Application of SWIM model in the Elbe basin: experience and new developments

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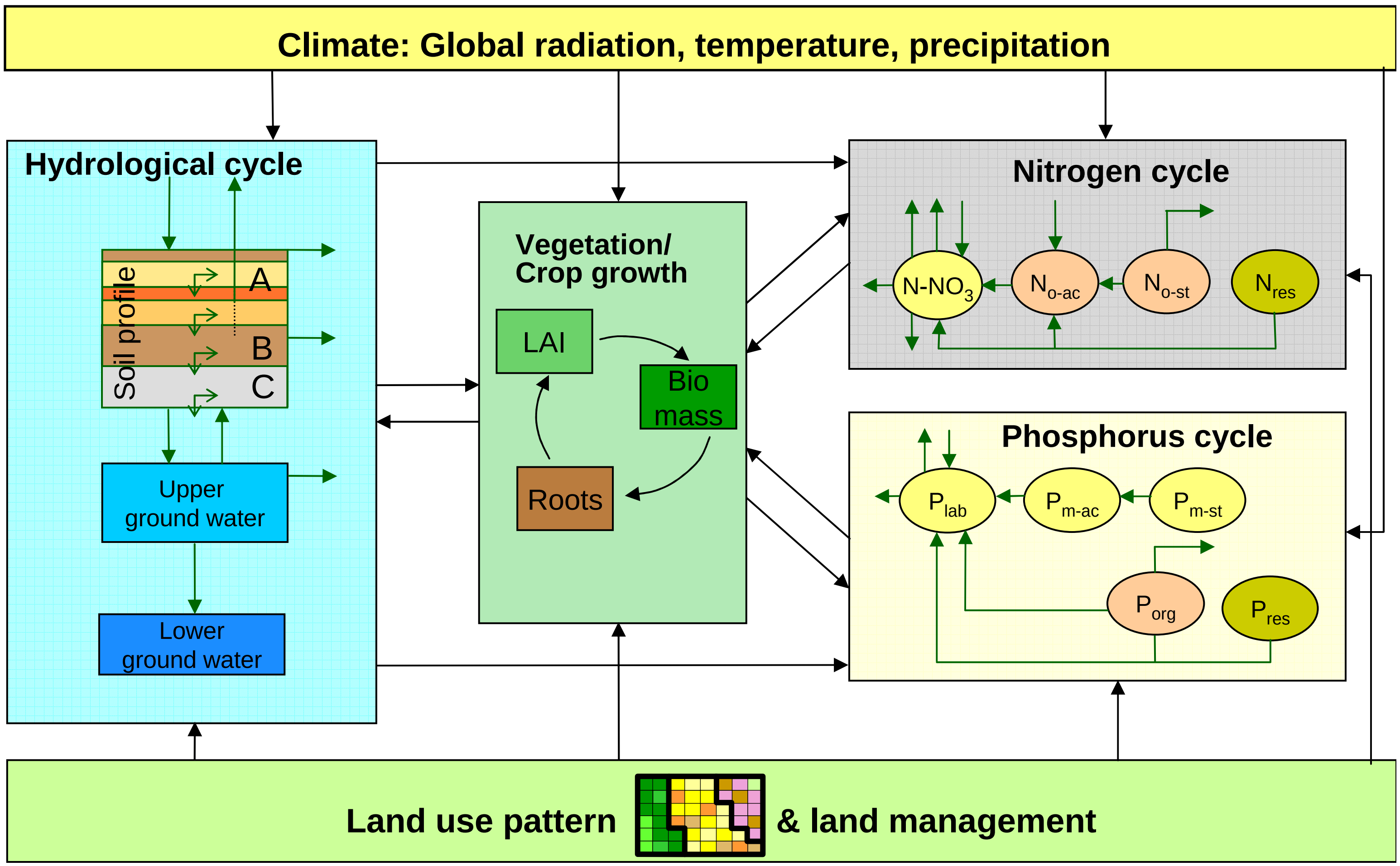
Outline

- the model SWIM: an overview
- the case study basin
- model development:
  - new components and techniques,
  - new modules,
  - impact assessment: examples
- literature on SWIM and applications

SWIM (Soil and Water Integrated Model) scheme



***SWIM** was developed in PIK (Potsdam) based on **SWAT-93** and **MATSALU** for climate and land use change impact studies*

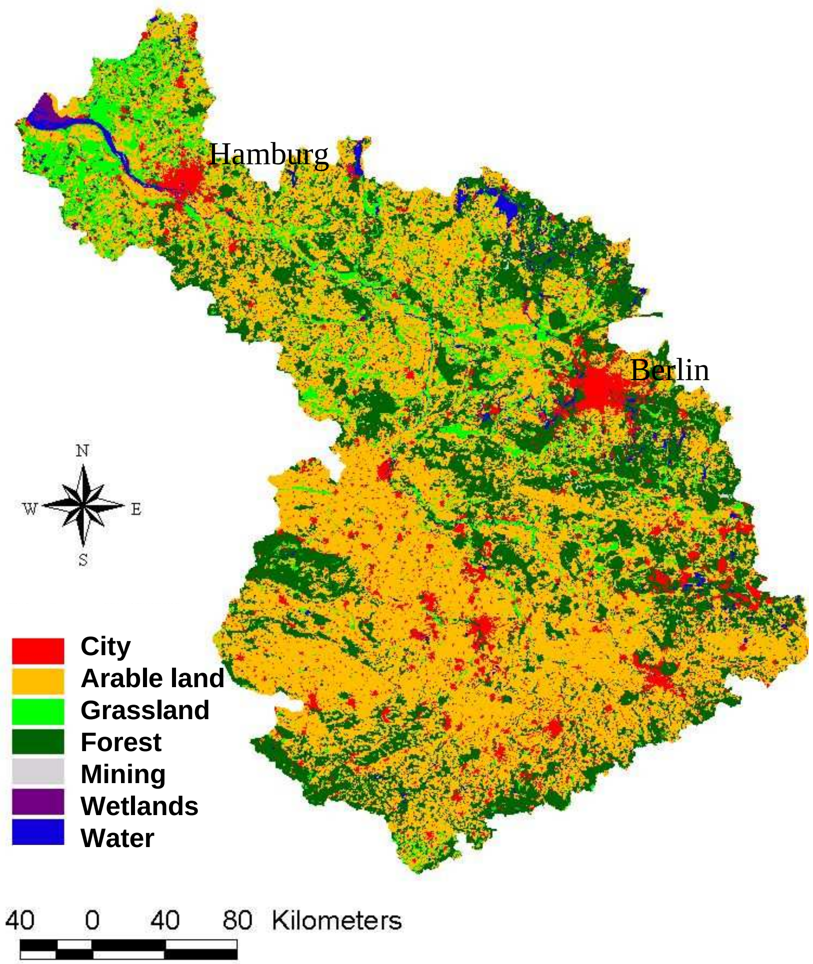
Case study area: the Elbe basin

Basin:

- drainage area 148.268 km^2
- long-term mean annual precipitation 659 mm
- agriculture areas: 56 %

River:

- total length 1092 km
- long-term mean discharge at the mouth 716 $m^3\ s^{-1}$
- specific discharge 6.2 $l\ s^{-1}\ km^{-2}$ or 29.7 % of annual precipitation

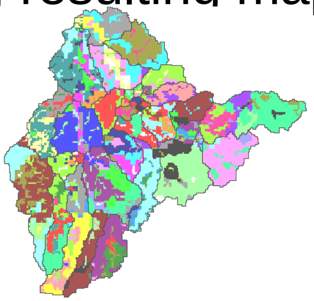


SWIM development: new components and techniques

Important!

The average subbasin size is essential both for lowland basins (accumulation time) and for mountainous basins (climate interpolation).

