How Realistic is the Implementation of the European Water Framework Directive in River Basins Dominated by Agriculture?

The Example of the Upper Ems River Basin (Germany)

Stefan Liersch, Martin Volk

Department of Computational Landscape Ecology

Contact: stefan.liersch@ufz.de

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- Site description
- Objectives
  - Development of a potential land use scenario achieving the environmental objectives of the WFD
- Land use scenarios implementation
- Results
- Conclusions

OUTLINE

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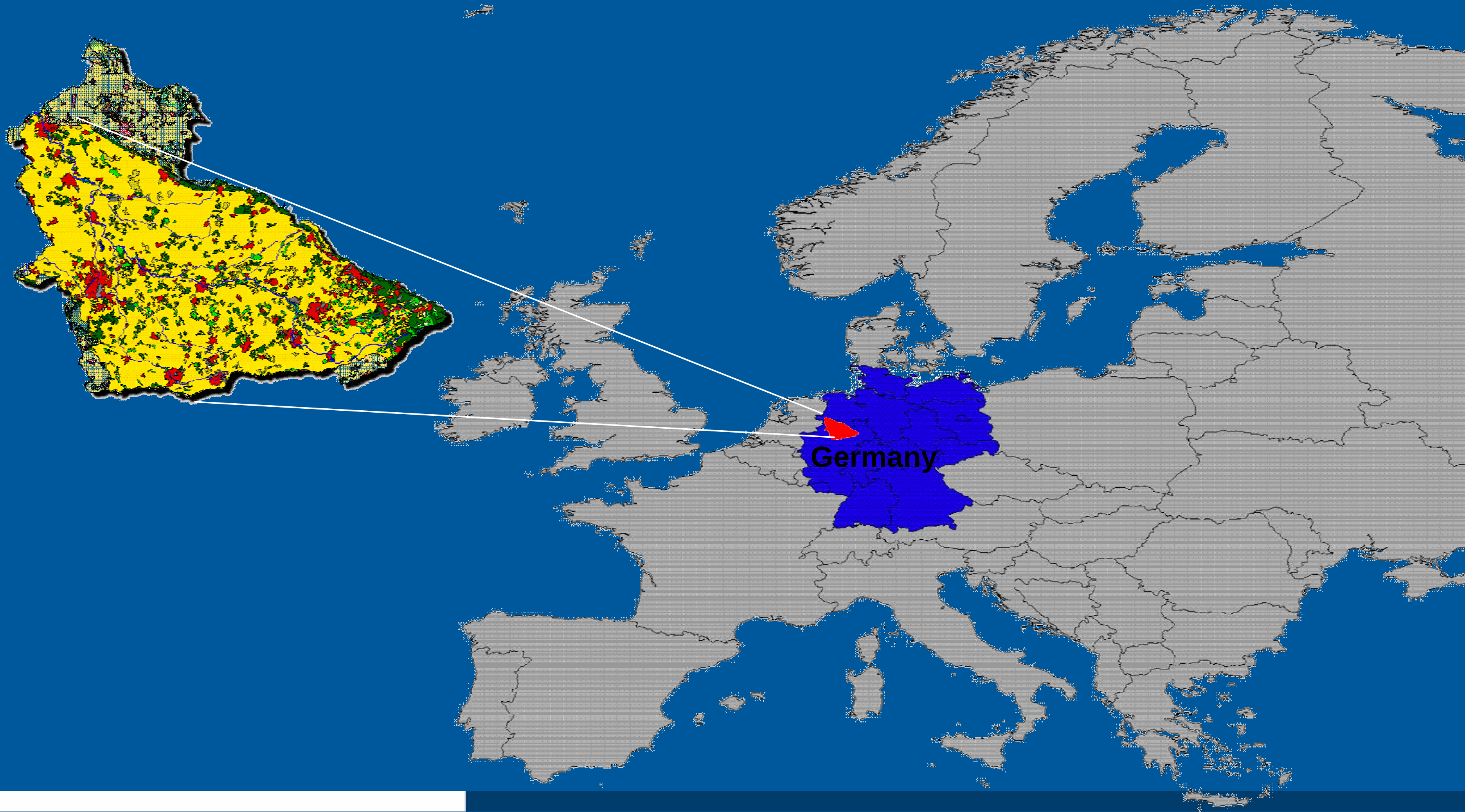

STUDY AREA

Location

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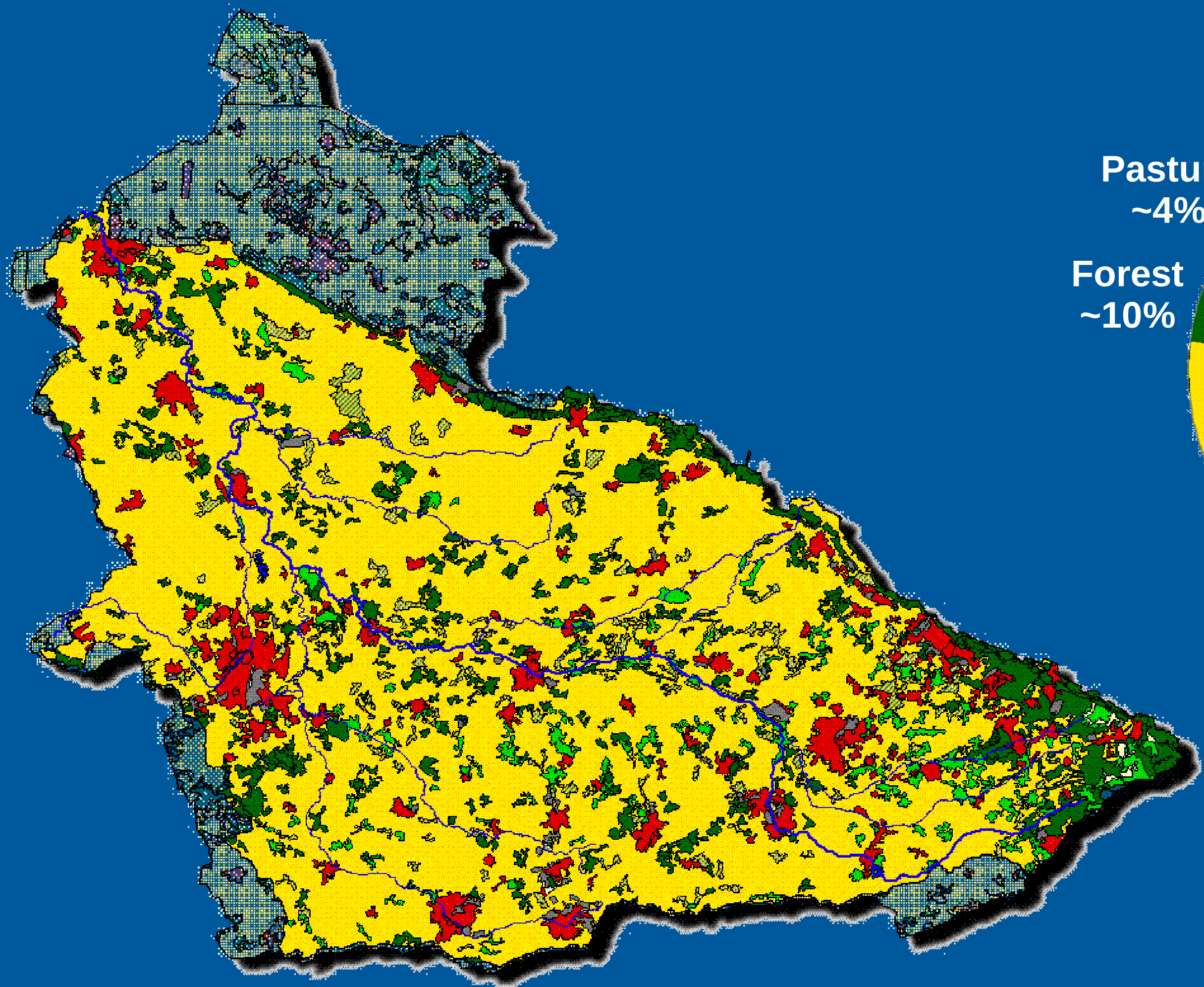

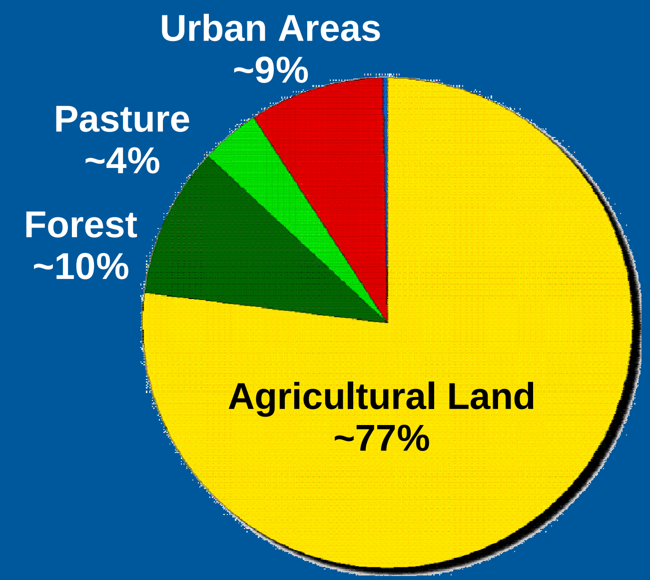

Catchment Area

~3500 km²

STUDY AREA

Land Use

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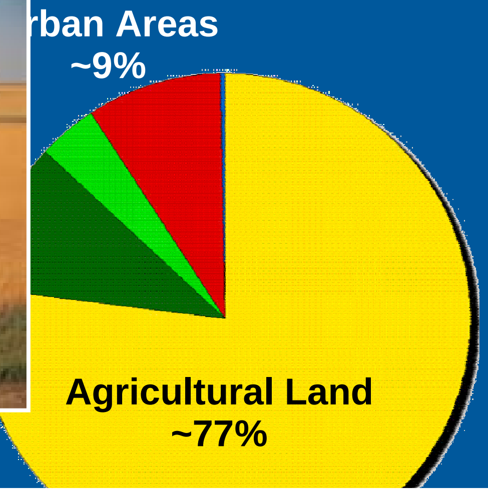

