrate in the whole catchment.
- ✓ Agriculture is found to be the dominant source of diffuse water pollution.
- ✓ Shallow groundwater flow was the major source of nitrate in the stream.

Comparison measured data and LAWA class II

Watershed	Variable	Unit	Period	Mean value	WFD target value*
Kielstau	Average discharge	m³/s	01/1993 - 12/2008	0.43	-
	Average NO_3-N	mg/l	05/2006 -12/2008	4.48	2.5
	Average NH_4-N	mg/l		0.15	0.3
	Average TN	mg/l		5.81	3.0
	Average PO_4-P	mg/l		0.18	0.1
	Average TP	mg/l		0.23	0.15
Moorau	Average discharge	m³/s	07/2007 - 06/2009	0.09	-
	Average NO_3-N	mg/l	11/2007 - 3/2009	7.39	2.5
	Average NH_4-N	mg/l		0.85	0.3
	Average PO_4-P	mg/l		0.16	0.1

*WFD (2000), LAWA (1998), class II

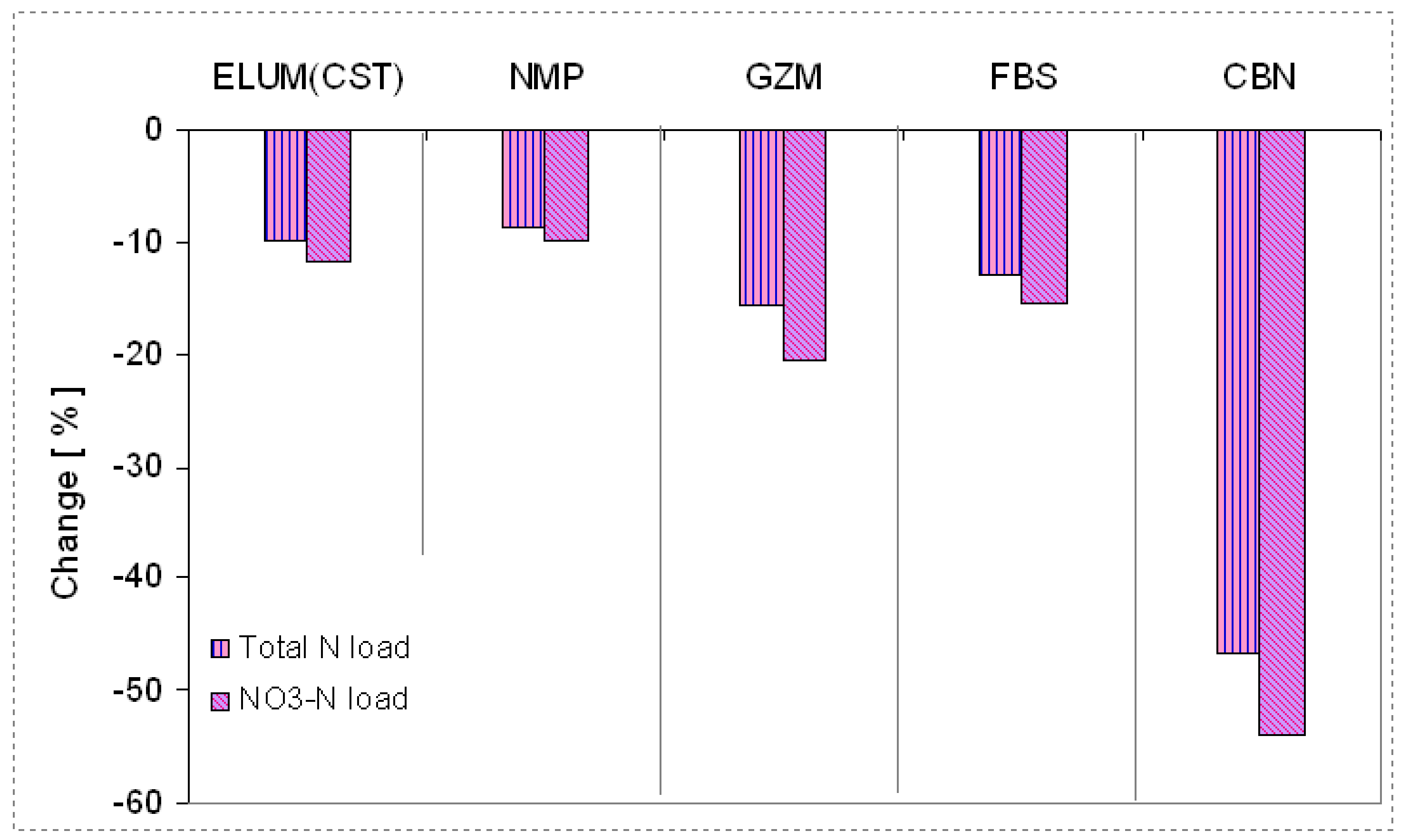
(yellow) nitrogen parameters, moderate to poor ecological status

