Effectiveness of water and nutrient retention measures in small agricultural catchments – Insights from the German OPTAIN case study

Michael Strauch, Felix Witing, Christoph Schürz, Martin Volk

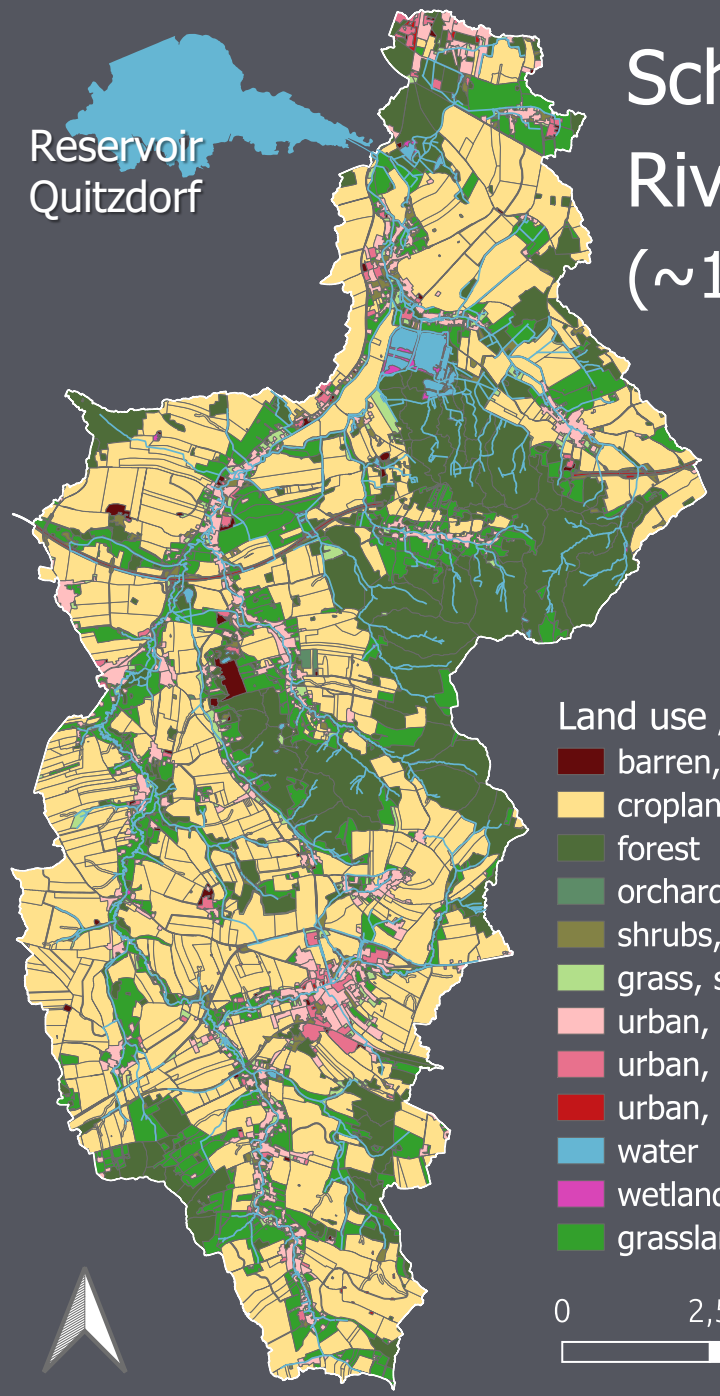
2024 International SWAT Conference in Strasbourg, FR, Session A2, July 10 2024

OPTAIN Optimal Strategies to Retain Water and Nutrients

UFZ HELMHOLTZ Centre for Environmental Research

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 862756.

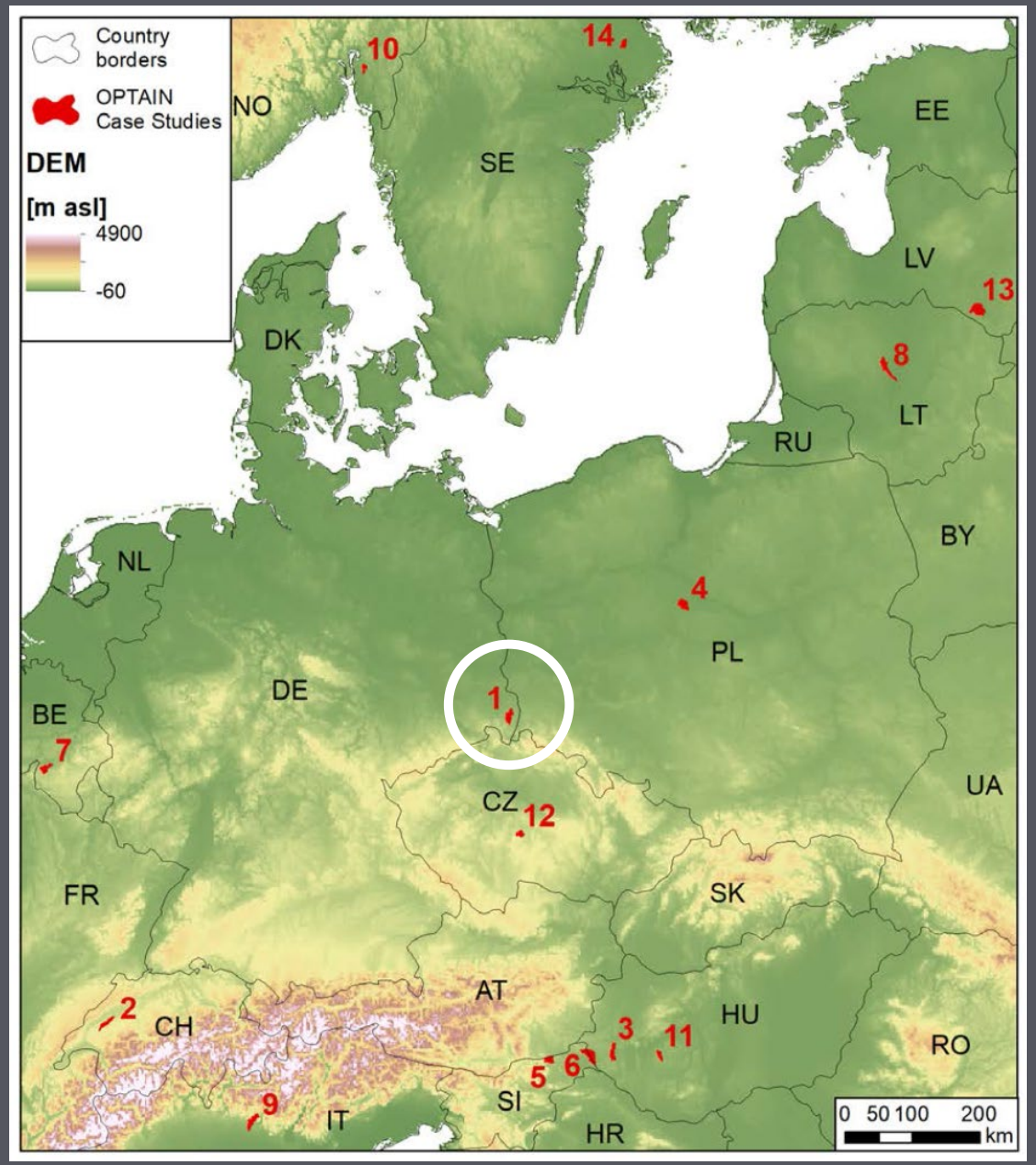
Schwarzer Schöps River Basin (~137 km²)