- 3-level disaggregation is included explicitely, resulting maps can be printed for hydrotopes or HRUs (VK),

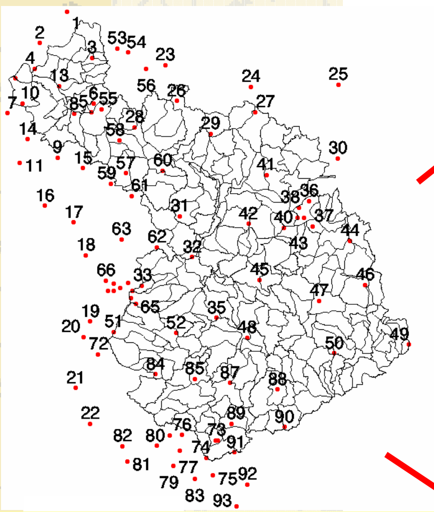


- preprocessing: climate interpolation using four methods, elevation can be considered (FH),
- crop generator (FH, JP),
- validation technique: multi-scale, multi-site, and multi-criteria (all),
- uncertainty analysis technique (FH).

Climate Interpolation example:

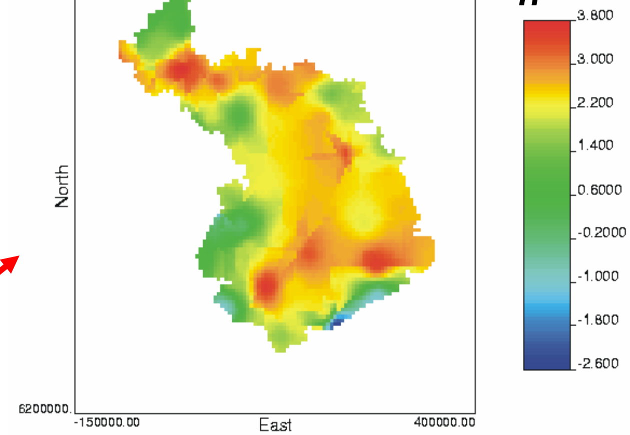
mean temperature

Climate stations



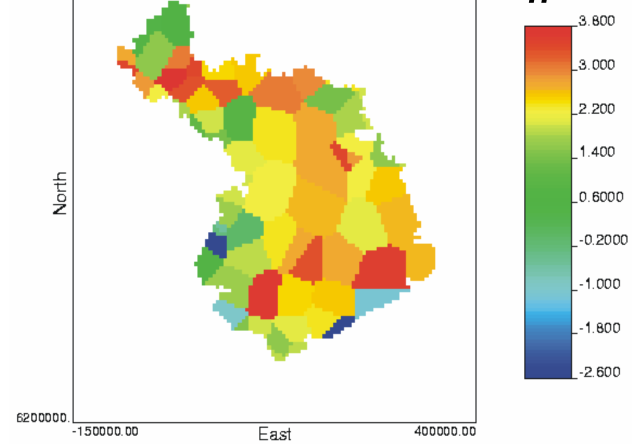
Inverse distance

Eff=0 .25



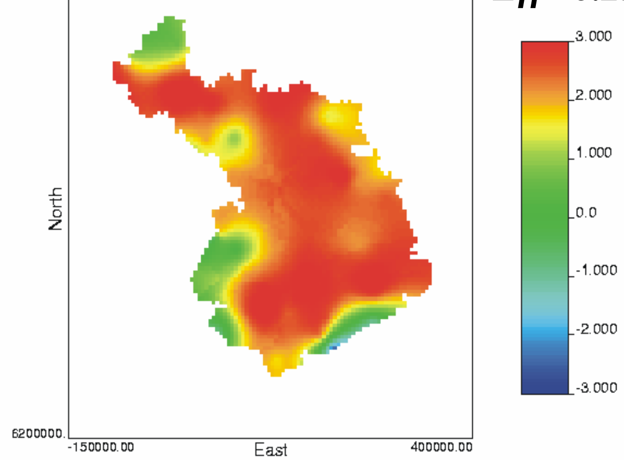
Thiessen polygons

Eff= -0.24



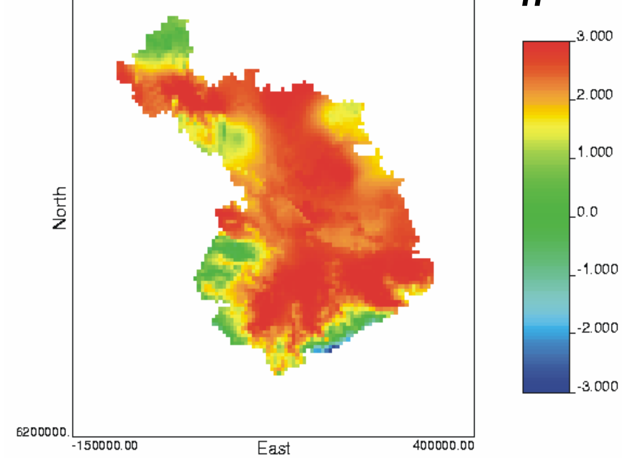
Ordinary kriging

Eff= 0.29



External drift kriging

Eff=0 .67



Important!

Climate interpolation is especially needed:

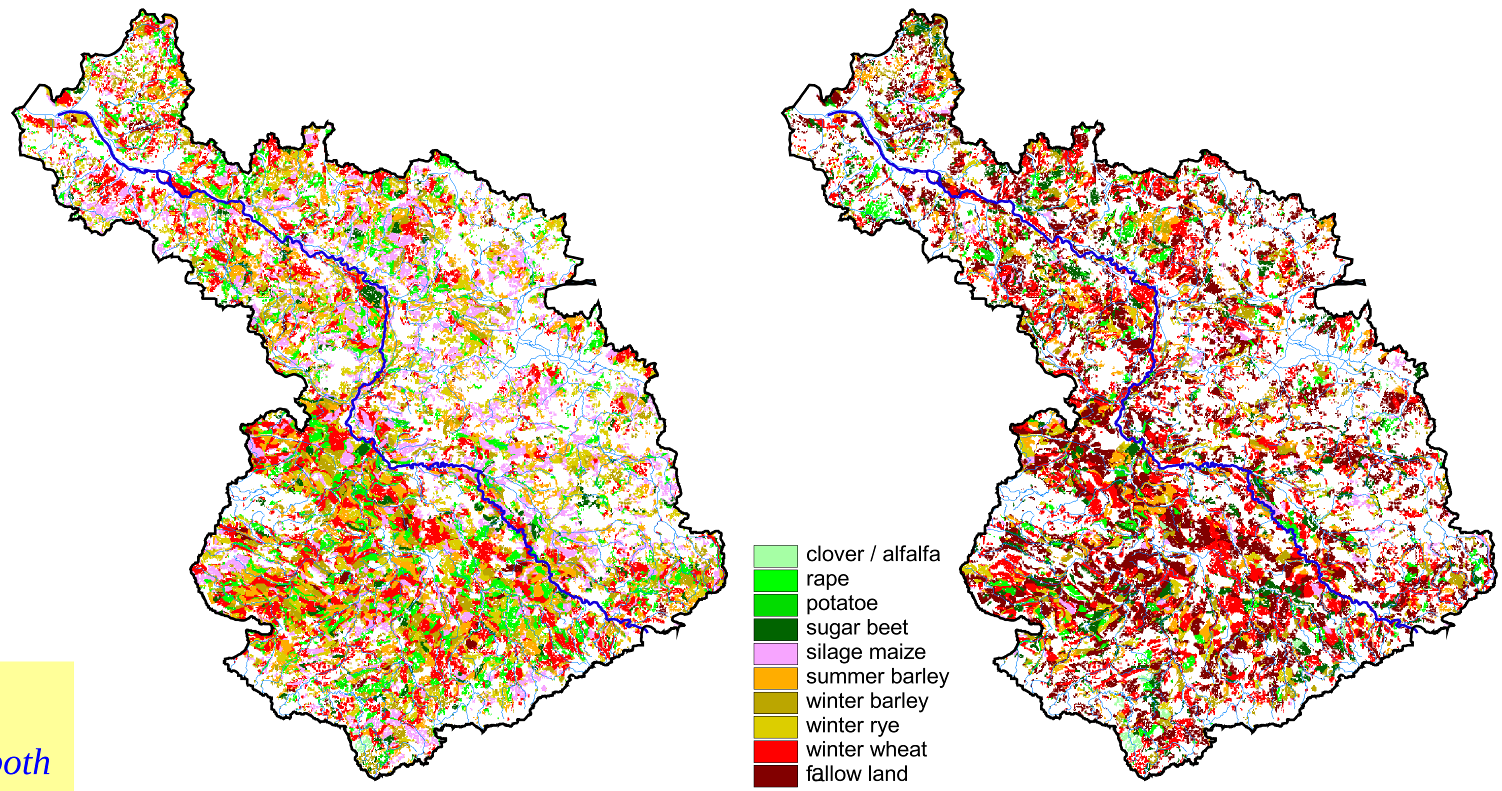
1. for precipitation,

2. in mountainous basins,

3. if the number of stations is low.

Crop generator:

examples for the reference and scenario periods



Crop distribution: reference (example)

Crop distribution: scenario (example)

Important!

Crop rotations affect both water and nutrient dynamics, and therefore should be adequately represented.

Validation technique: examples

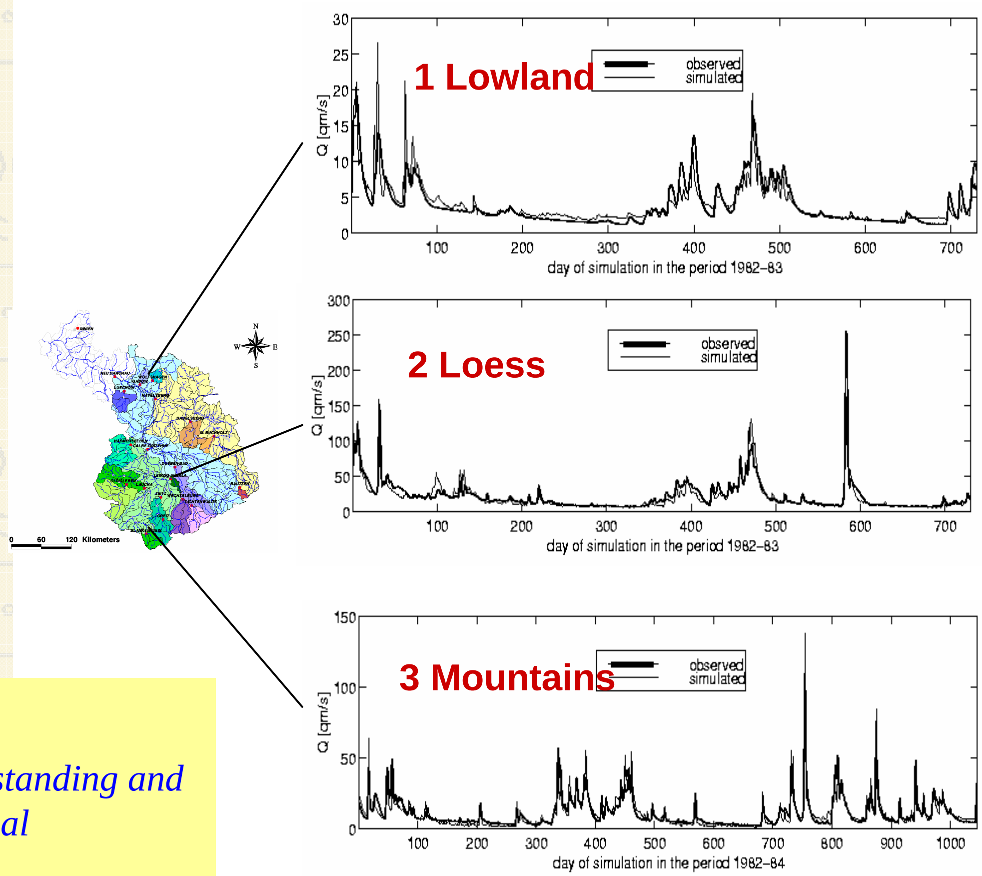
+ large scale

+ g-w

+ crop

+erosion

+ N, P



1: Stepenitz, 576 km², North. Pleistocen Efficiency: **0.73**

2: Upper Mulde, 2091 km², Mountains / Loess Efficiency: **0.77**

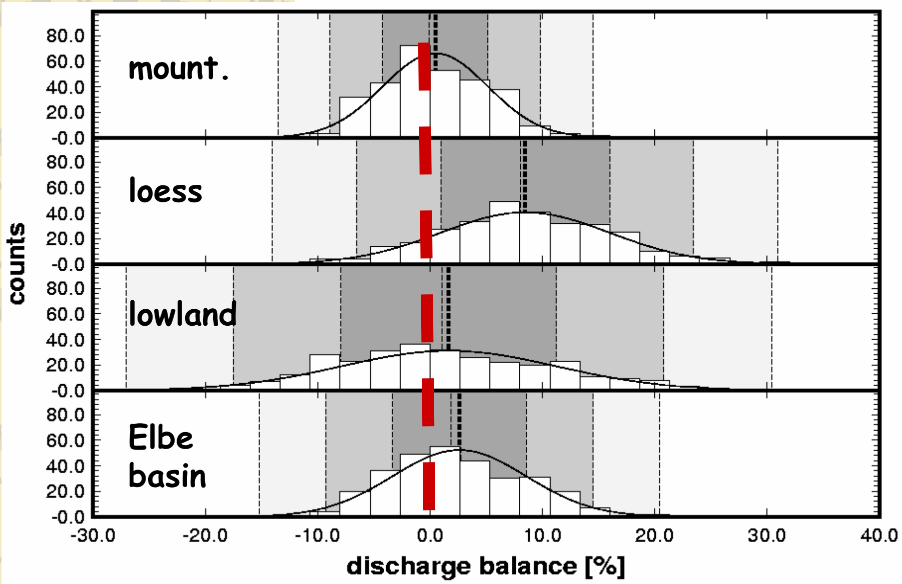
3: Upper Saale, 1013 km², Thüringer Wald, Efficiency: **0.82**

Important!

First: model understanding and experience in manual calibration,

Then: automatic calibration

Uncertainty analysis



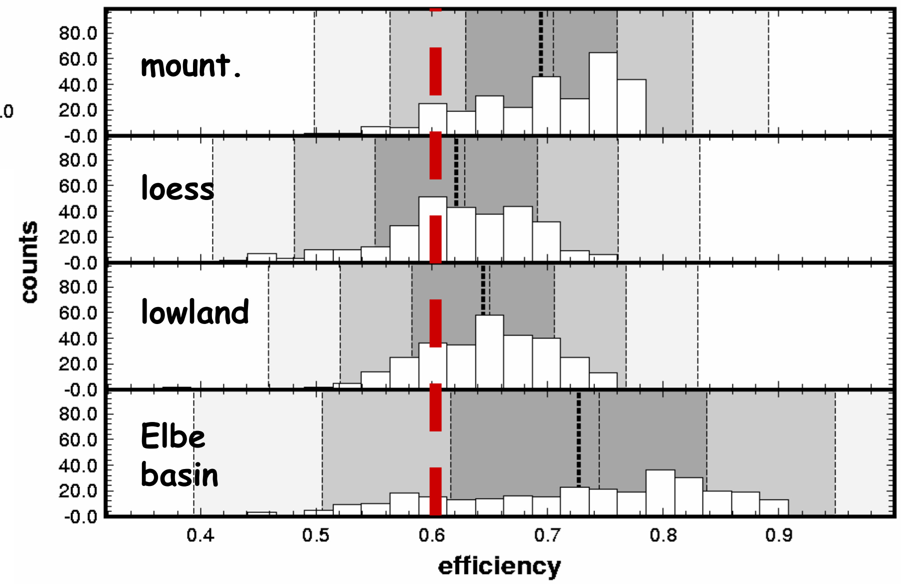
Histograms of N&S efficiency and % error assuming a stochastic choice of parameters

Summary:

N&S is better in mountainous basins and at the large scale;

% error is lower in mountainous basins.