STUDY AREA

Land Use

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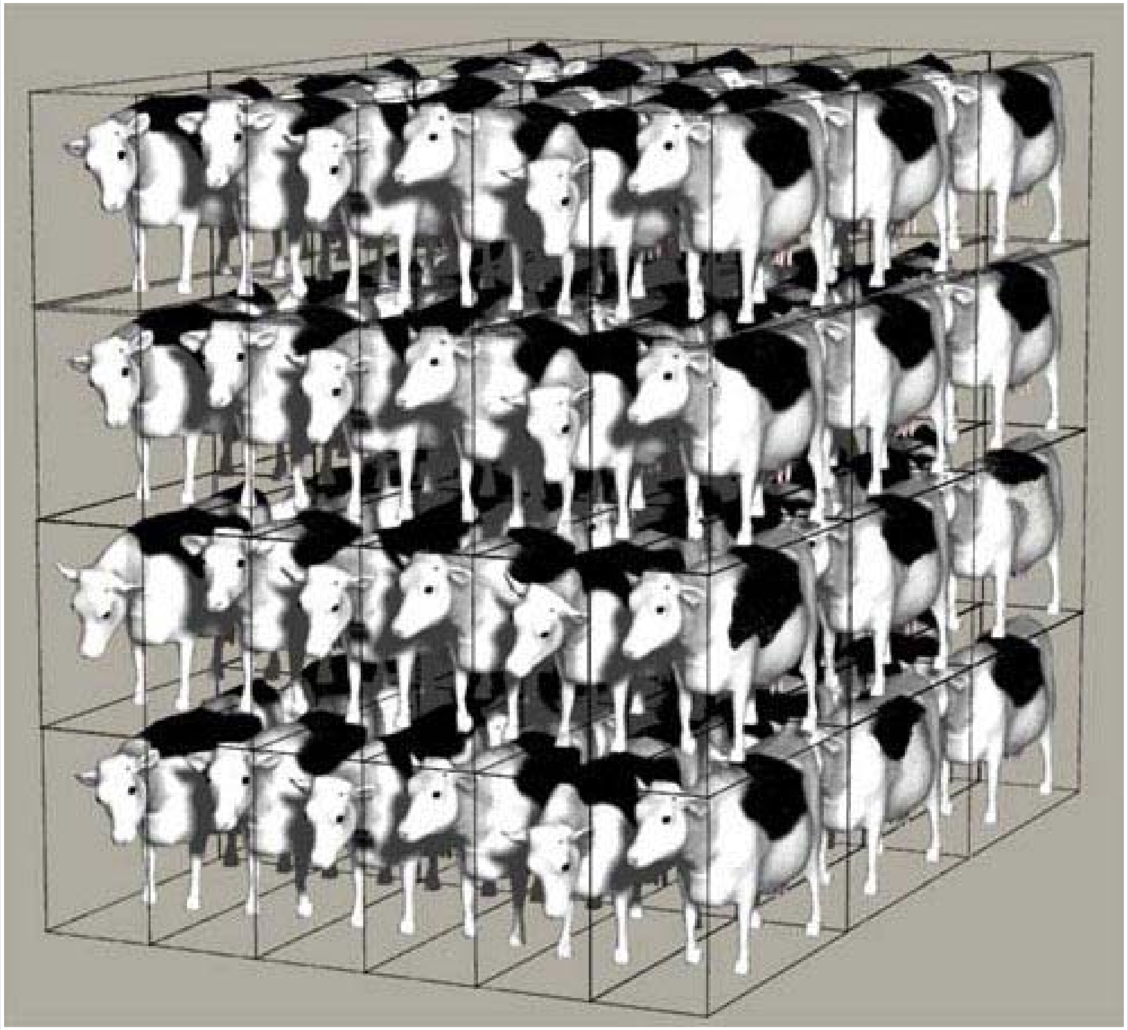

Large amounts of mineral and organic fertilizers

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- Belongs to the most intensive used agricultural regions in Europe
- Mainly sandy (permeable) soils
- Mean annual precipitation: 600 to 1200 mm/a
- Mainly flat, altitudes up to 360 m a.s.l.
- River morphology: heavily modified / regulated

“poor” soils → large amounts of fertilizers
sandy soils → high percolation rates

STUDY AREA

Characteristics

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- Nitrogen concentrations in surface and groundwater bodies exceeding limit values
- Land use is far from sustainability
- Far from achieving the water quality standards of the Water Framework Directive (WFD)

MAIN PROBLEMS

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Good ecological and chemical status of the water environment (water bodies)

Limit values for nitrogen, water quality class II (LAWA, 1998)

	Total N	Nitrate-N	Nitrite-N	Ammonium-N
Maximum concentration [mg/l]	<= 3.0	<= 2.5	<= 0.1	<= 0.3
STUDY AREA	**~ 6-10**	**~5.4**	**~0.2**	**~0.3**

OBJECTIVES of the European WFD

- **Development of a potential land use scenario which meets the standards of the WFD concerning the chemical water quality.**

FLUMAGIS

River basin management with geoinformation systems

www.flumagis.de

From a natural scientist point of view **!**

(not taking socio-economic aspects into account)

OBJECTIVES OF THE STUDY

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- **Overall goal: Reduction of nutrient inputs into the ecosystem**
  - Reduction of agricultural land
  - Introduction of environmentally friendly management practices
- Step-wise implementation of different measures
- Scenario development on the basis of policy instruments
  - Water Framework Directive (WFD)
  - Common Agricultural Policy of the EU (CAP)
  - Local landscape development program (KULAP)

LAND USE SCENARIOS

Development

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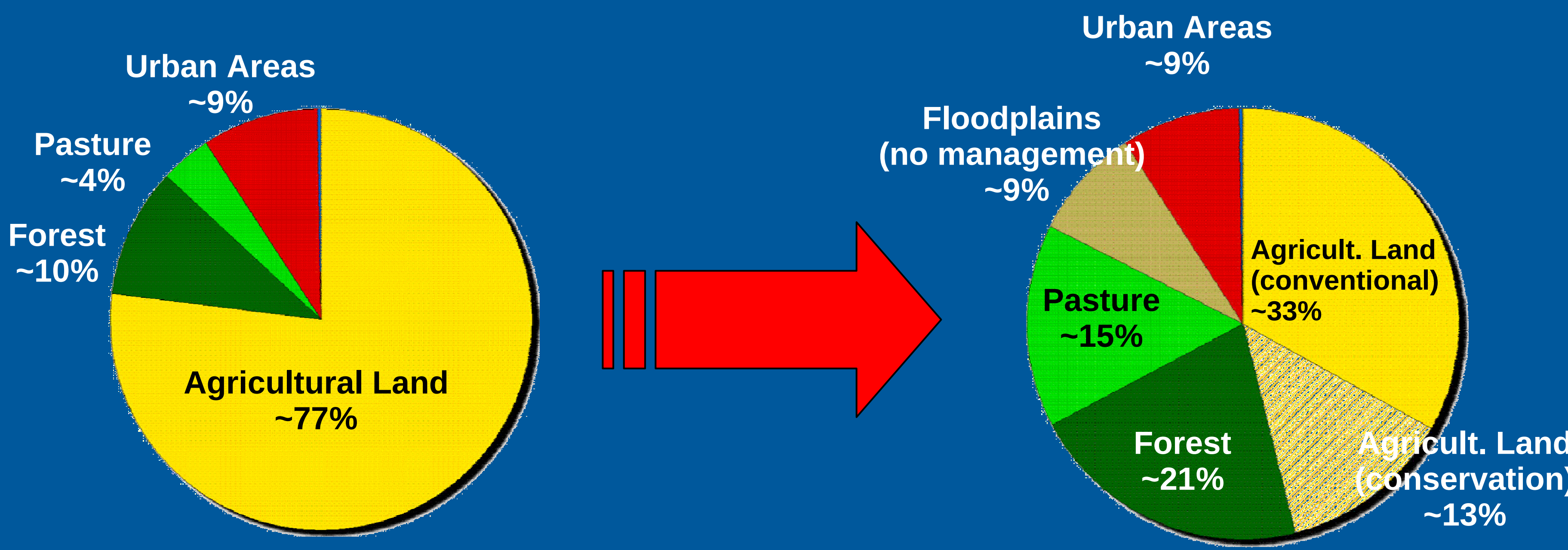

QUESTIONS

To what extend agricultural management has to be changed in order to improve the water quality?

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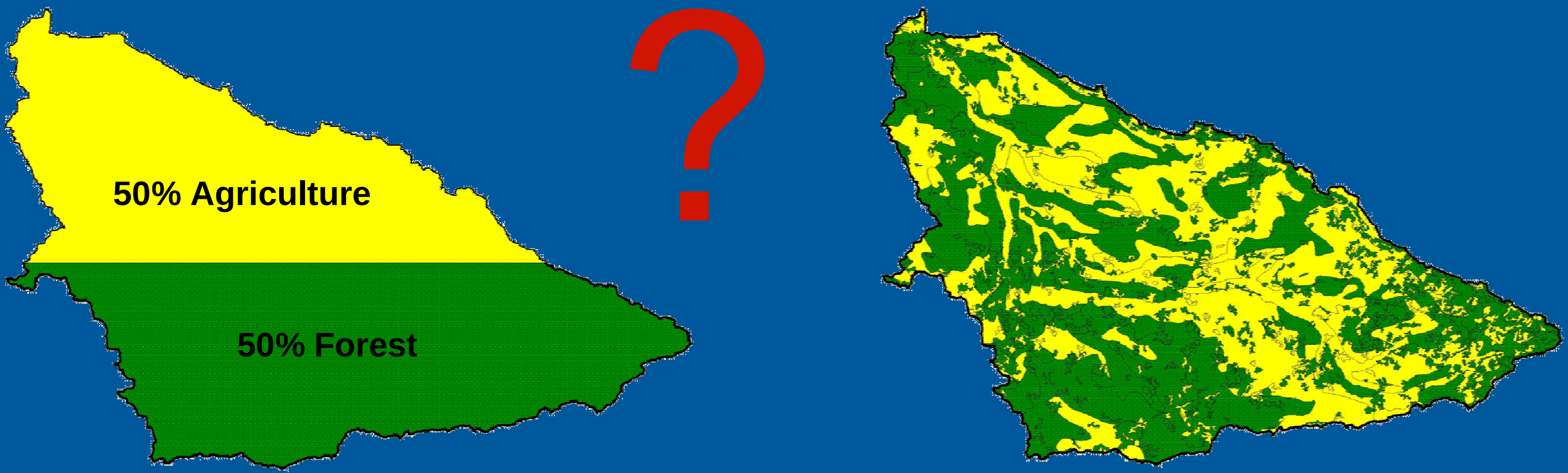

QUESTIONS

How could a sustainable land use configuration look like in the Ems catchment?