Land use / cover
- barren, sparse vegetation
- cropland
- forest
- orchards
- shrubs, semi-natural
- grass, semi-natural
- urban, low density
- urban, moderate density
- urban, transport
- water
- wetlands
- grassland, meadows

0 2,5 5 km

OPTAIN case studies

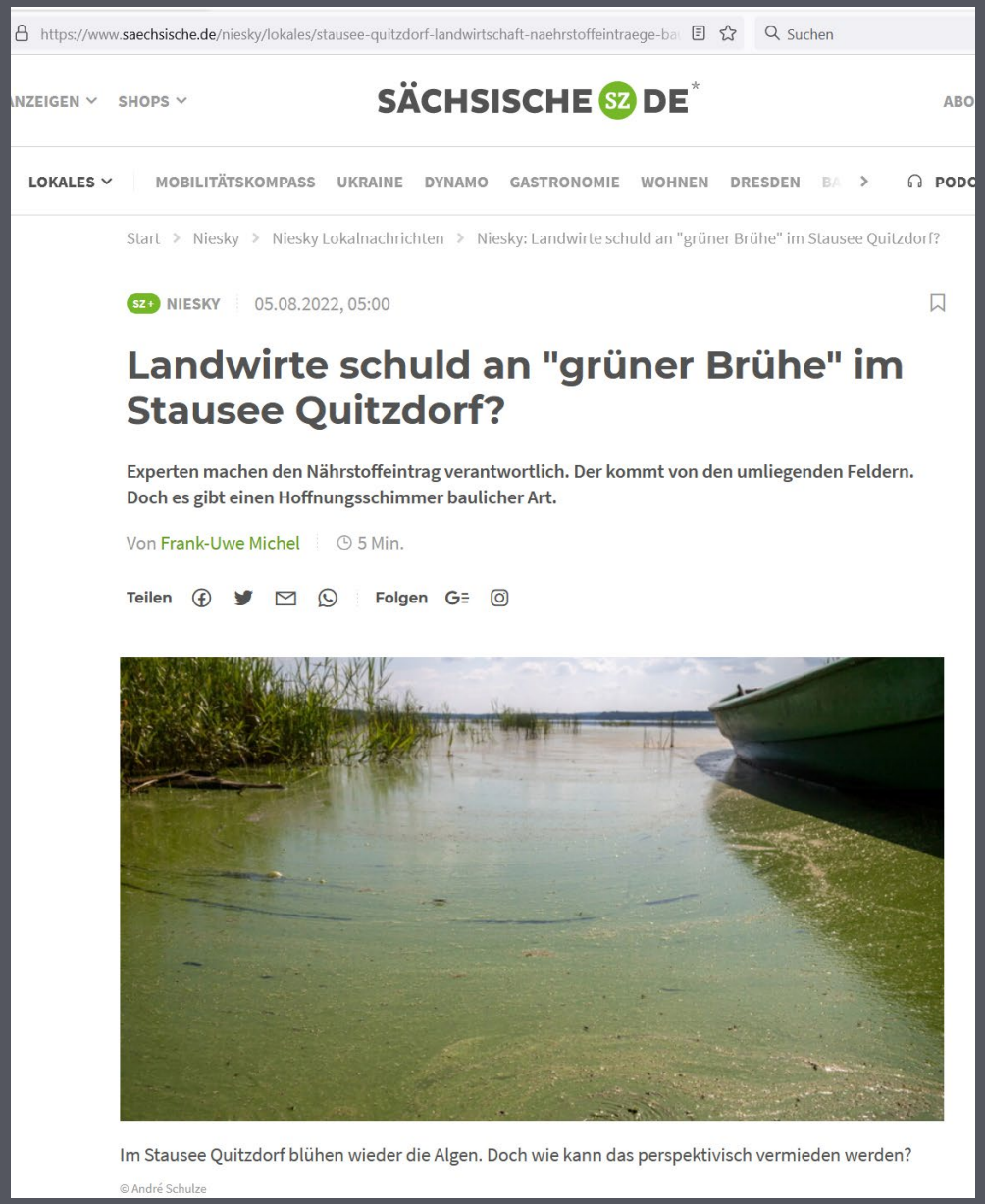


OPTAIN

Background: Retention problem in the German case study

- Blue algae bloom in reservoir Quitzdorf
- Average P load entering the reservoir ~ 6 tons/yr (reference: 3-4 tons/yr) + decreasing water inflows in dry periods
- Strategies announced by authorities:
  (1) reservoir restoration (incl. removal of sediments)
  (2) increase water and P retention in the catchment