⇨ **Nitrogen** parameters need to be improved

Implementation of BMPs on the lowland areas

Measure	Description	Code
Extensive land use management	Combination of different crop rotations and tillage (CST: conservation tillage and WRyRy rotation)	ELUM
Nutrient management plan	Reducing nutrient application (both mineral fertilizer and manure) in arable land by 20%	NMP
Grazing management practice	Reduction of livestock density from 2 to 1.1 LU/ha and no fertilizer application on pasture land	GZM
Field buffer strip	Application of 10 m field buffer strips on arable and pasture land. Field buffer strips are installed along the edge of main channel	FBS
Combination scenarios	Combination of the 4 single scenarios	CBN

Impact of BMP implementation, Kielstau

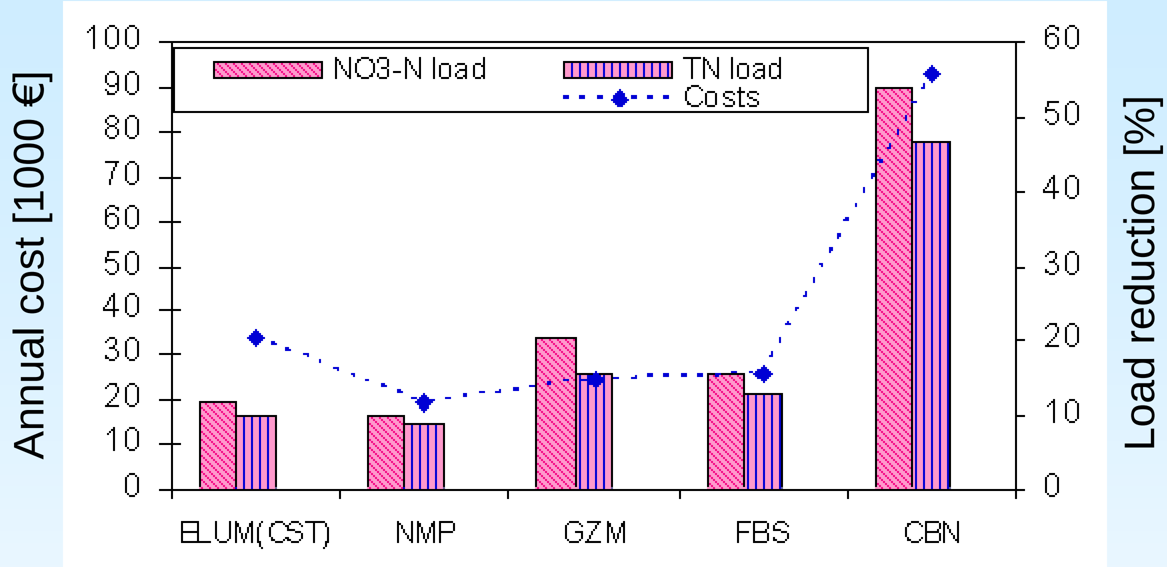


Load reduction

Parameters	Single BMP	Combined BMPs
NO3-N	9.9% – 20.5%	53.9%
TN	8.6% – 15.6%	46.7%