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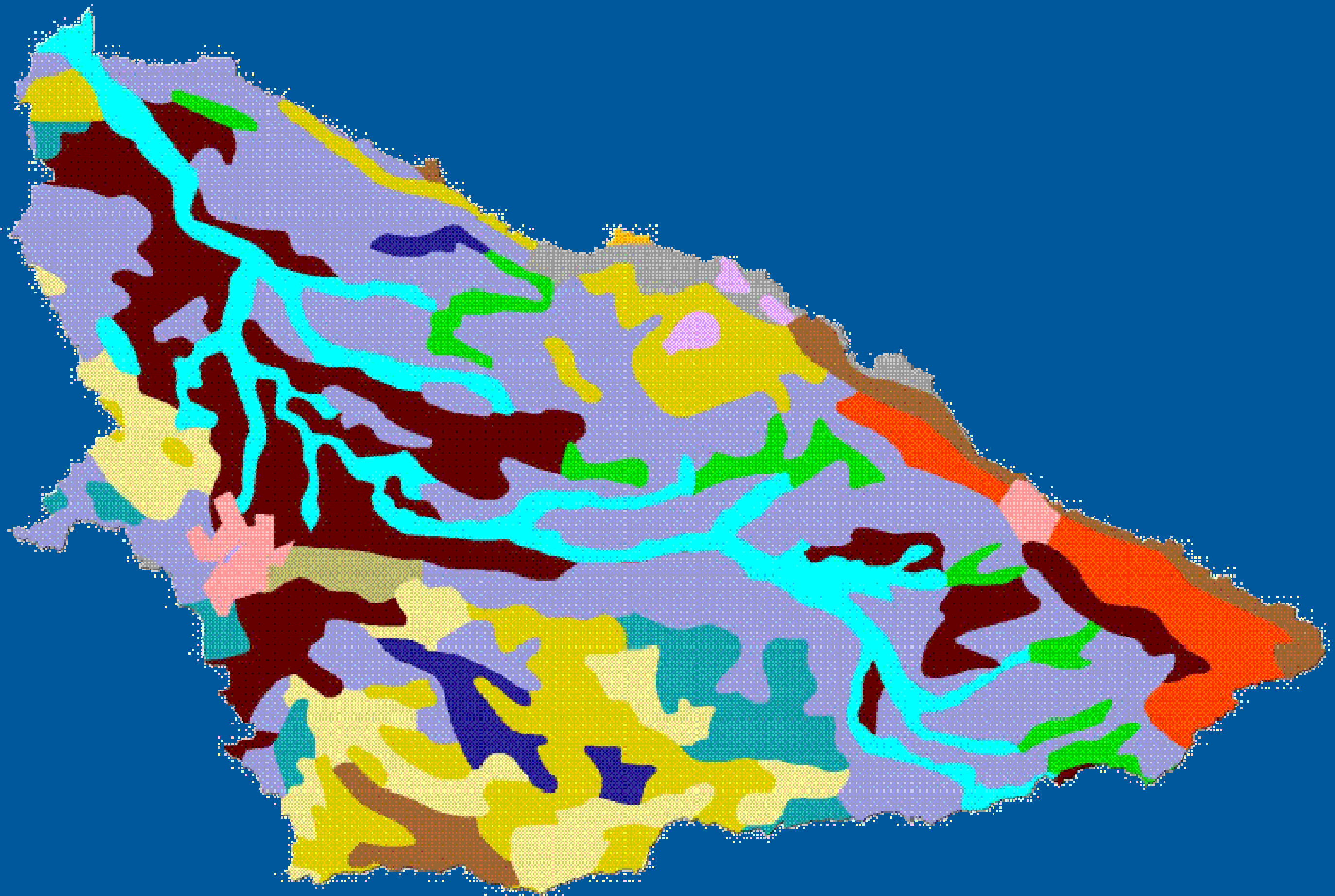

SOIL MAP

Supporting the localization of measures

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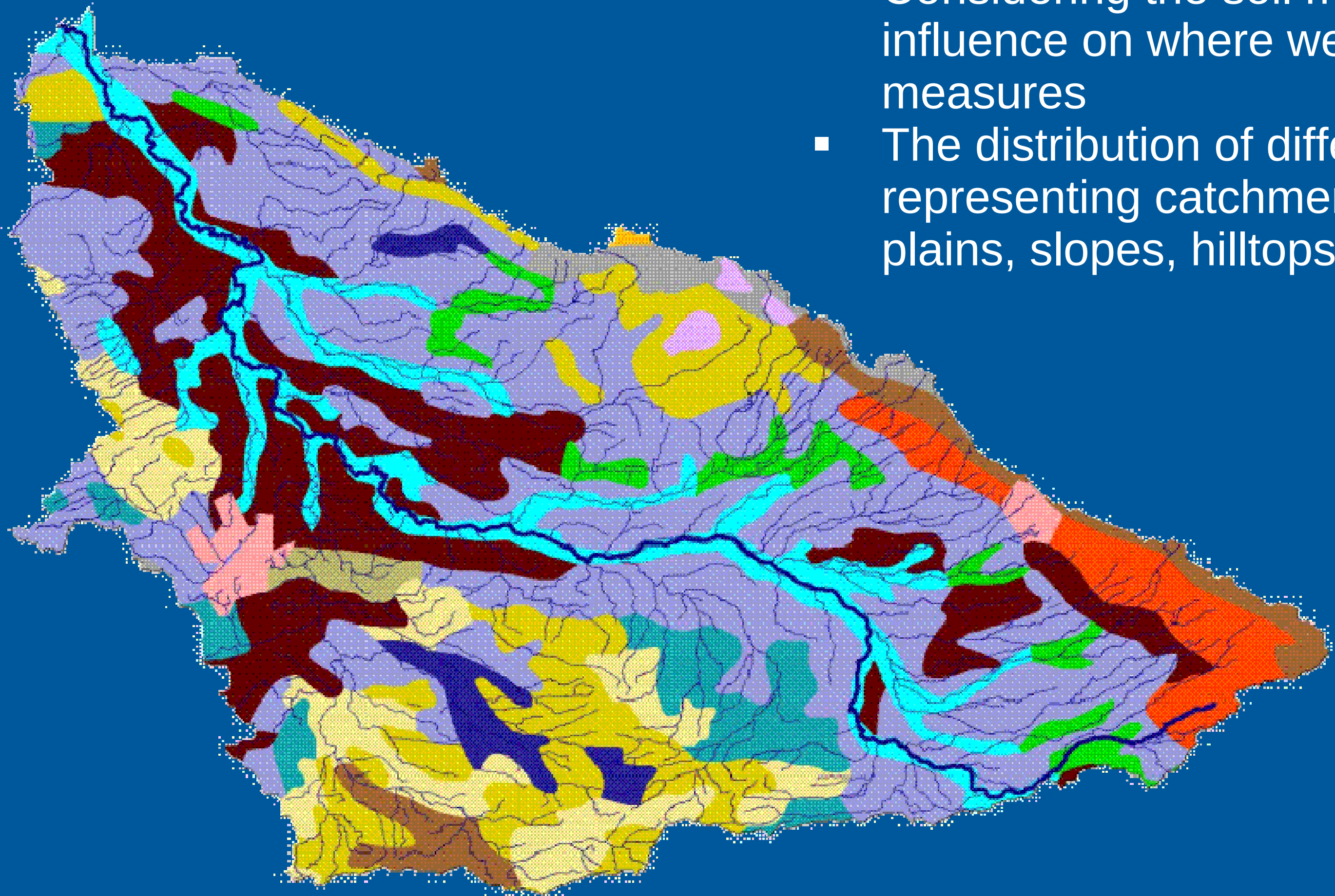

- Considering the soil map we gain some influence on where we implement certain measures
- The distribution of different soil types are representing catchment locations (flood plains, slopes, hilltops)

SOIL MAP

Supporting the localization of measures

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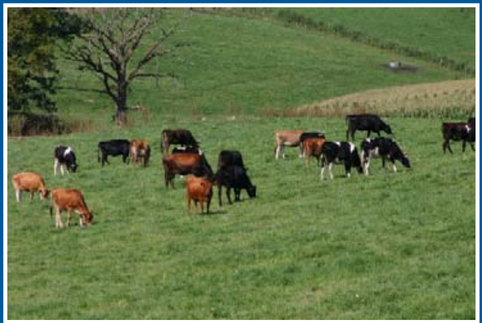
Conventional

Eco-farming

Forest

Pasture



QUESTIONS

What could be reasonable land management practices in specific regions of the catchment?

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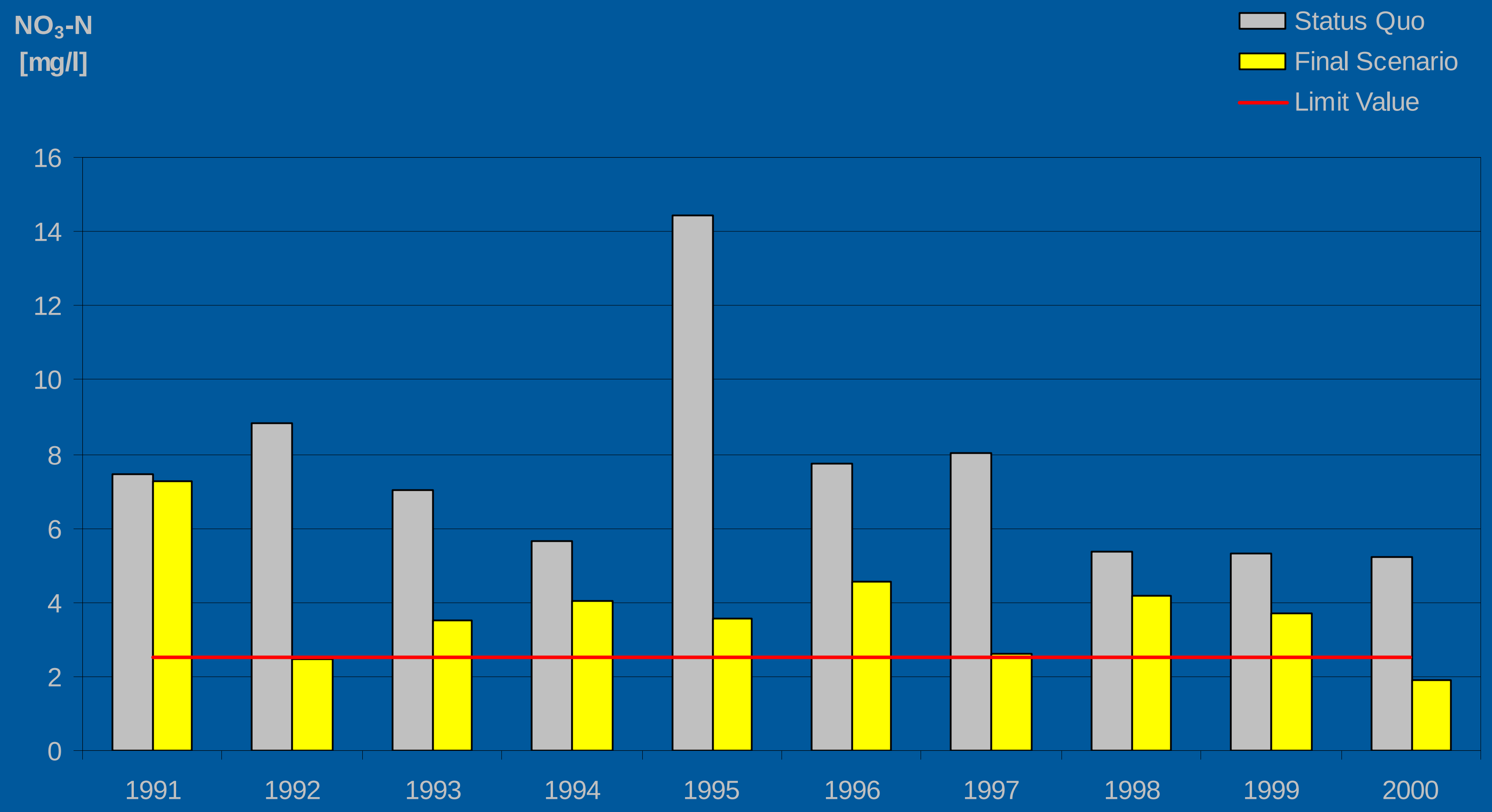

QUESTIONS

Is the recent data availability adequate to simulate such scenarios?