OPTAIN Optimal Strategies to Retain Water and Nutrients


https://www.saechsische.de/niesky/lokales/stausee-quitzdorf-landwirtschaft-naehrstoffeintraege-ba

Suchen

ANZEIGEN SHOPS SÄCHSISCHE SZ DE ABO

LOKALES MOBILITÄTSKOMPASS UKRAINE DYNAMO GASTRONOMIE WOHNEN DRESDEN BA PODC

Start > Niesky > Niesky Lokalnachrichten > Niesky: Landwirte schuld an "grüner Brühe" im Stausee Quitzdorf?

SZ+ NIESKY 05.08.2022, 05:00

Landwirte schuld an "grüner Brühe" im Stausee Quitzdorf?

Experten machen den Nährstoffeintrag verantwortlich. Der kommt von den umliegenden Feldern. Doch es gibt einen Hoffnungsschimmer baulicher Art.

Von Frank-Uwe Michel 5 Min.

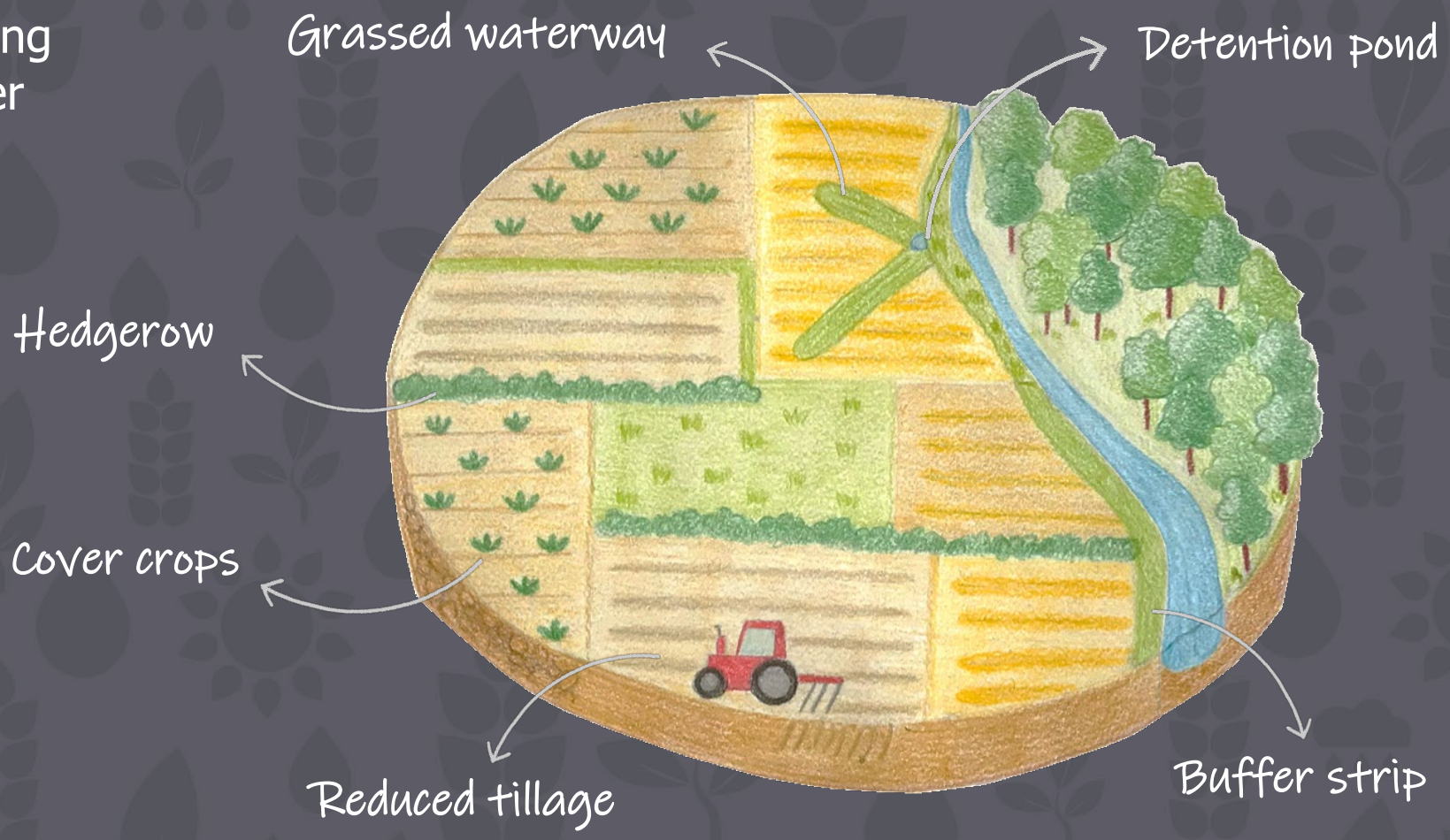
Teilen Folgen

Im Stausee Quitzdorf blühen wieder die Algen. Doch wie kann das perspektivisch vermieden werden?