Simulation results in the loess basins could be improved by appliying better soil parametrization.



SWIM development: new modules

- **Riparian zone module in SWIM:**

  SWIM-rip model version

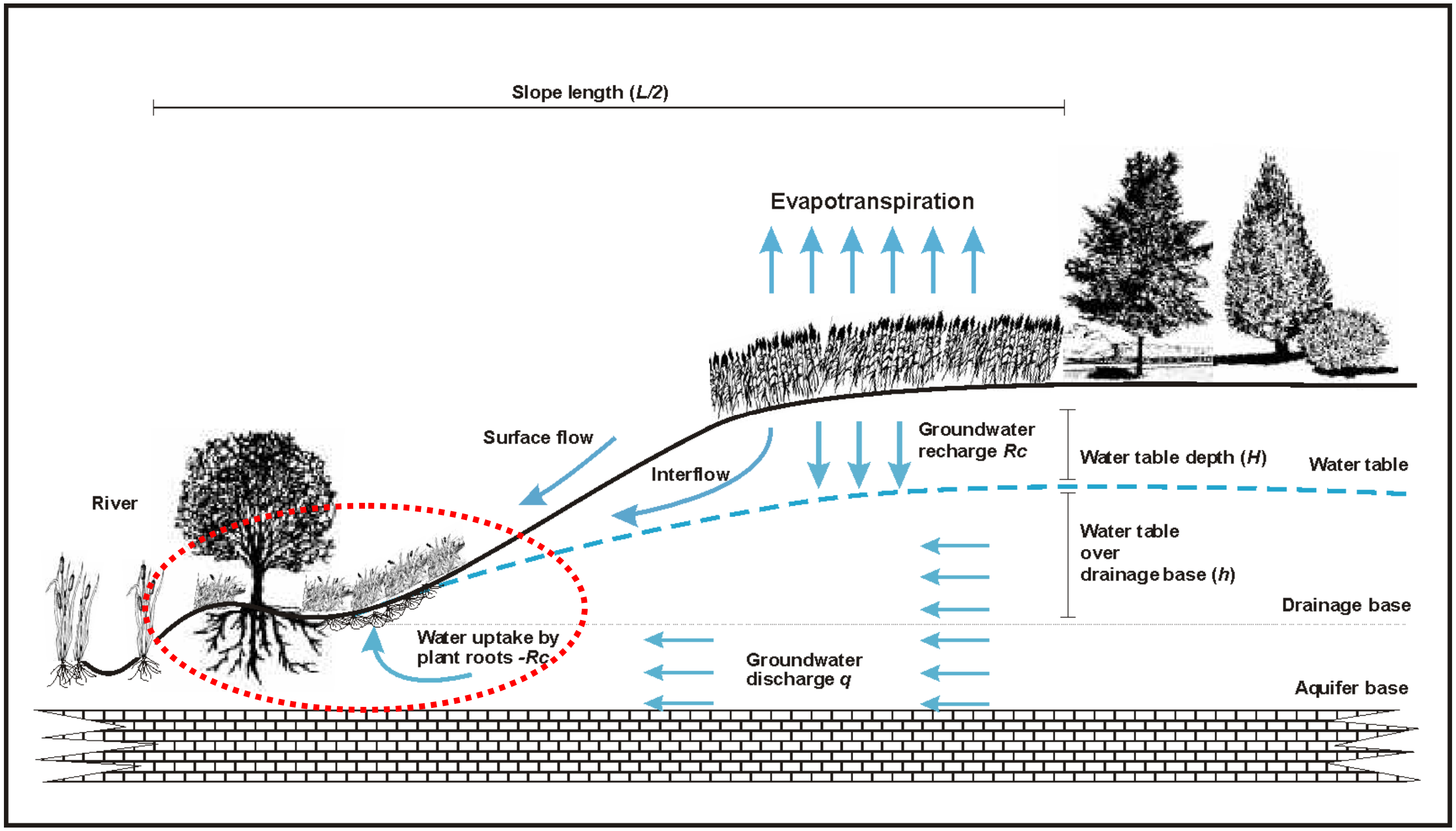
  (Fred Hattermann et al.)

- **Carbon module included explicitely in SWIM:**

  SWIM-SCN model version

  (Joachim Post et al.)

SWIM-rip concept: Water fluxes at the catchment scale and the role of riparian zone



⇒**Riparian zone serves as an interface between upland and river network (or: between subbsins and streams),**

1) **It interacts with groundwater,**
2) **lateral fluxes from upland pass through riparian zone**

SWIM-rip concept: Water fluxes at the catchment scale and the role of riparian zone

Model definition: A riparian zone or wetland is defined as a hydrotope with shallow g-w table, where plant roots can reach groundwater, and having lateral inflow from upland areas

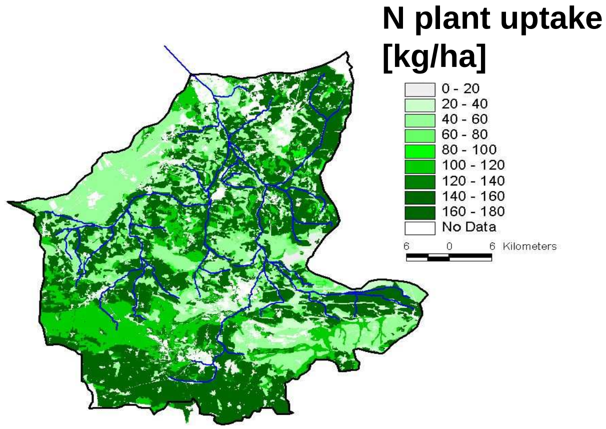
Three main changes introduced in the model:

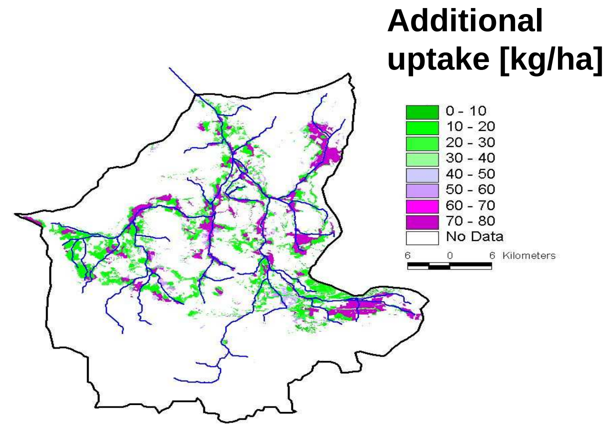
A. implementation of daily groundwater table dynamics at the hydrotope level and soil-groundwater interaction,