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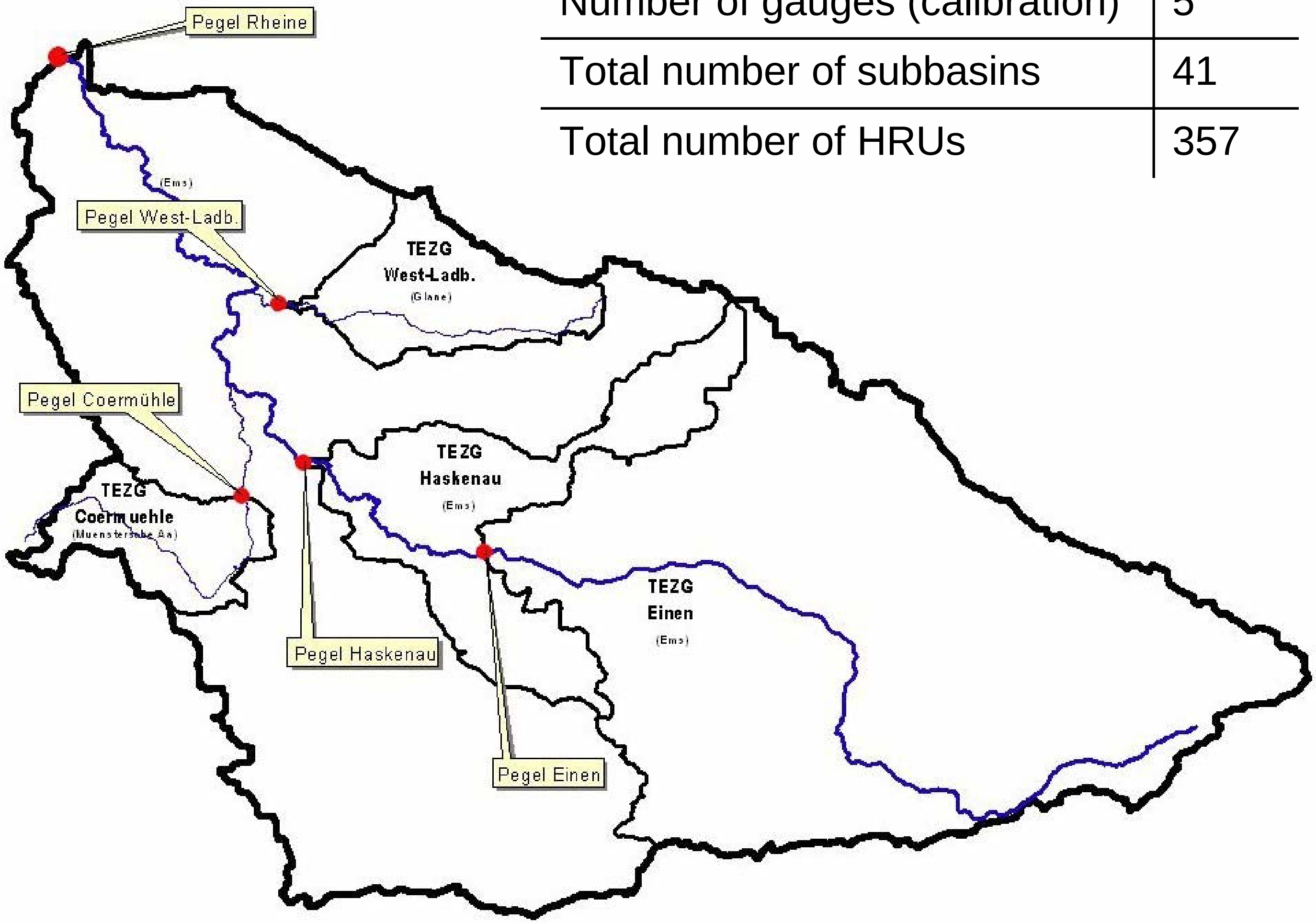

Number of gauges (calibration)	5
Total number of subbasins	41
Total number of HRUs	357

MODEL CALIBRATION

Streamflow

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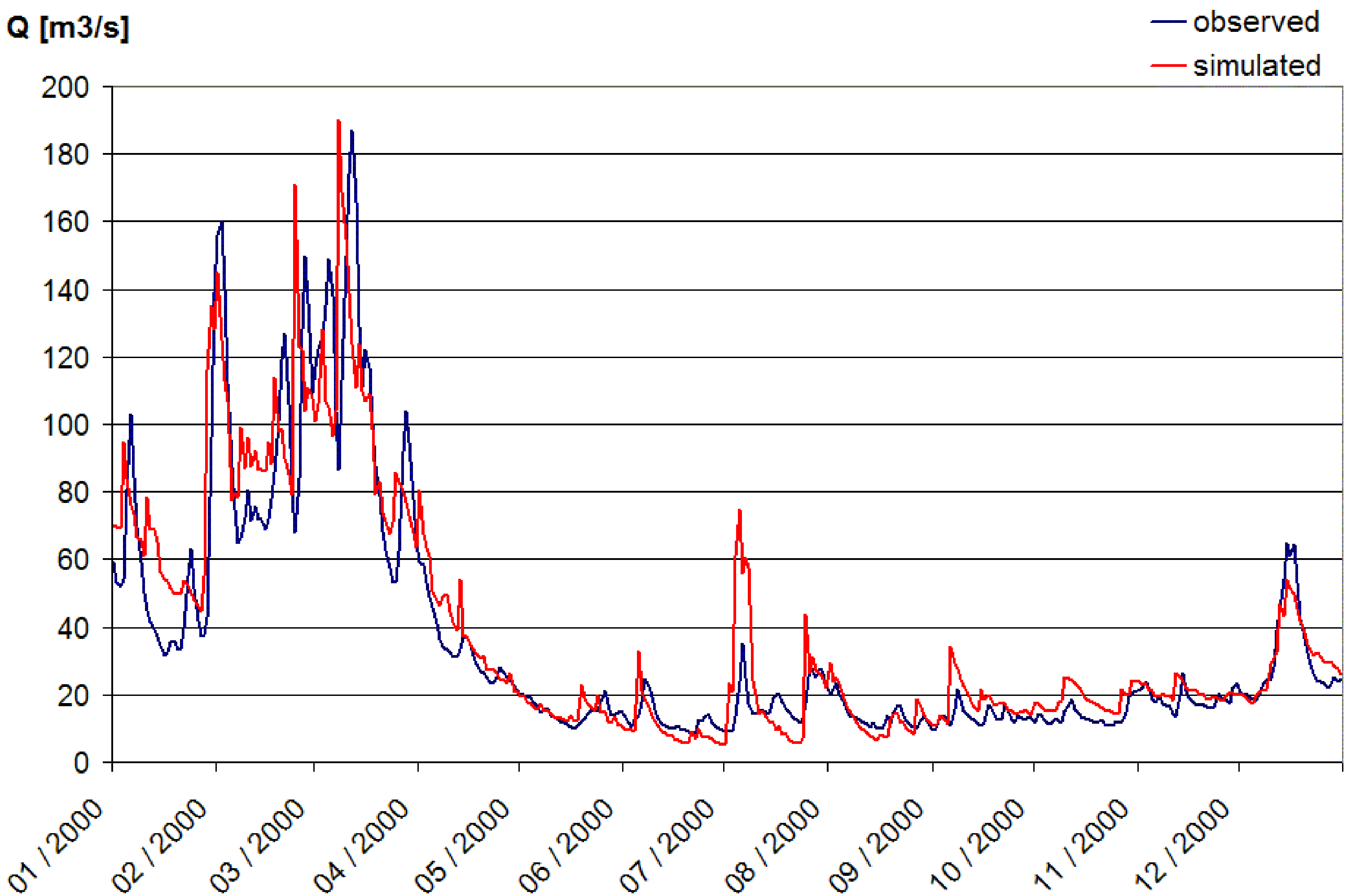

MODEL CALIBRATION

Streamflow (Year 2000)

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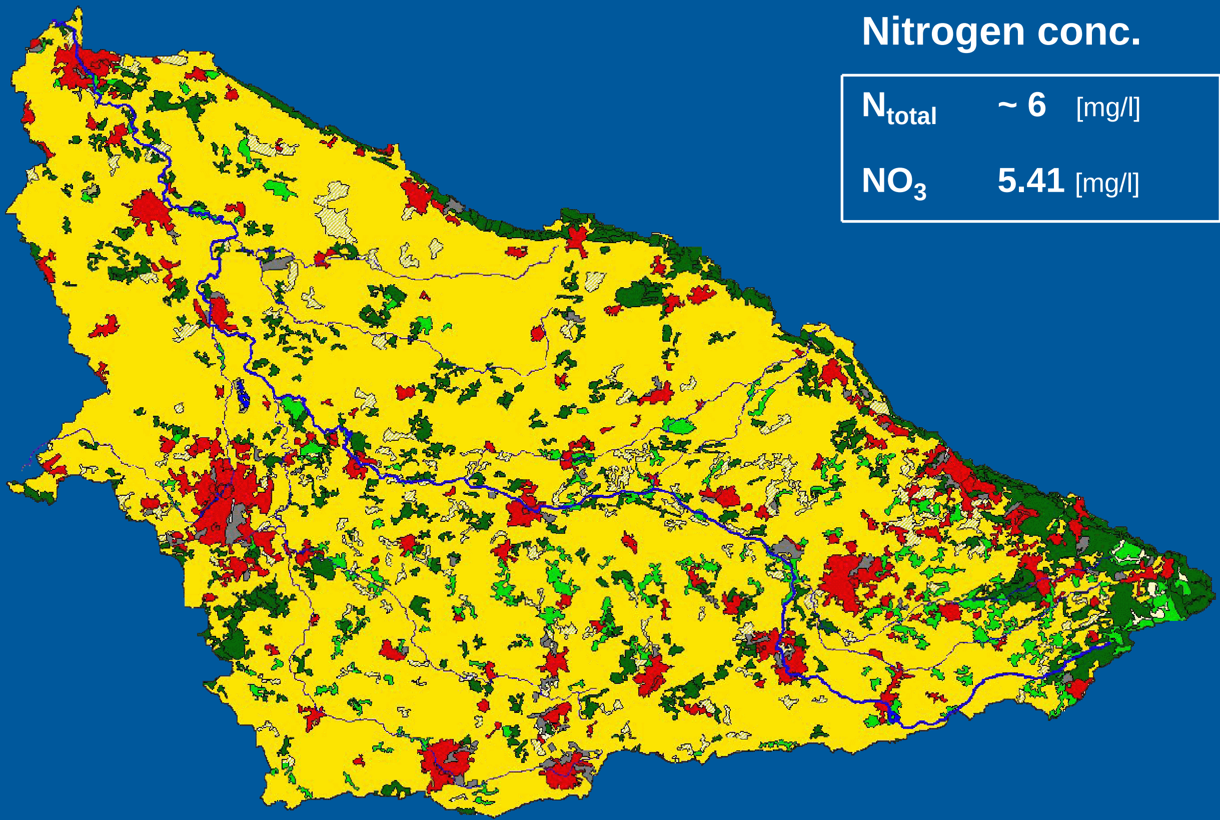
Period	Nash-Sutcliffe	BIAS
Calibration 1986 – 2000	0.75 (0.48 – 0.81)	2%
Validation 1976 – 1985	0.63 (0.37 – 0.69)	2.5%