© André Schulze

Retention measures in the German case

Selection and mapping of measures together with local actors



OPTAIN

Catchment modelling – overview of inputs and outputs

Input data

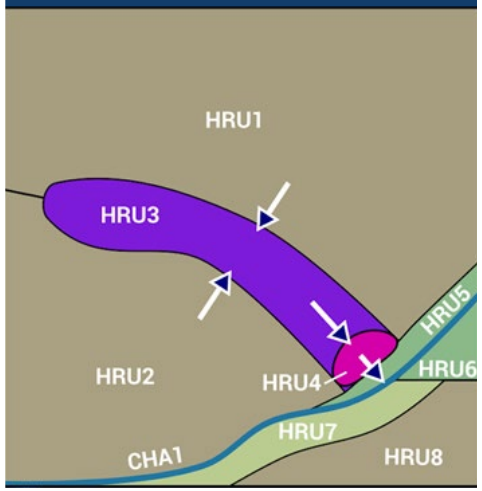
Status quo
- Weather
- Atmospheric depostion
- Point sources
- Water bodies
- Elevation map
- Soil map
- Land use map
- Field boundaries
- Agricultural practices

Scenarios
- Climate scenarios
- Measure allocation maps

Economic data on agricultural practices & measures

Catchment model

SWAT+
Soil & Water Assessment Tool
COCOA



Model results

For each land unit:
- Crop yields
- Soil moisture
- Water fluxes
- Sediment fluxes
- Nutrient fluxes

For each channel:
- Discharge
- Sediment loads
- Nutrient loads

Environmental and economic performance of retention measures under current & future climate

OPTAIN

Side note

Input data

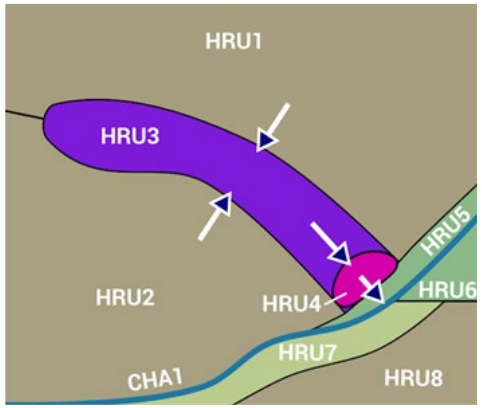
- Point sources
- Water bodies
- Elevation map
- Soil map
- Land use map

Catchment model

SWAT+
Soil & Water Assessment Tool

SWATbuildR

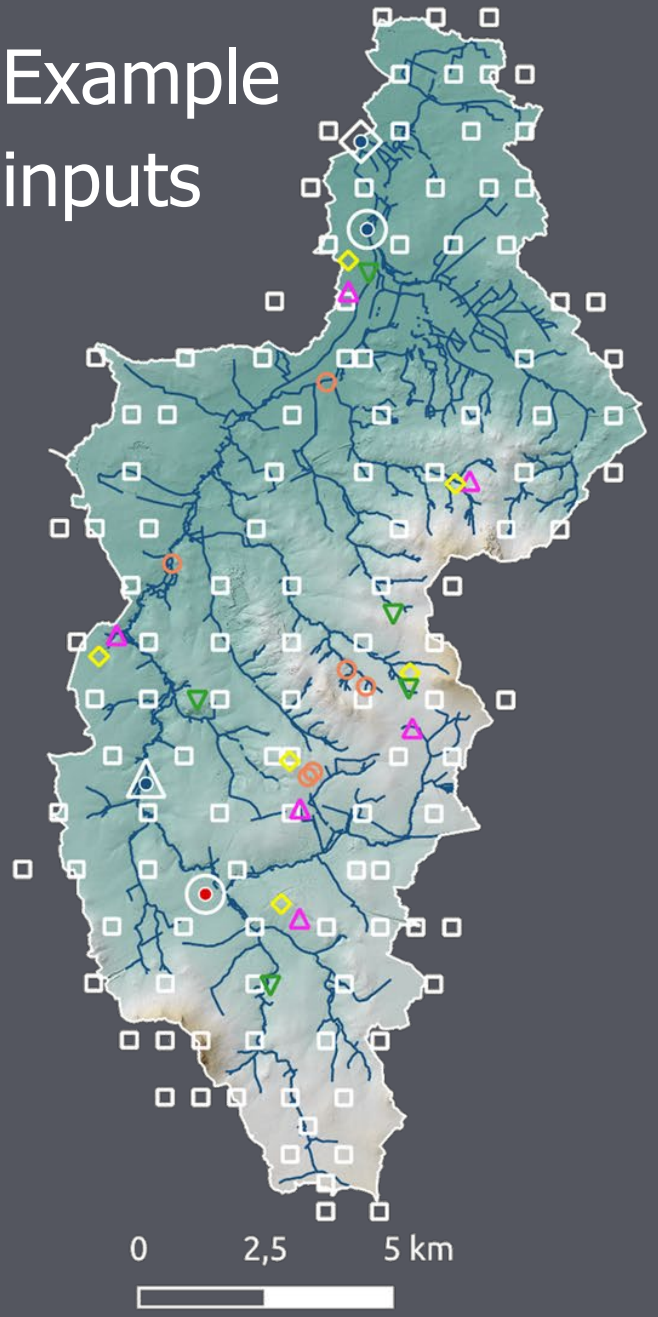
An object connectivity based SWAT+ model builder