Costs and effectiveness of BMPs, Kielstau

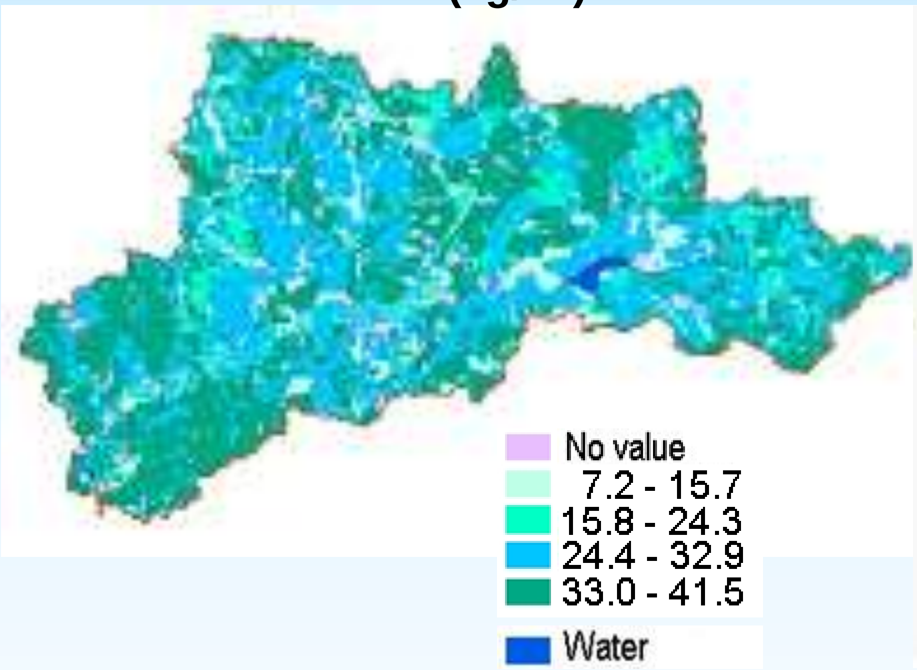
- Annual cost for single BMPs range: 19.000 - 34.000 €
- Most expensive single BMP was ELUM
- CBN: largest reduction with 93.000 €/a



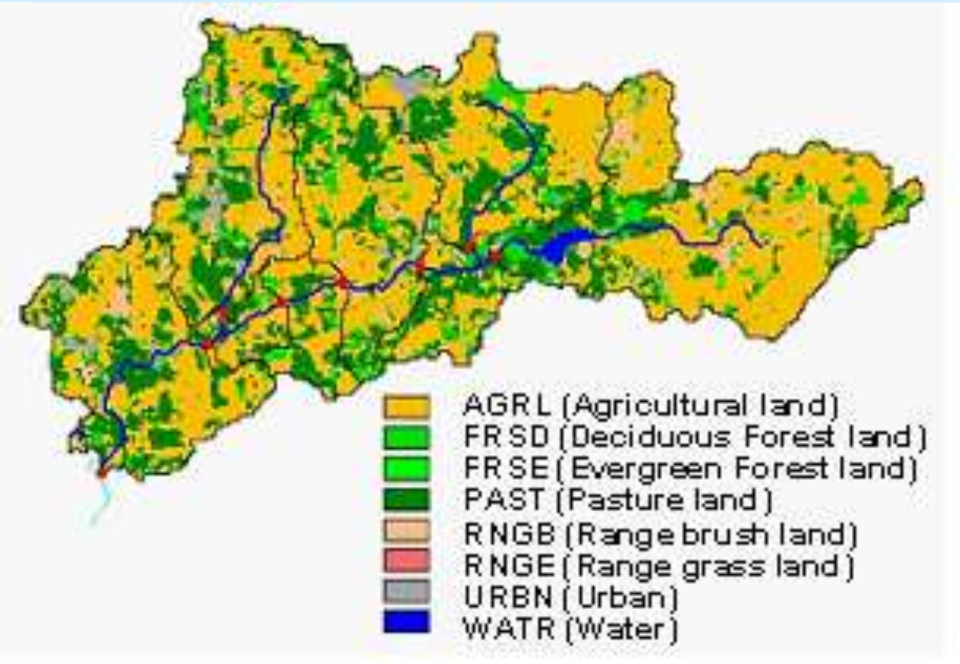
BMPs	Life-time (year)	Unit	Annual cost
ELUM (Extensive land use management)	1	€/ha	17.83
NMP (Nutrient management plan)	3	€/ha	7.17
GZM (Grazing management practice)	25	€/ha	24.40
FBS (Field buffer strip)	25	€/100m	19.60

Spatial distribution of TN loads and land use, Kielstau

TN load (kg/ha)