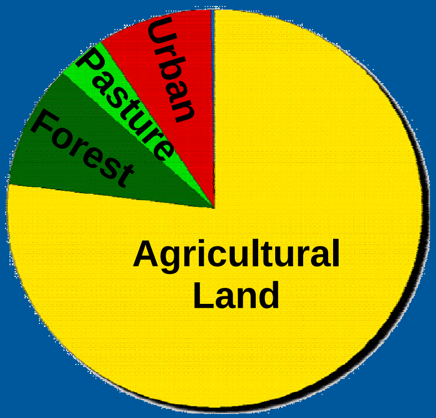
MODEL CALIBRATION

Streamflow



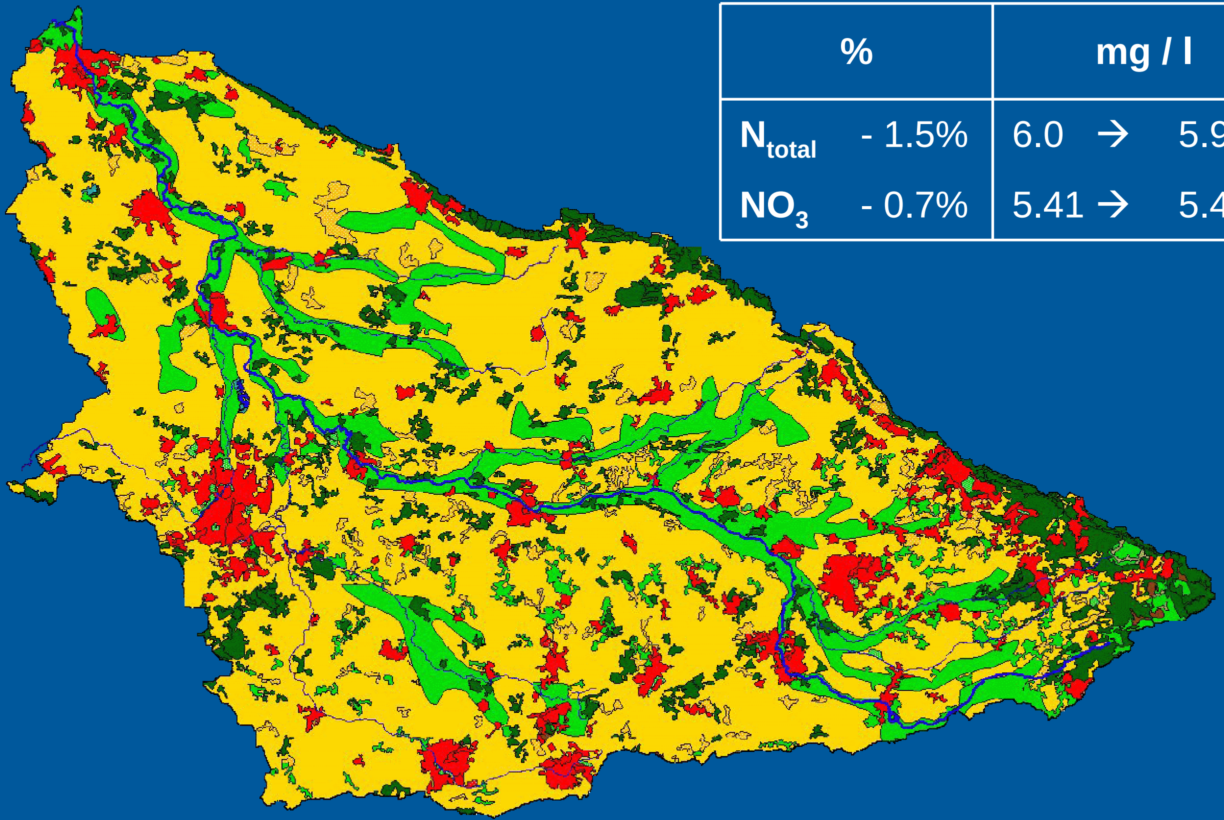
Nitrogen conc.

N_{total}	~ 6	[mg/l]
NO_3	5.41	[mg/l]



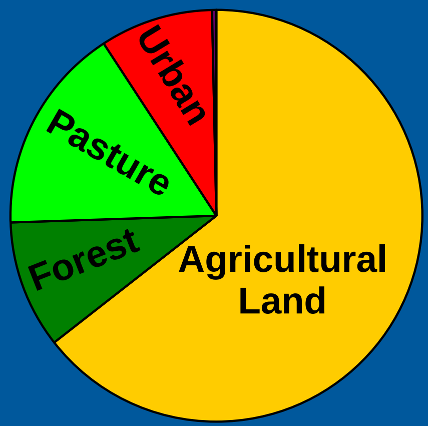
Scenarios

Status Quo



Impact

	%	mg / l
N_{total}	- 1.5%	6.0 → 5.9
NO_3	- 0.7%	5.41 → 5.4



Measure

	AGRC	=	- 13%
→	PAST	=	+13%

Scenario 1

Reduction of agricultural land → pasture

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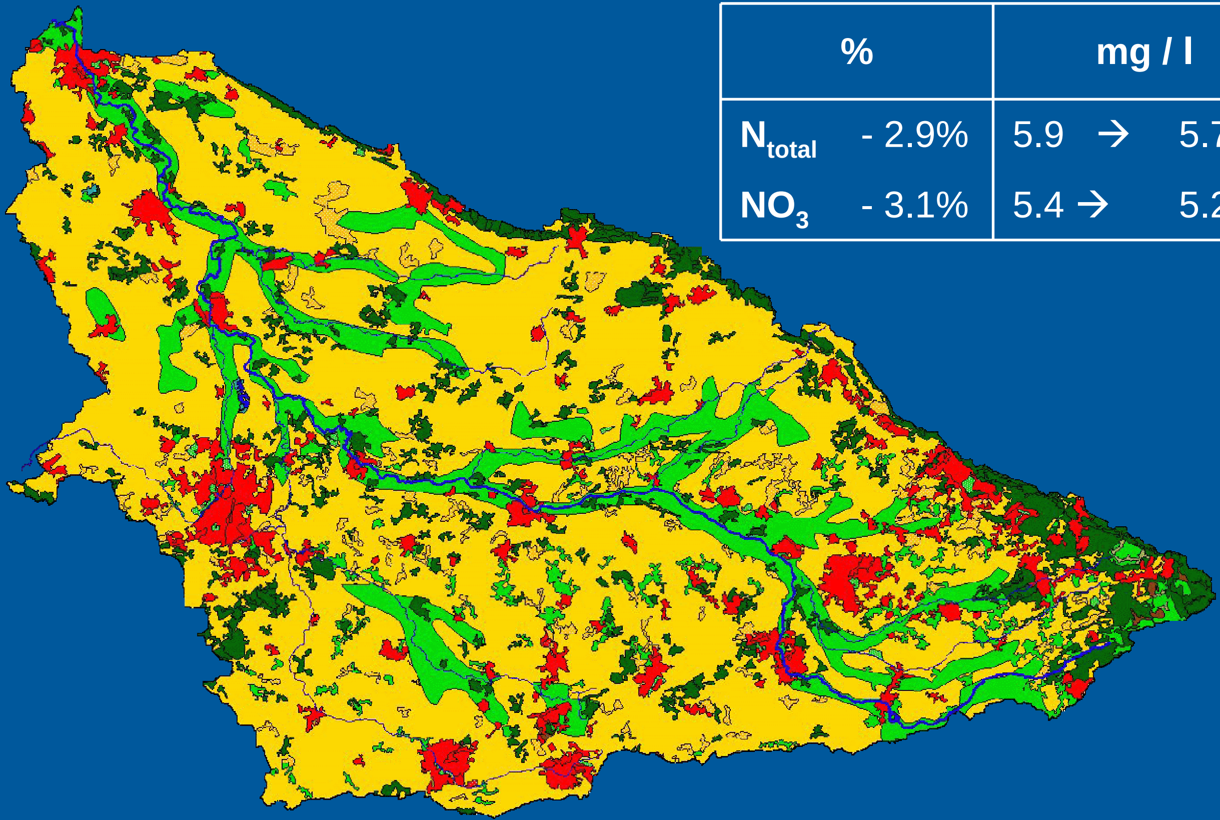
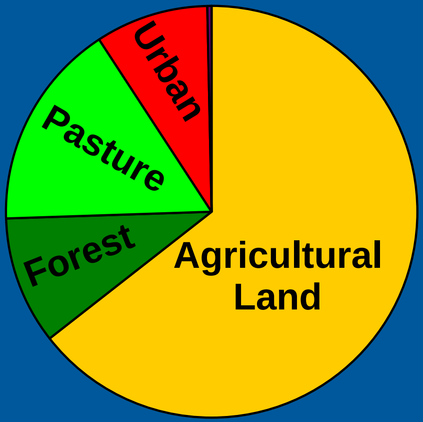


Impact

%		mg / l	
N_{total}	- 2.9%	5.9 →	5.7
NO_3	- 3.1%	5.4 →	5.2



Measure

Extensification (Pasture)

- No mineral fertilizer
- Reduced live stock units
  →Reduced manure applications