Further input data supply and model parameterisation…

OPTAIN

Example inputs

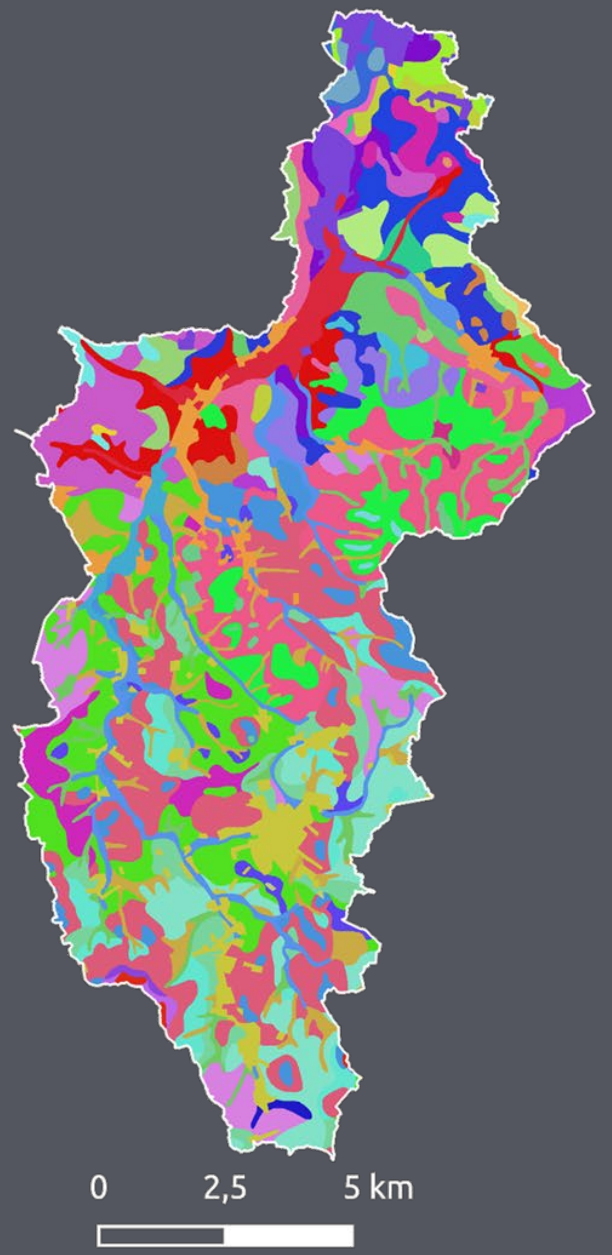


DEM (2m)
[geodaten.sachsen.de]
m a.s.l.
449.15
159.34

Weather stations (virtual)
[ReKIS RaKliDa]
- Precipitation
- Wind speed
- Temperatue (min, max)
- Solar radiation
- Relative humidity

Stream gauges
[iDA Sachsen, LTV Bautzen]
- Jänkendorf 1
- Schöps
- Zufluss TS Quitzdorf

Point source [UWB Görlitz]
- ZKA Reichenbach



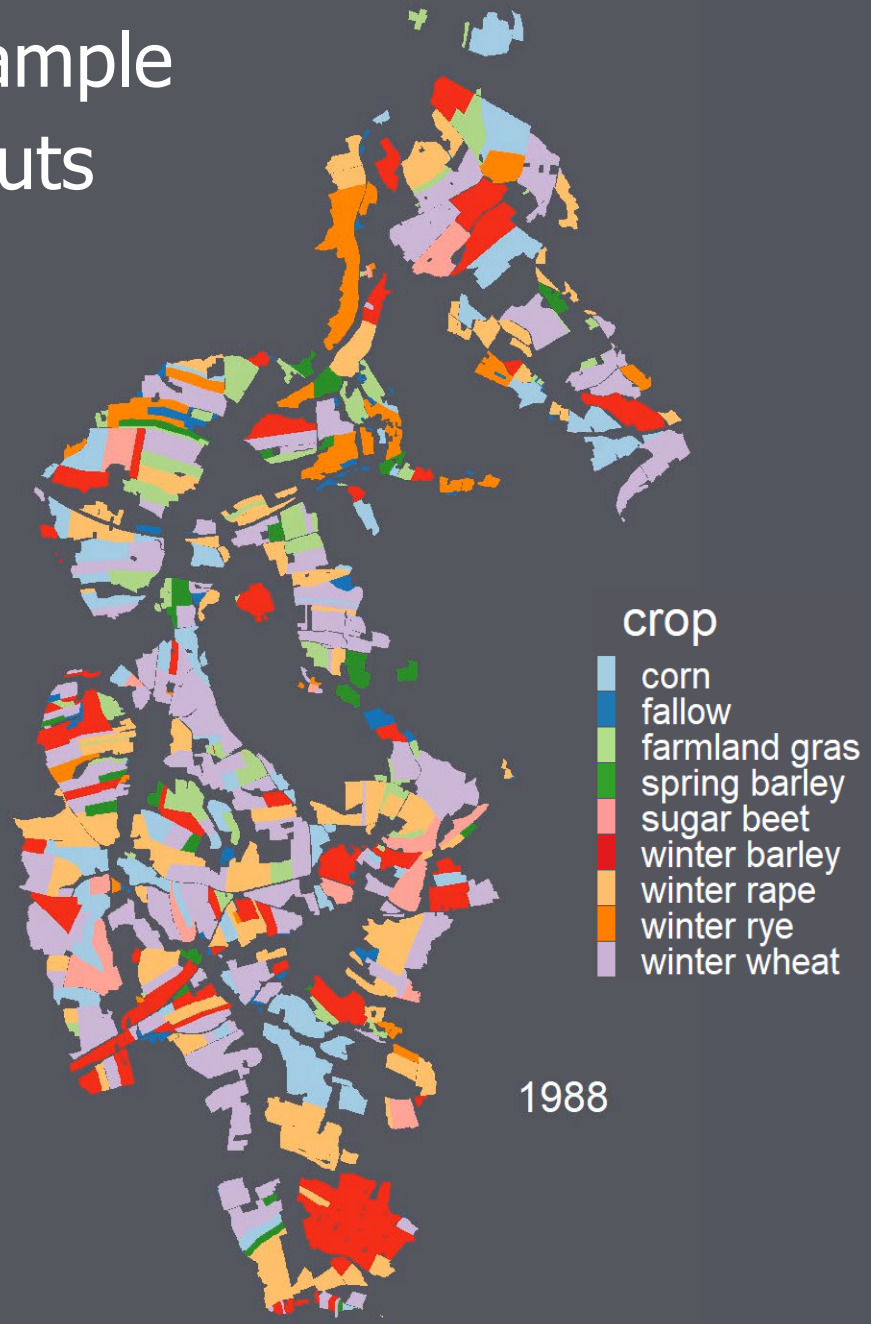
Soils (1:50,000)
[BK50, LfULG (2020)]
54 soil classes