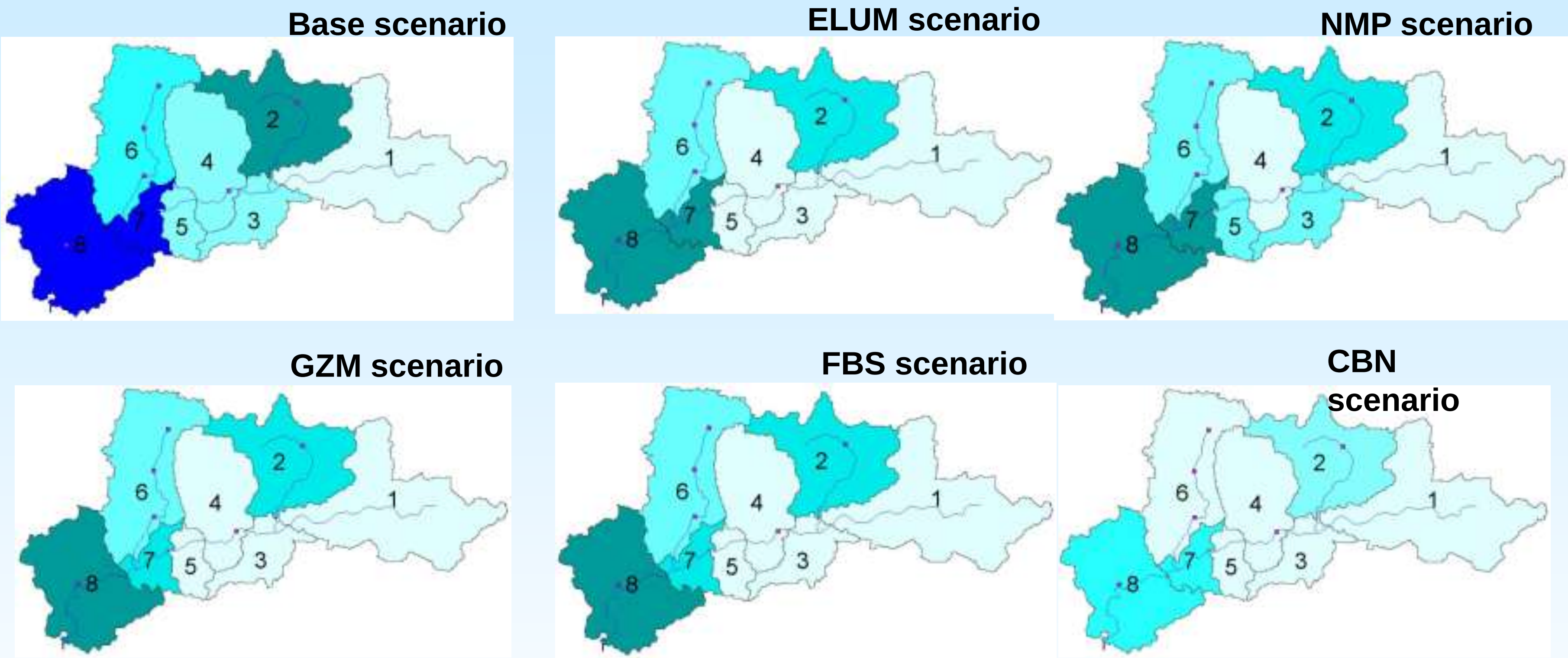


Land use (DLR, 1995)

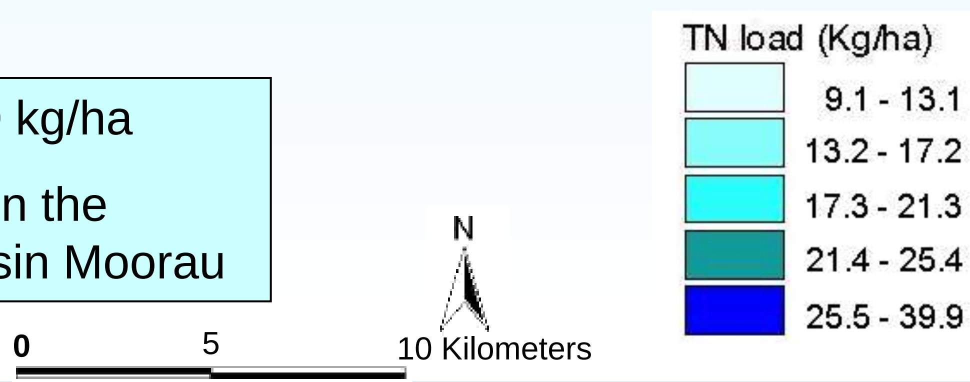


- High TN loads are mostly originated from HRUs which are covered by arable land
- Forest land is found to be the lowest contributor to TN loads