Scenario 2

Pasture extensification

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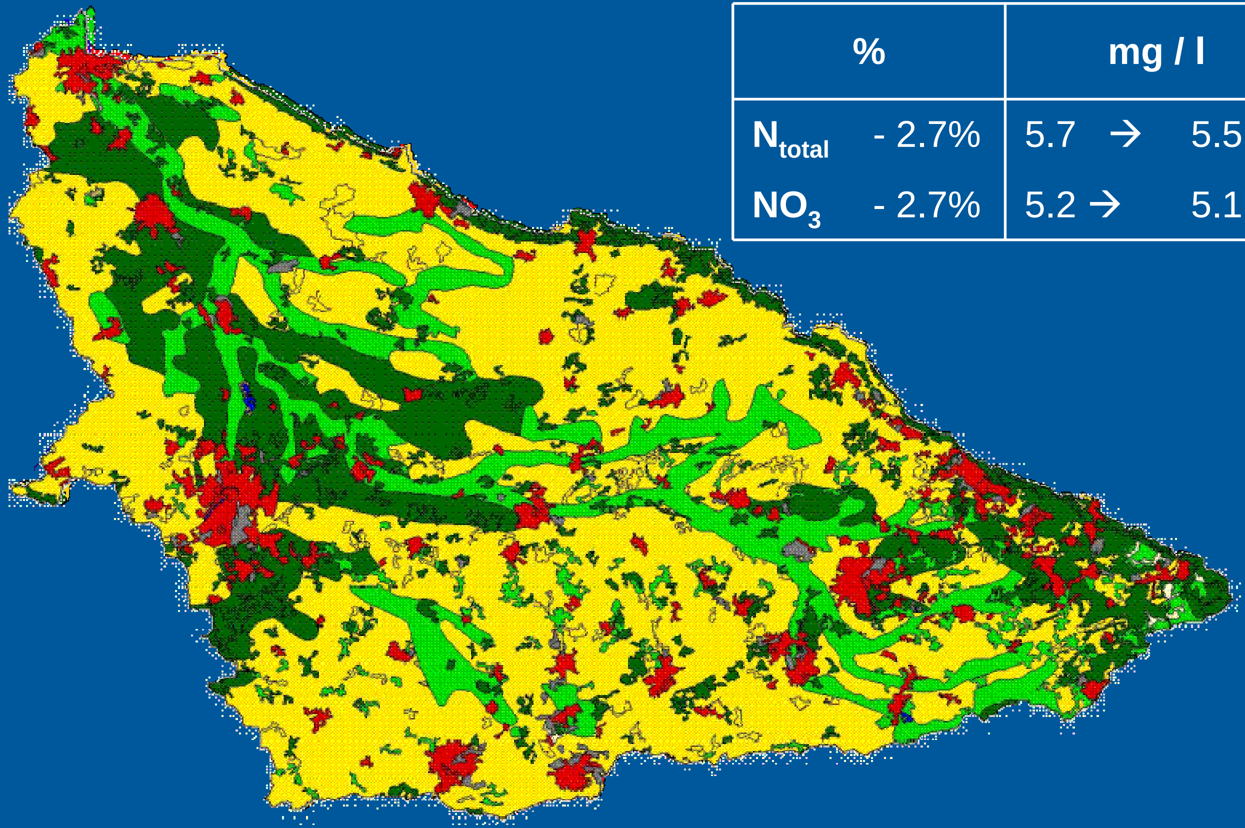
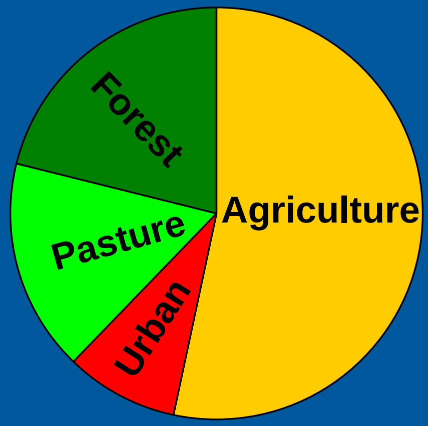


Impact

%		mg / l	
N_{total}	- 2.7%	5.7 →	5.5
NO_3	- 2.7%	5.2 →	5.1



Measure

	AGRC	=	- 11.2%
→	FRST	=	+11.2%

Scenario 3

Reduction of agricultural land → Forest

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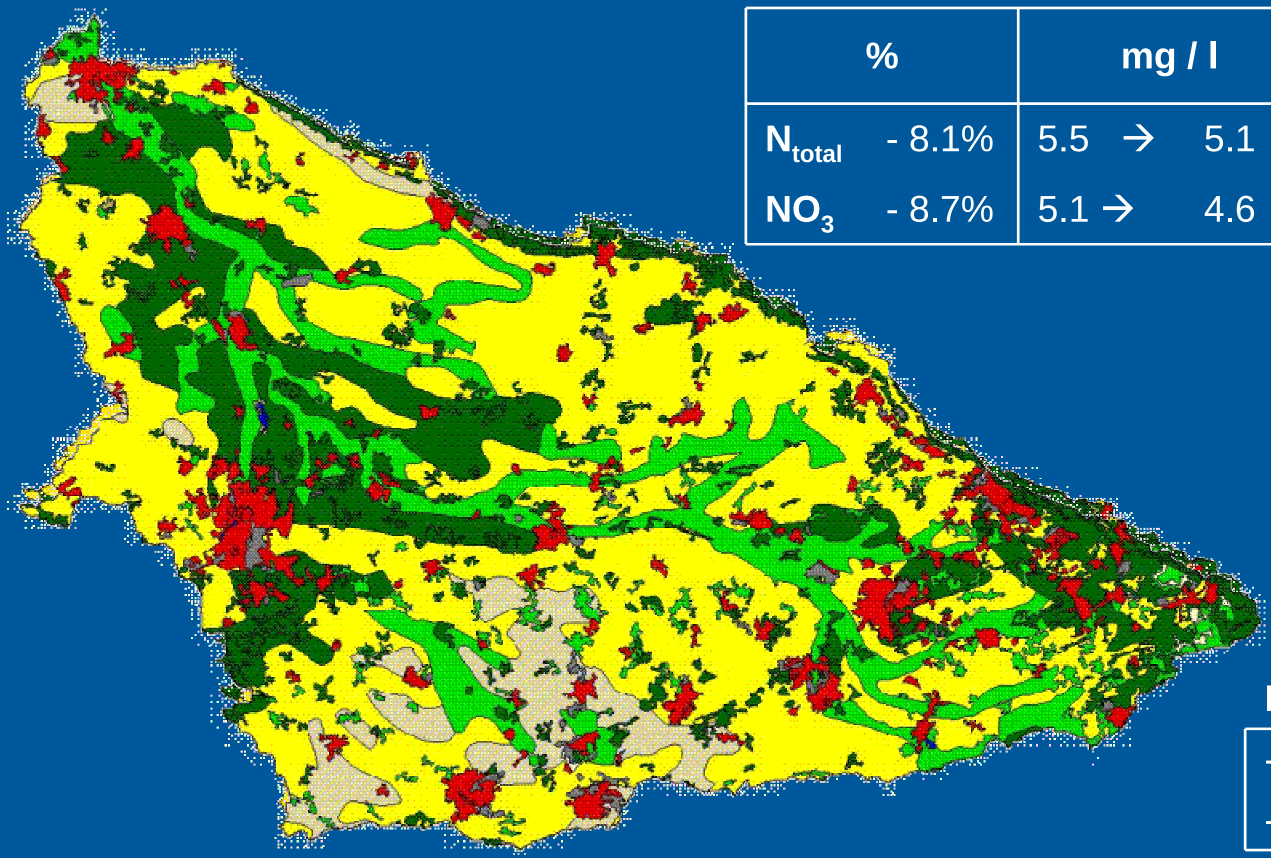
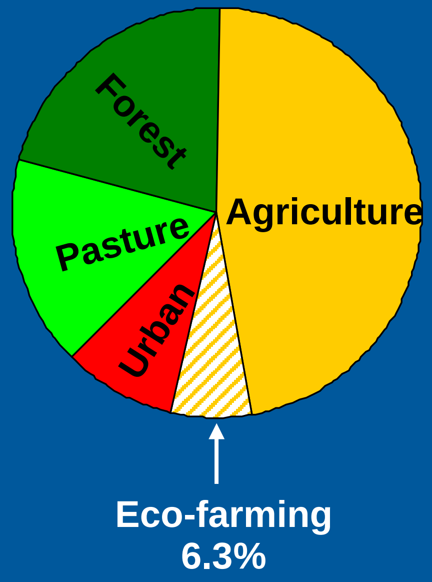


Impact

	%	mg / l
N_{total}	- 8.1%	5.5 → 5.1
NO_3	- 8.7%	5.1 → 4.6



Measure

- Changed crop rotations
- Reduced fertilizer applications

Scenario 4

Agricultural extensification measures

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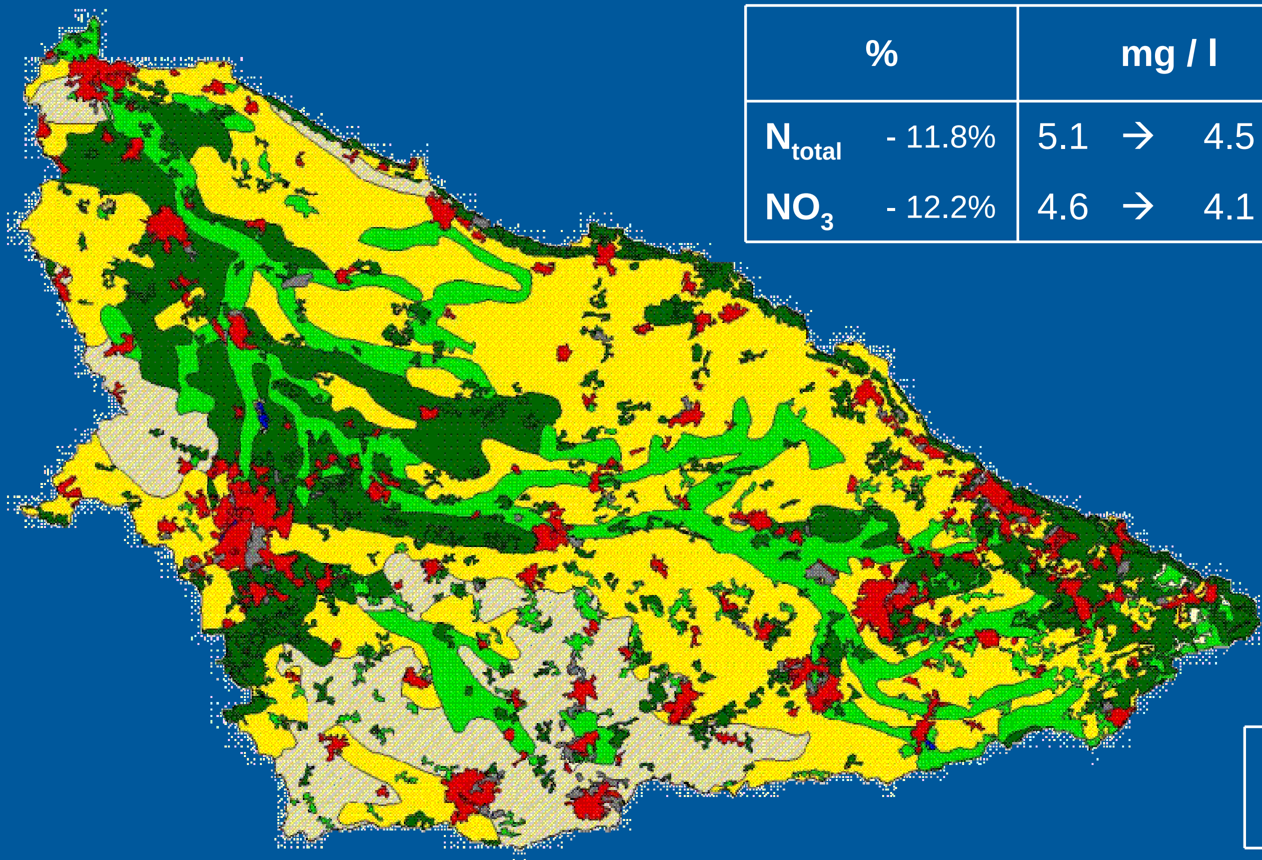
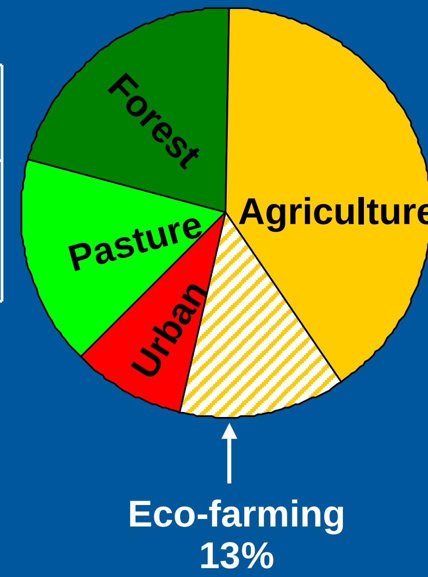