SWAT soil properties
(for each soil class and layer*)
- Soil Hydrologic Group[2]
- Maximum soil depth[1]
- Depth[1]
- Moist bulk density*[3]
- Available water capacity*[1]
- Saturated hydraulic conductivity*[3]
- Organic carbon content*[1]
- Clay content*[1]
- Silt content*[1]
- Sand content*[1]
- Rock content*[1]
- Albedo*[4]
- USLE K factor*[5]

[1] provided with soil map,
[2] Thuerkow (2002),
[3] Renger et al. (2008),
[4] Gascoin et al. (2009),
[5] Auerswald & Ehlhaus (2013)

OPTAIN

Example inputs



Management of cropland

- Crop rotations based on IACS (2016-2021)
- Crop-specific operations (based on literature and local farm advisor):
  - Tillage (date, type)
  - Planting (date)
  - Fertiliser (date, type, amount)
  - Harvest (date, type)
- Operation dates account for precipitation (e.g. no fertiliser application on a rainy day)

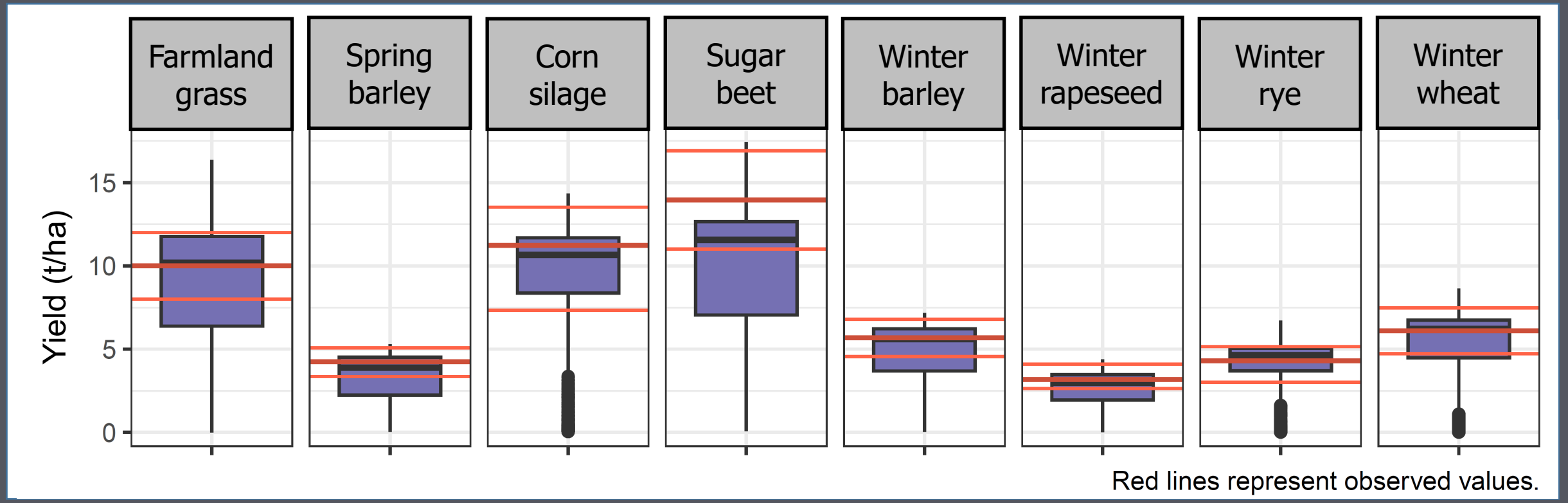
SWATfarmR

Simple rule based management operation scheduling

OPTAIN

Model performance

Crop yields



Model performance

Ensemble of 10 best simulations from calibration

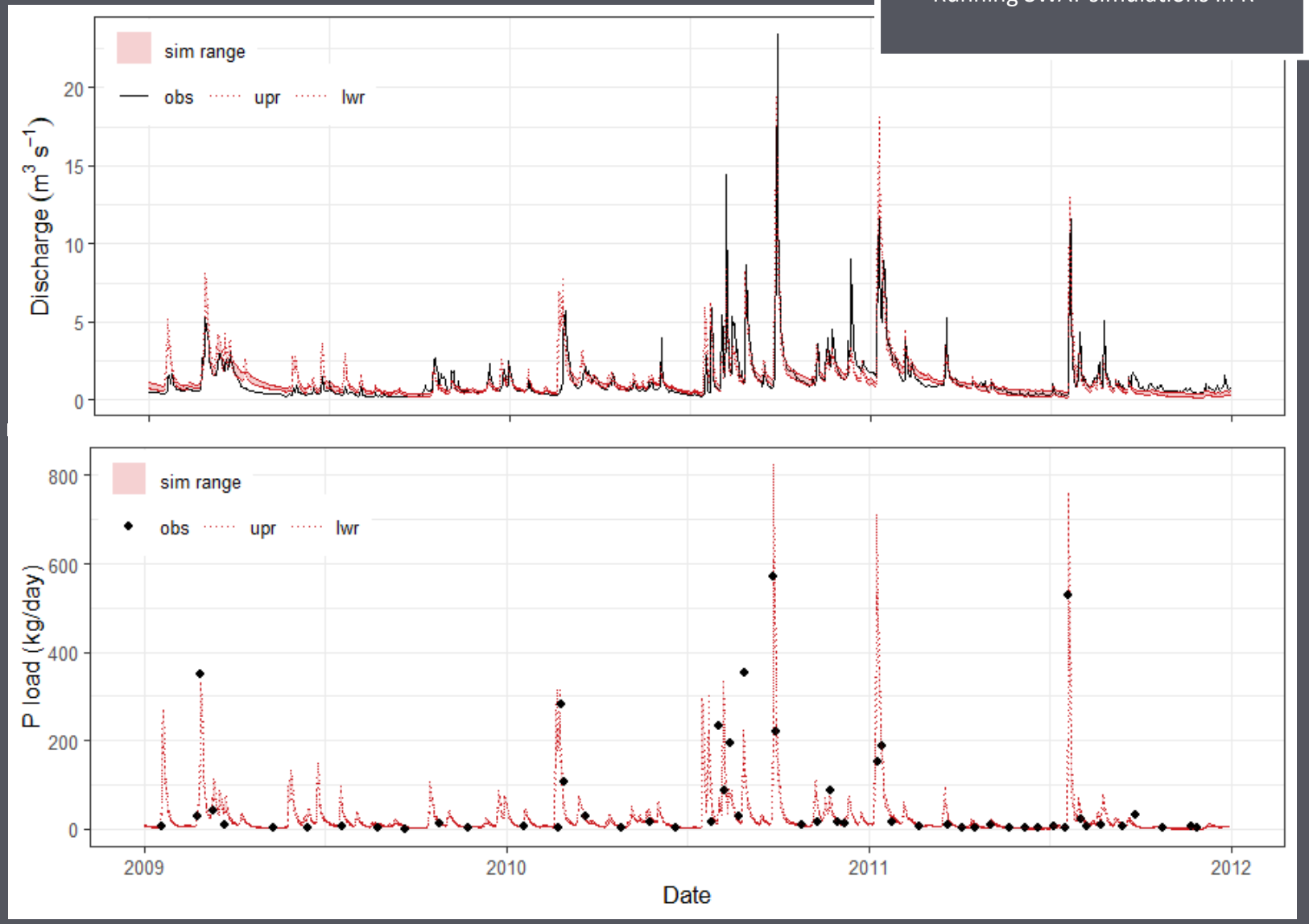
	Calibration 2009-2020	
	Q	P
NSE	0.65 – 0.73	0.62 – 0.65
KGE	0.76 – 0.82	0.57 – 0.71
R^2	0.66 – 0.73	0.63 – 0.67
PBIAS	-2.1 – 1.8	-16.3 – 5.2

	Validation 1991-2008	
	Q	P
NSE	0.08 – 0.33	0.24 – 0.30
KGE	0.42 – 0.56	0.33 – 0.40
R^2	0.56 – 0.63	0.27 – 0.31
PBIAS	28.5 – 35.4	-10.6 – -17.7