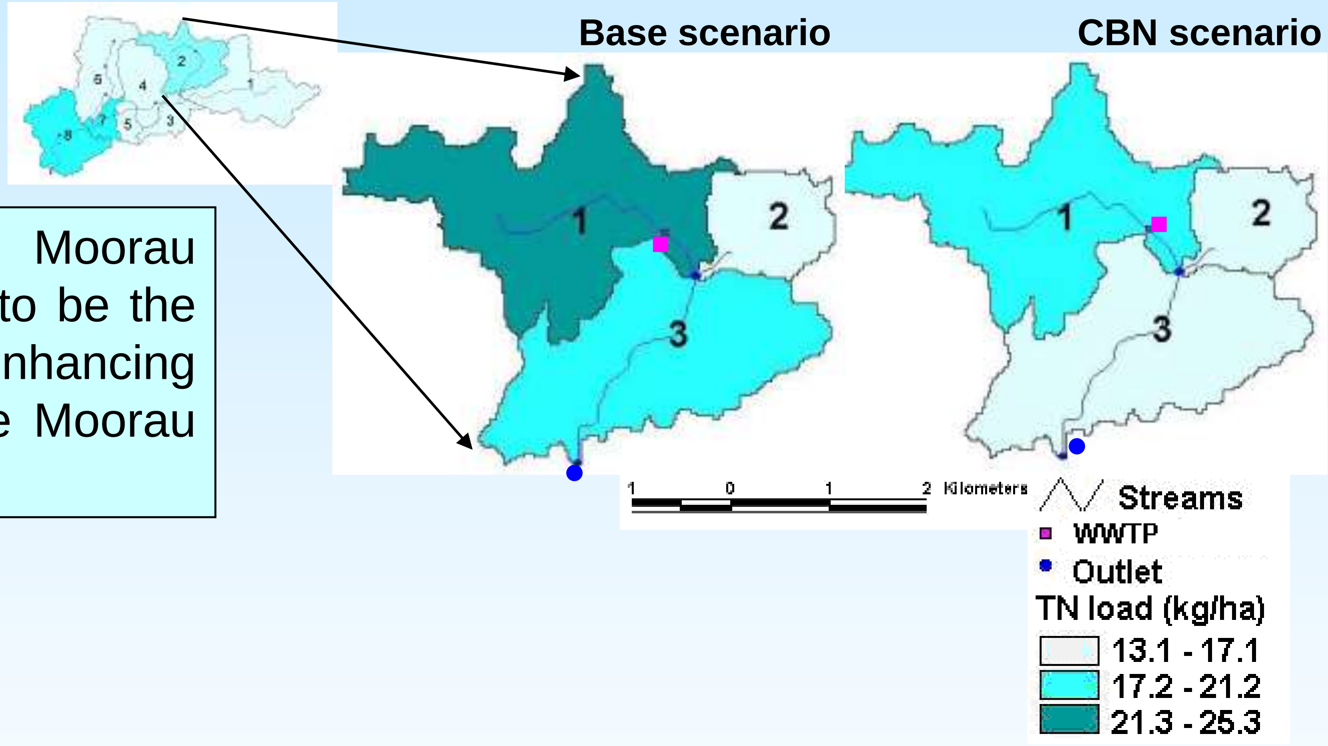
Impact of BMPs on spatial distribution of annual TN load, Kielstau



- TN load from subbasins: 9 - 40 kg/ha
- The highest TN load occurred in the subbasin 8, followed by subbasin Moorau