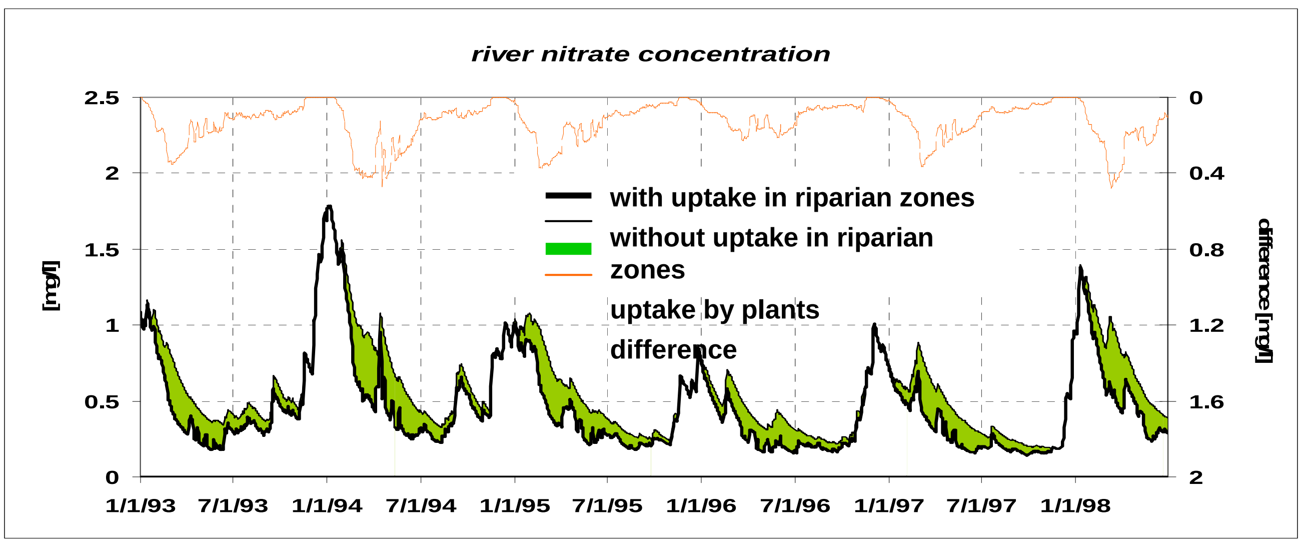
B. implementation of nutrient retention in groundwater and interflow (mainly through denitrification),

C. implementation of water and nutrient uptake by plants from groundwater in riparian zones and wetlands.

The effect of additional N uptake in riparian zones on N concentrations in the river







Attention!

More details in Fred Hattermann's presentation 14.7

SWIM-SCN model version: the concept

C/N turnover pools:

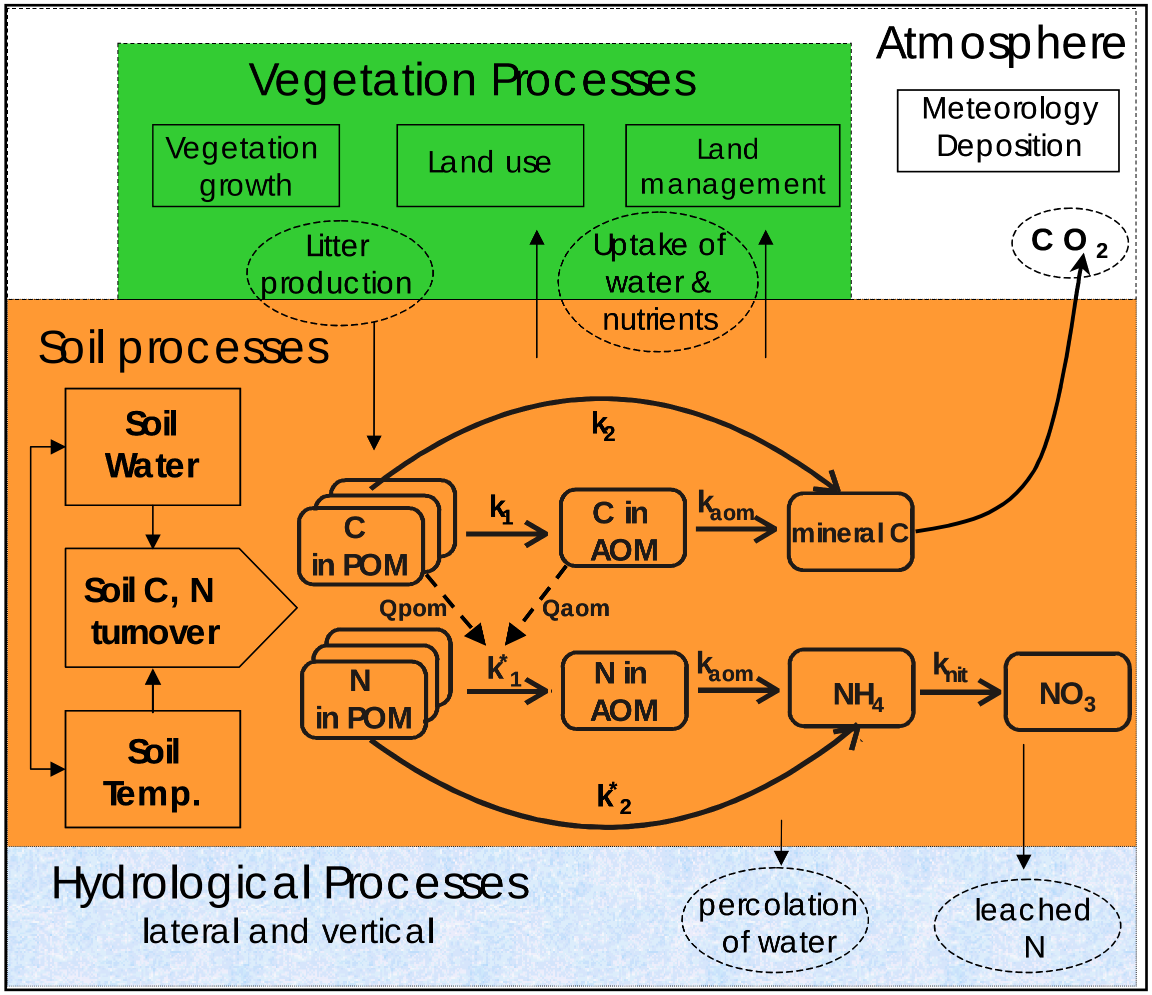
POM, AOM and mineral pools

5 POM fractions for each plant species

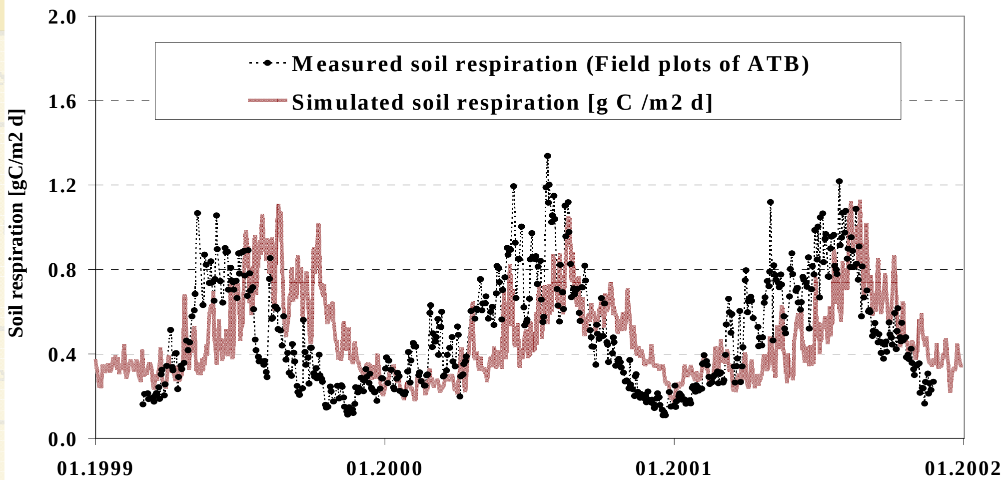
first order reaction kinetics, depending on soil moisture, soil temperature

Important!