Impact

	%	mg / l
N_{total}	- 11.8%	5.1 → 4.5
NO_3	- 12.2%	4.6 → 4.1



Measure

- Changed crop rotations
- Reduced fertilizer applications

Scenario 5

Agricultural extensification measures II

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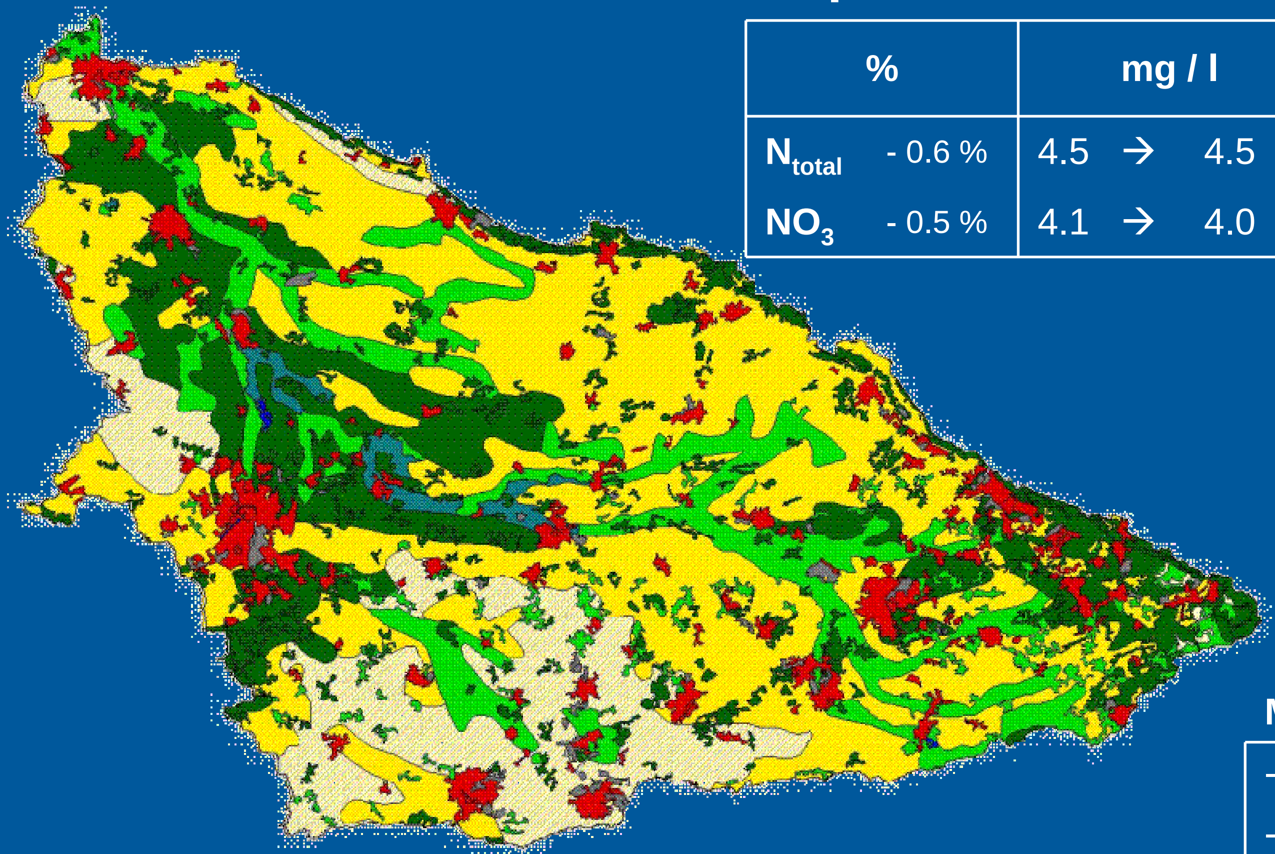
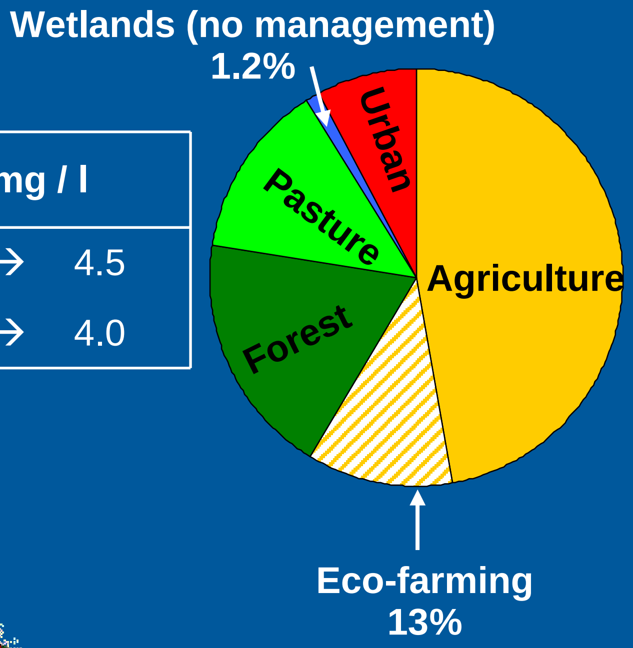


Impact

	%	mg / l
N_{total}	- 0.6 %	4.5 → 4.5
NO_3	- 0.5 %	4.1 → 4.0



Measure

- Wetland Extensification
- 1.2% PAST → WETL

Scenario 6

Floodplain Renaturation

CH_L = +10km
CH_N 0.044 → 0.06
FILTERW = 10m

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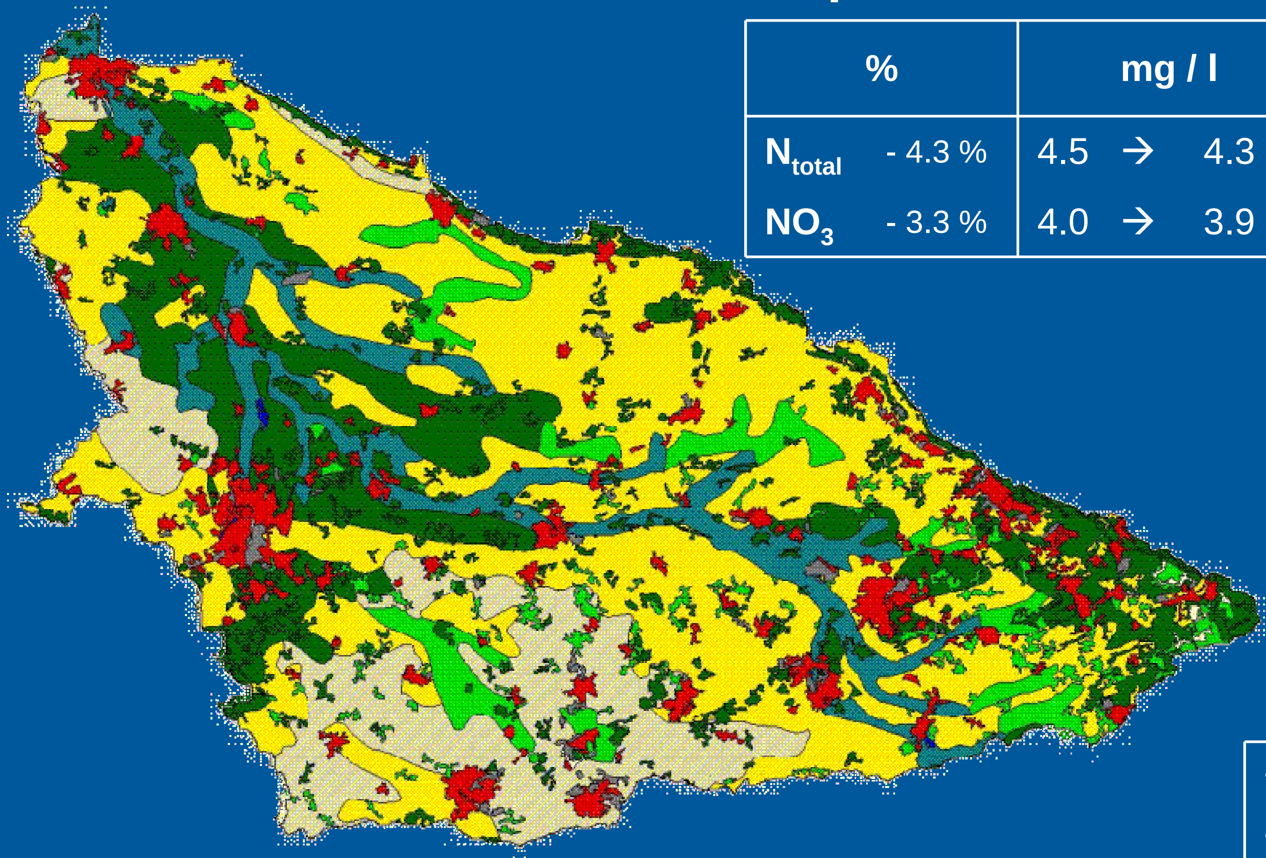
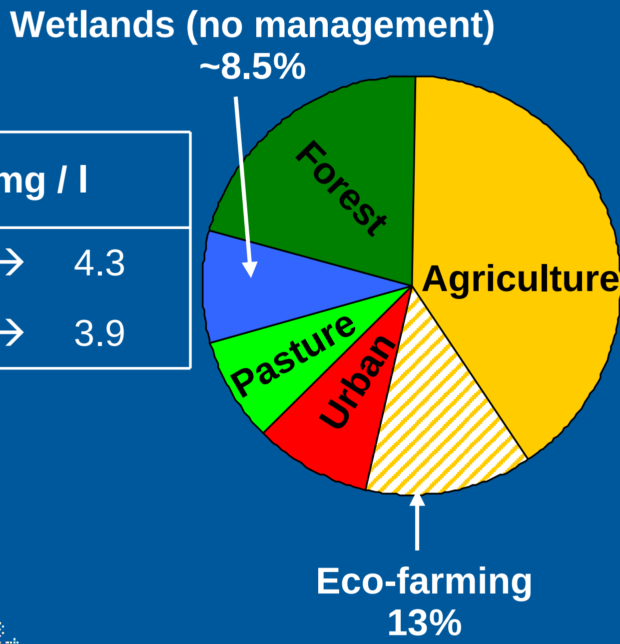