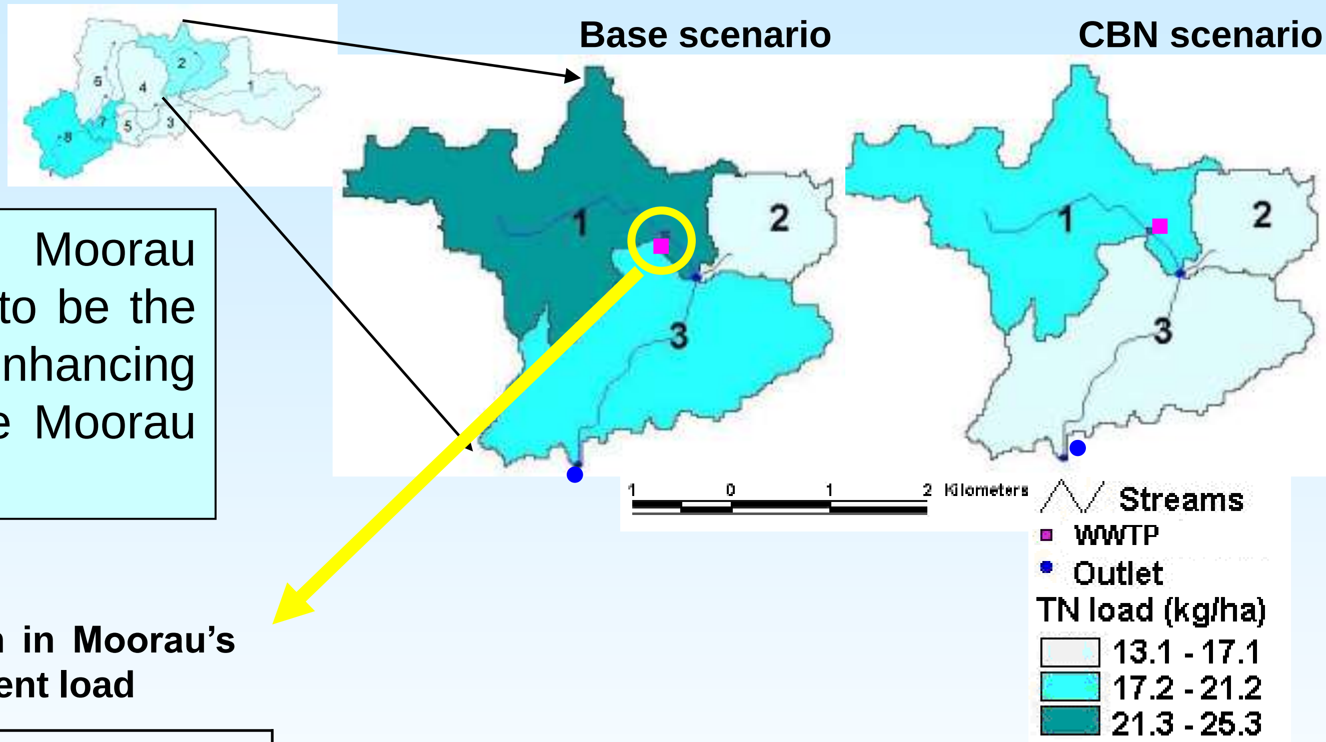


Impact of BMPs on spatial distribution of annual TN load, Moorau



Subbasin 1 of the Moorau catchment is found to be the most nutrient load enhancing pollution level at the Moorau outlet

Impact of BMPs on spatial distribution of annual TN load, Moorau



Subbasin 1 of the Moorau catchment is found to be the most nutrient load enhancing pollution level at the Moorau outlet

Impact of 20% reduction in Moorau's WWTP emission on nutrient load

Catchment	Reduction in TN load (%)
Kielstau	1.7
Moorau	7.6

20% nitrogen reduction in WWTP of Moorau reduced considerably N load at the Moorau outlet and also improved water quality at the Kielstau catchment

Conclusions

The implementation of BMPs in the SWAT model shows significant effects on the water quality of the Kielstau catchment:

✓Reduction only in one type of BMP did not obtain the water quality target value for EU-WFD.

✓The combination of BMPs improved considerably the water quality, achieving a 54% and a 47% reduction in nitrate and total nitrogen load, respectively, with annual implementation costs of 93,000 Euro.

✓Applying a spatially distributed modeling approach was an appropriate method to identify the crucial pollution areas within a watershed.

Thanks for your attention!

For further questions:

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Reference list

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