The level of complexity of the new carbon module is compatible with those of other SWIM modules

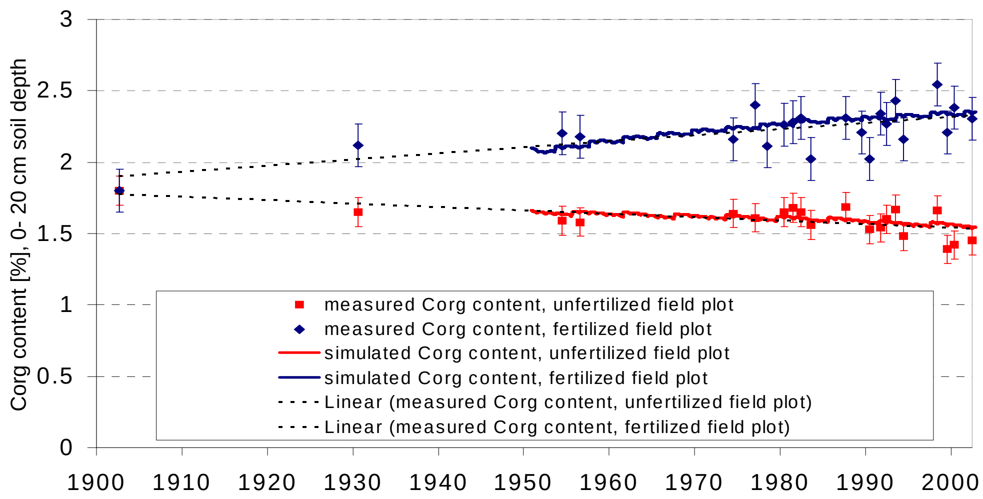


SWIM-SCN model version: verification



Heterotrophic soil respiration
Field plots ATB Potsdam, Germany

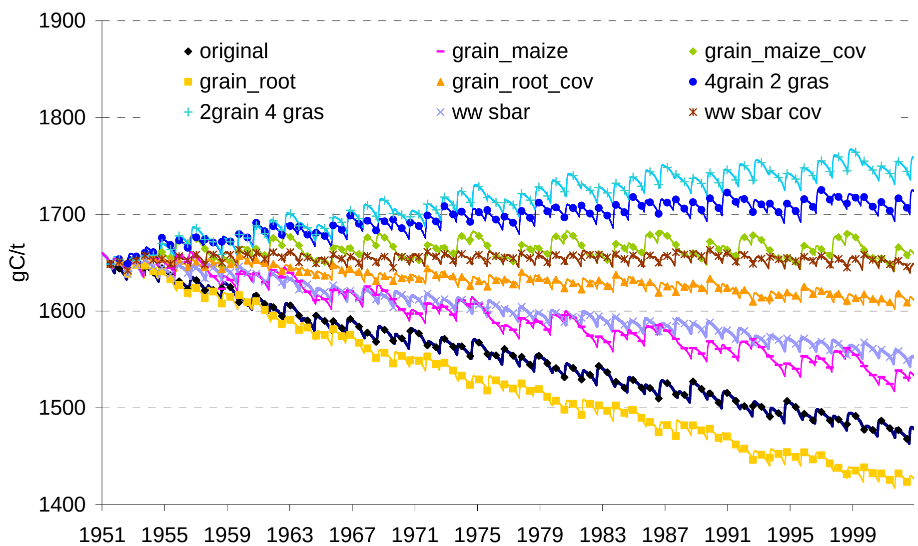
→ sandy soil, wheat – rye rotation
→ quick warming and cooling of sandy soil in spring / autumn causes a shift in simulations



Long term simulation
(1902 – 2002)
Field plots UFZ Bad Lauchstädt, Saxony-Anhalt, Germany

→ silty-loamy soil, high fertility
→ 4 year crop rotation
→ 2 fertilisation regimes

Effect of crop rotations on long term soil C dynamics Bad Lauchstädt experimental site (1951 – 2002)



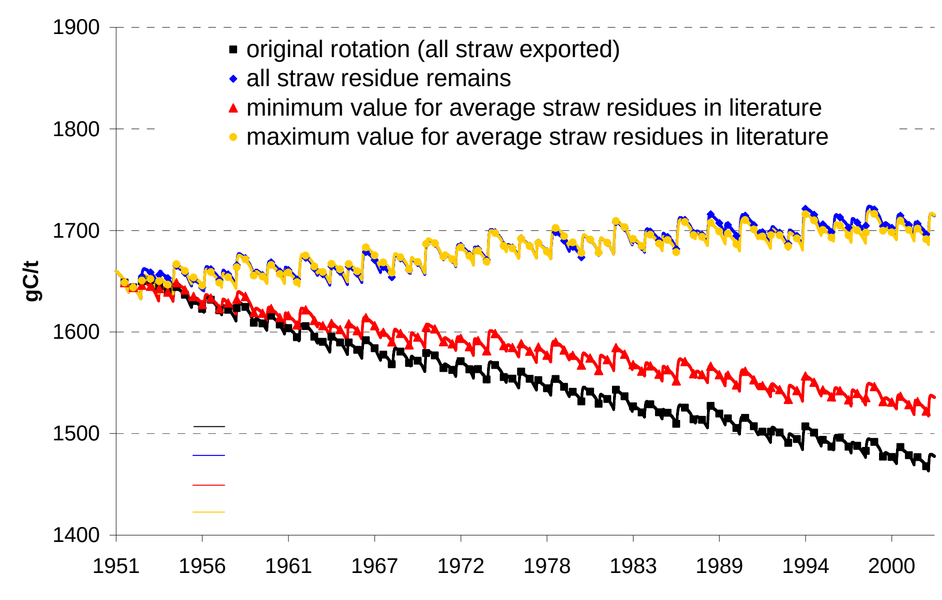
→ 4 yrs ley – 2 yrs grain: + 2.4 tC/ha 51 yr
→ 2 yrs ley – 4 yrs grain: + 1.6 tC/ha 51yr

→ grain rotations with cover crops: no trend

→ grain rotations without cc: - 2.7 tC/ha 51yr

→ grain – root crops: ~ - 5.0 tC/ha 51 yr

Effect of crop residue management on long term soil C dynamics, Bad Lauchstädt experimental site (1951 – 2002)



→ incorporate all straw residue:
→incorporate 1.7 t C/ha 2 yrs (as straw)
+ 1.3 t C/ha 51 yr

→ incorporate 0.7 t C/ha 2 yrs - 3.1tC/ha 51yr
→ original rotation (all straw removed):
- 4.6 tC/ha 51 yr

Attention!

See poster for more details: Joachim Post et al.