Impact

	%	mg / l
N_{total}	- 4.3 %	4.5 → 4.3
NO_3	- 3.3 %	4.0 → 3.9



Measure

- Wetland Extensification
- 7.5% PAST → WETL

Scenario 7

Wetland Extensification

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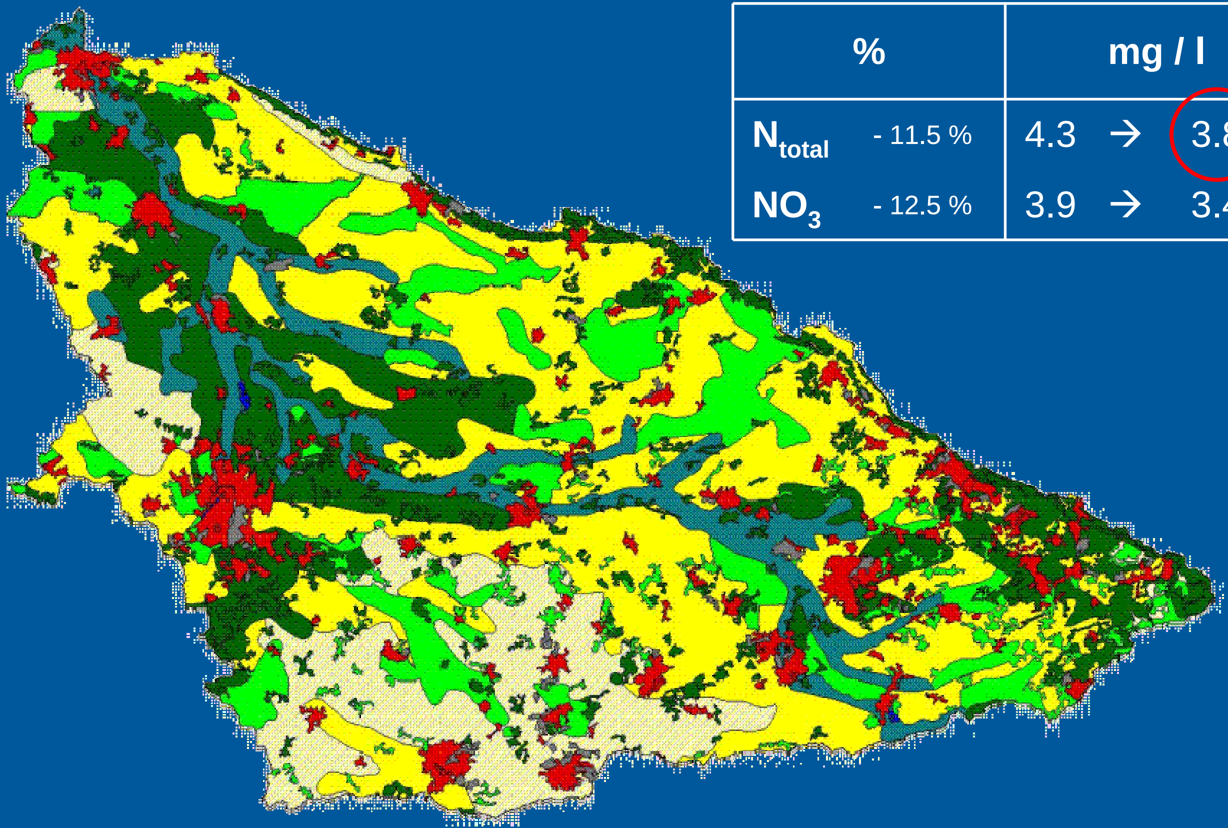
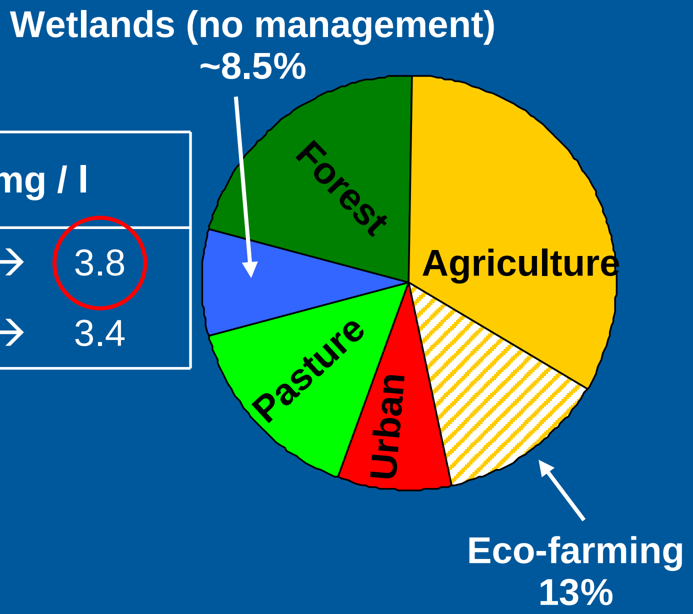
Impact

%		mg / l	
N_{total}	- 11.5 %	4.3 →	3.8
NO_3	- 12.5 %	3.9 →	3.4





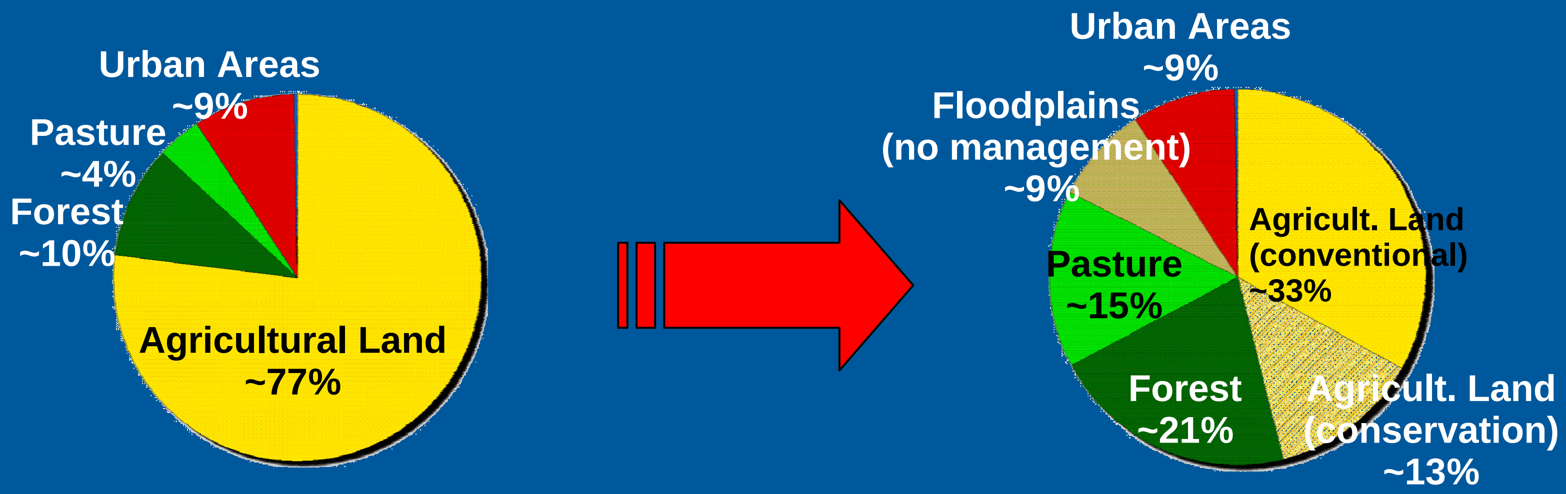
Measure

	AGRC	=	- 7%
→	PAST	=	+7%

Final Scenario

Reduction of agricultural land → pasture

Drastic land use and management changes are necessary to achieve the objectives of the WFD in the region



→ **Implementation unrealistic**

- (To take the management out of the floodplains would cost 500 Euro/ha ~ 30 Mio. Euro)

→ Designation as heavily modified and artificial water body

RESULTS

SWAT seems to be suitable to simulate trends of the impact of land use and management scenarios on water quality

But:

- Quality of simulation results depends on data quality and availability
  - Existing water quality monitoring strategies are not adapted to the requirements of the WFD
  - Dynamics of nutrient fluxes can not be calibrated and validated in a sound way
  - Lack of transparency in management practices (e.g. amounts of nutrients applied by the farmers)
- Cause and effect delay between catchment response to implemented measures in the model and in reality

CONCLUSIONS

Martin Volk, Jesko Hirschfeld, Gerd Schmidt, Carsten Bohn, Alexandra Dehnhardt, Stefan Liersch and Leo Lymburner. 2007. A SDSS-based Ecological-economic Modelling Approach for Integrated River Basin Management on Different Scale Levels – The Project FLUMAGIS. Water Resources Management. DOI: 10.1007/s11269-007-9158-z

Thank you for paying attention!

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- Cause and effect delay between catchment response to implemented measures in the model and in reality
- Another topic to be stressed here is the cause and effect delay between catchment response to implemented measures in the model and in reality. In the model the impact of measures takes effect immediately, because the scenarios starts always in the same year with same initial conditions. On the one hand this is necessary to compare the results of different scenarios. But on the other hand this procedure is far from reality. Depending on catchment characteristics, such as permeability of soils and initial nutrient loads, the impact of land use and management changes in the real world will usually take effect delayed. Maybe this delay is in the range of many years – which represents another problem for the implementation of the WFD.

PROBLEMS

Why are measures implemented in scenario 1 to 3 not as effective as the following measures?

→ An explanation for these discrepancies could be that in scenario 1 the nutrient inputs in the entire catchment are still very high and exceed critical thresholds. Under these circumstances the effect of reduced nutrient inputs remains rather small. Where in scenario 8 the nutrient inputs probably fall below a critical catchment threshold, and thus increase the effect of the measure. This would also explain the relative “un-effectiveness” of the measures implemented in scenarios 1 to 3.