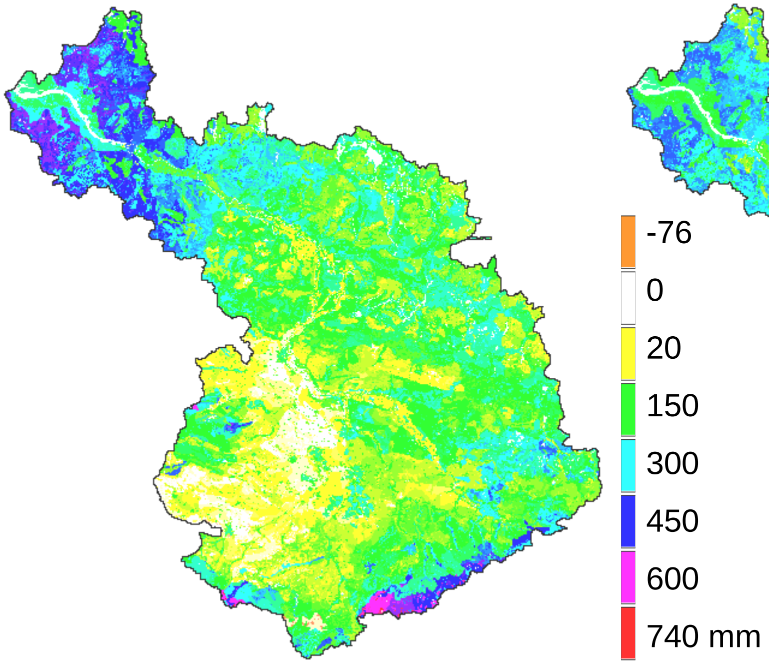
SWIM application for impact studies

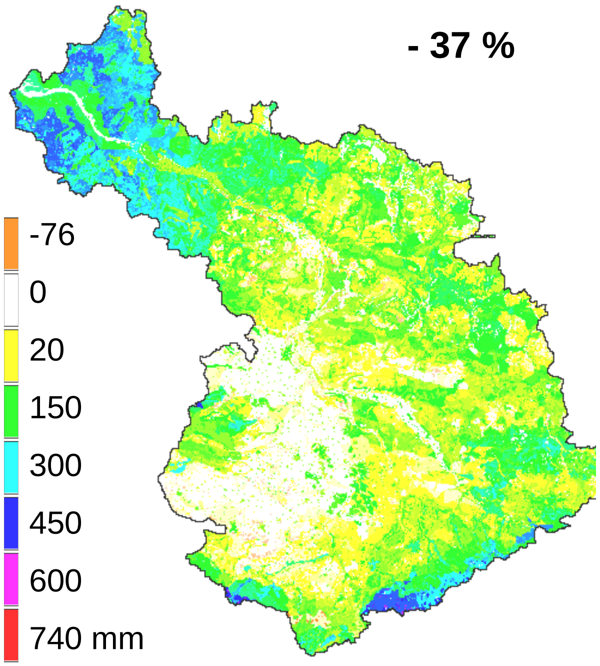
- Climate change impact assessment (water, crop yield, water quality: N) (VK, FH)
- Land use change impact assessment (water, water quality: N & P) (VK, AH)

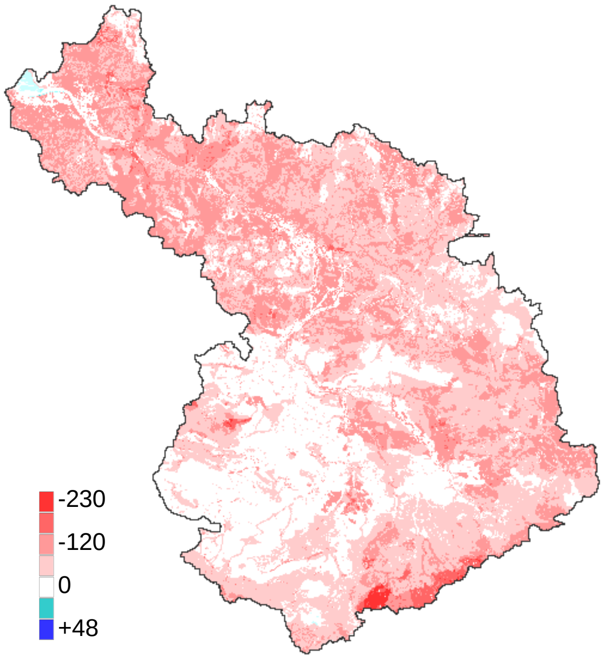
Climate change impact on groundwater recharge

Reference period	Scenario (v. 32)	Difference map
1991-2000	2046-2055	(Scenario – Reference)
Average = 133 mm	Average = 84 mm	

- 37 %







Climate change impact on crop yield

Winter wheat:

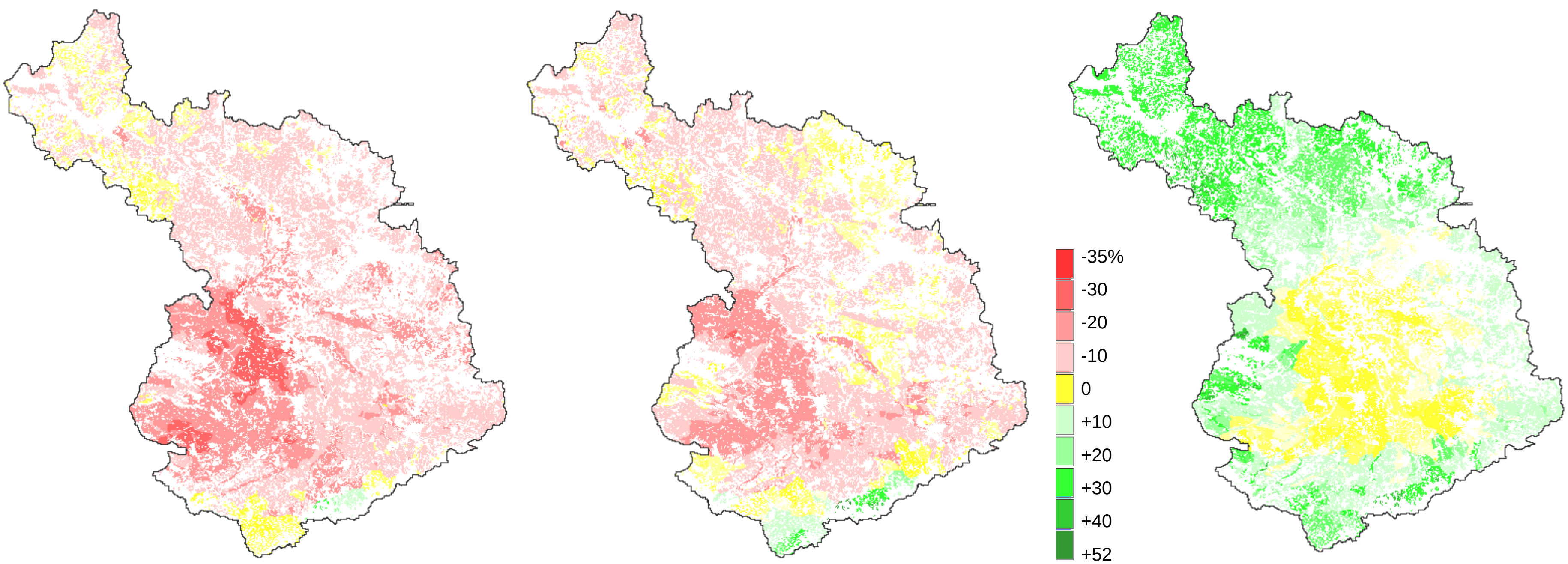
Change in %

Winter barley:

Change in %

Silage maize:

Change in %



Average = - 13 %

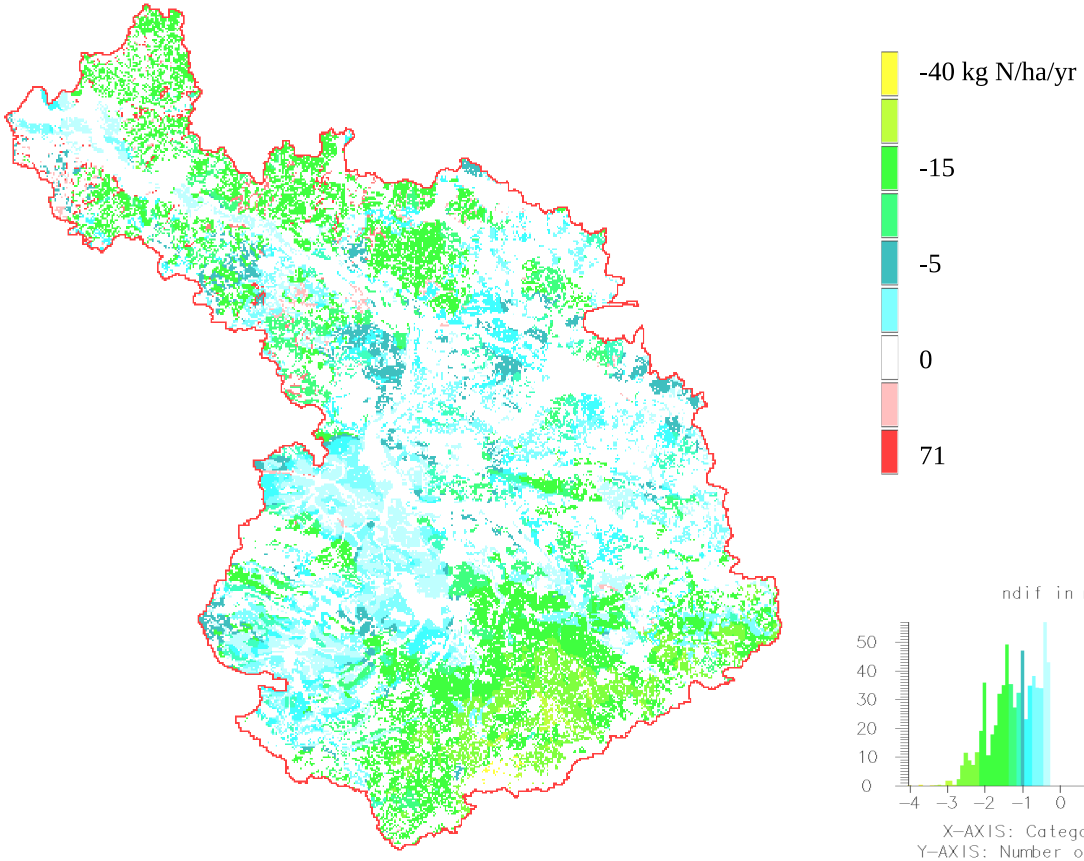
Average = - 9 %

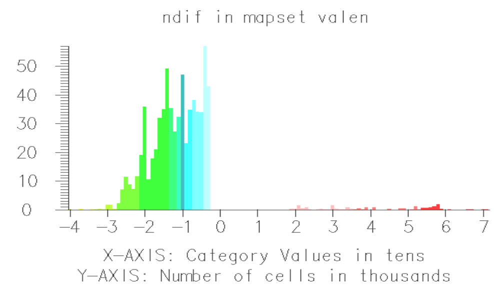
Average = + 9 %

Climate change impact on N losses with water from arable land

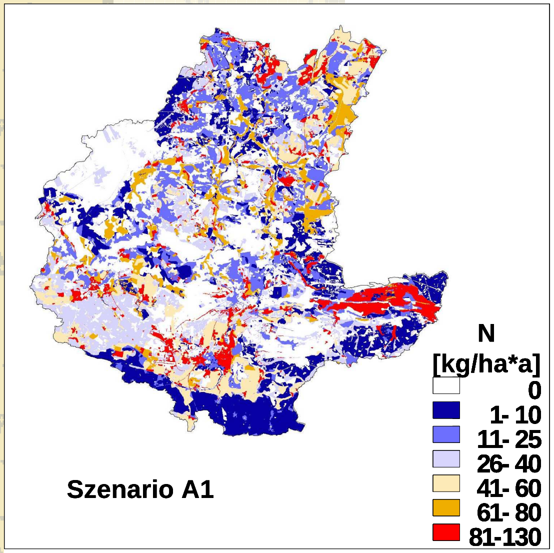
Difference map

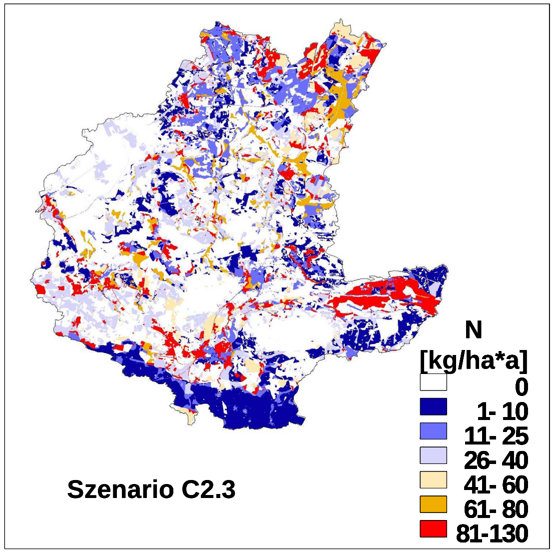
(Scenario – Reference)

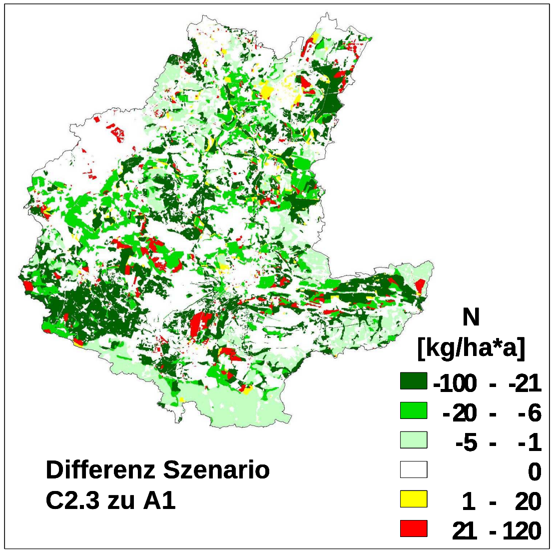


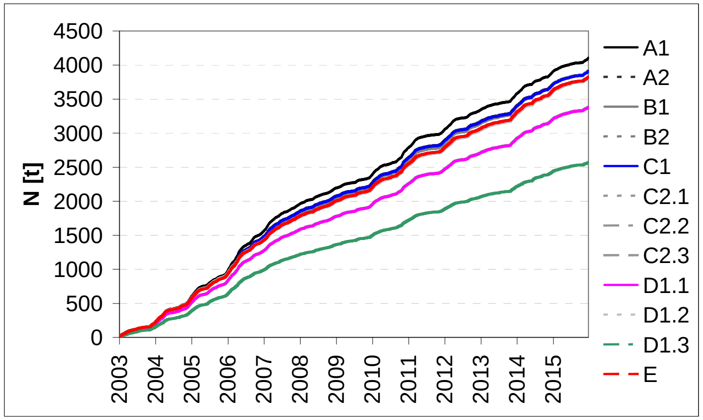


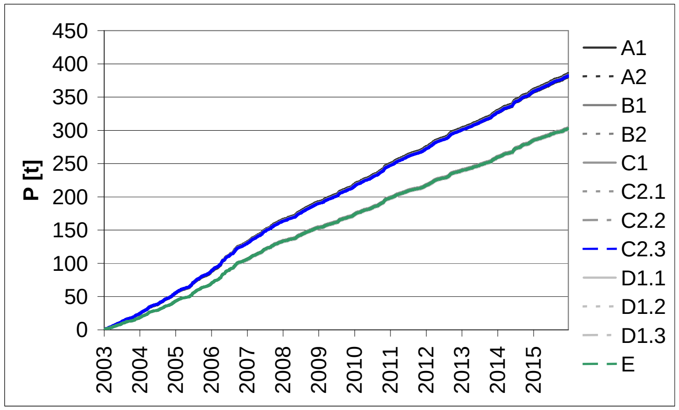
Land use change impact on N losses from diffuse sources and accumulated N & P loads (Nuthe, Babelsberg)











Selected references on SWIM

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Wechsung, F., Krysanova, V., Flechsig, M., Schaphoff, S., **2000**. May land use change reduce the water deficiency problem caused by reduced brown coal mining in the state of Brandenburg? *Landscape and Urban Planning*, 51 /2-4, 105-117.