Discharge and P load

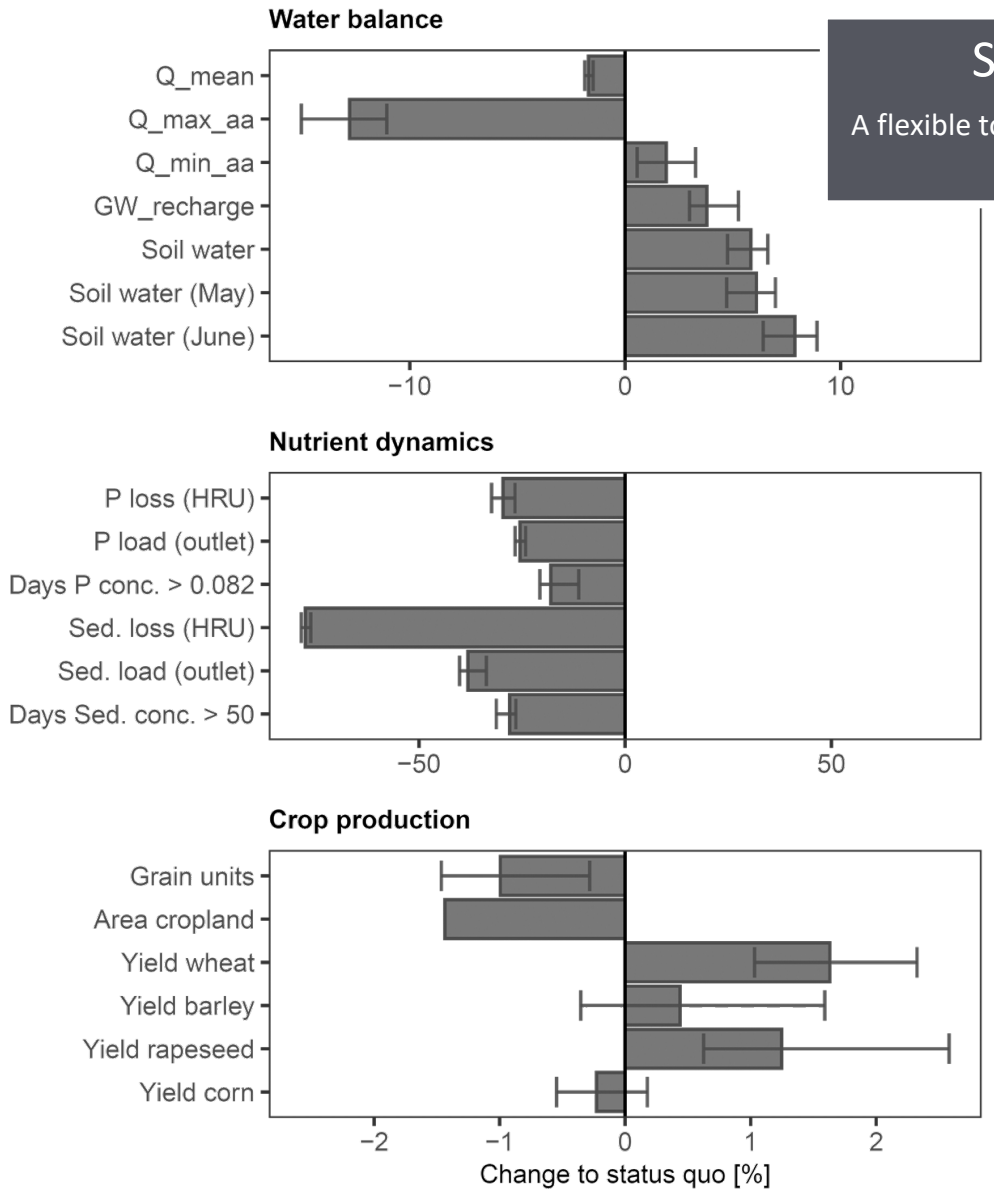
SWATrunR

Running SWAT simulations in R



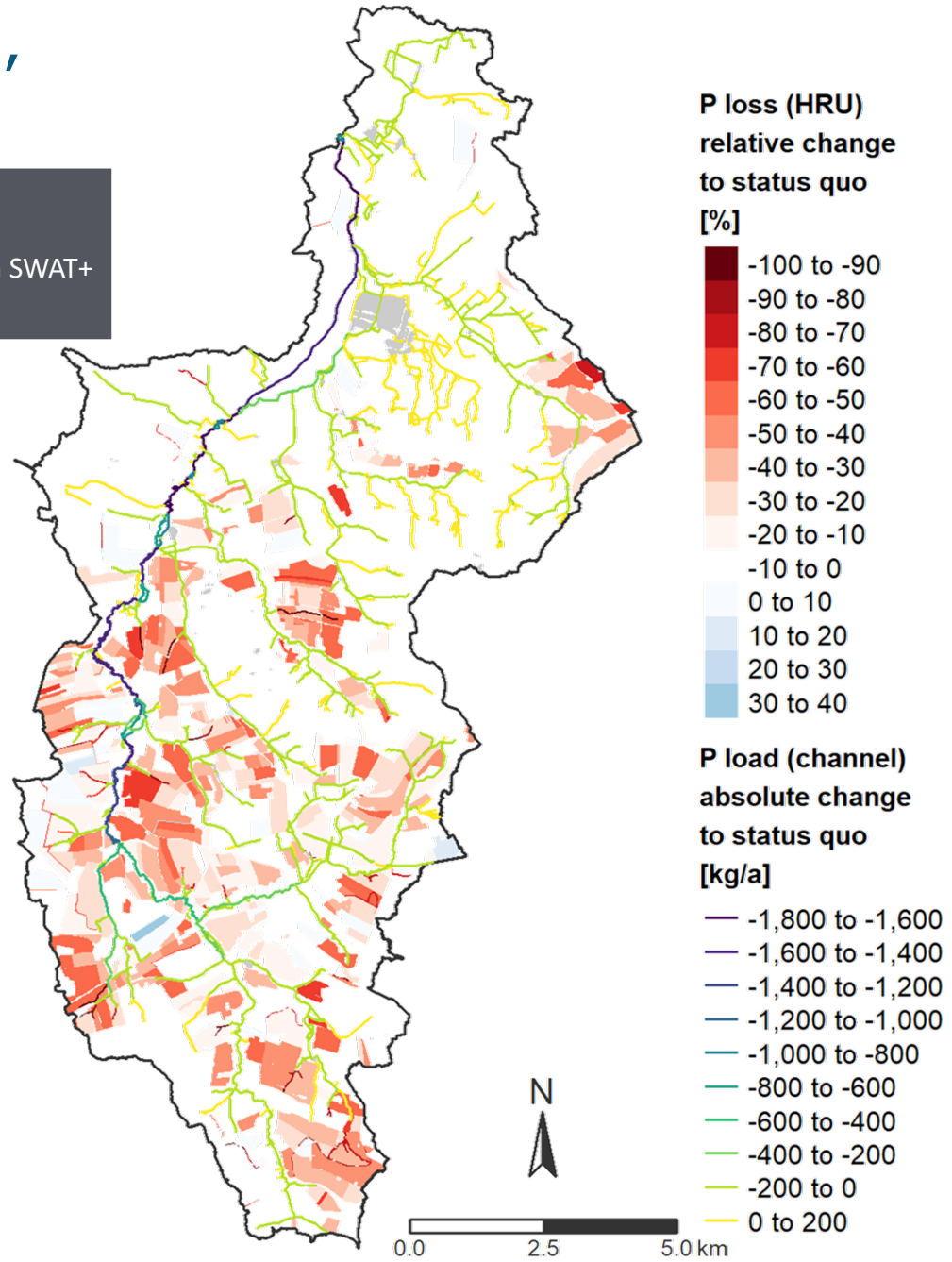
OPTAIN

Effectiveness of retention measures: Scenario 'all'



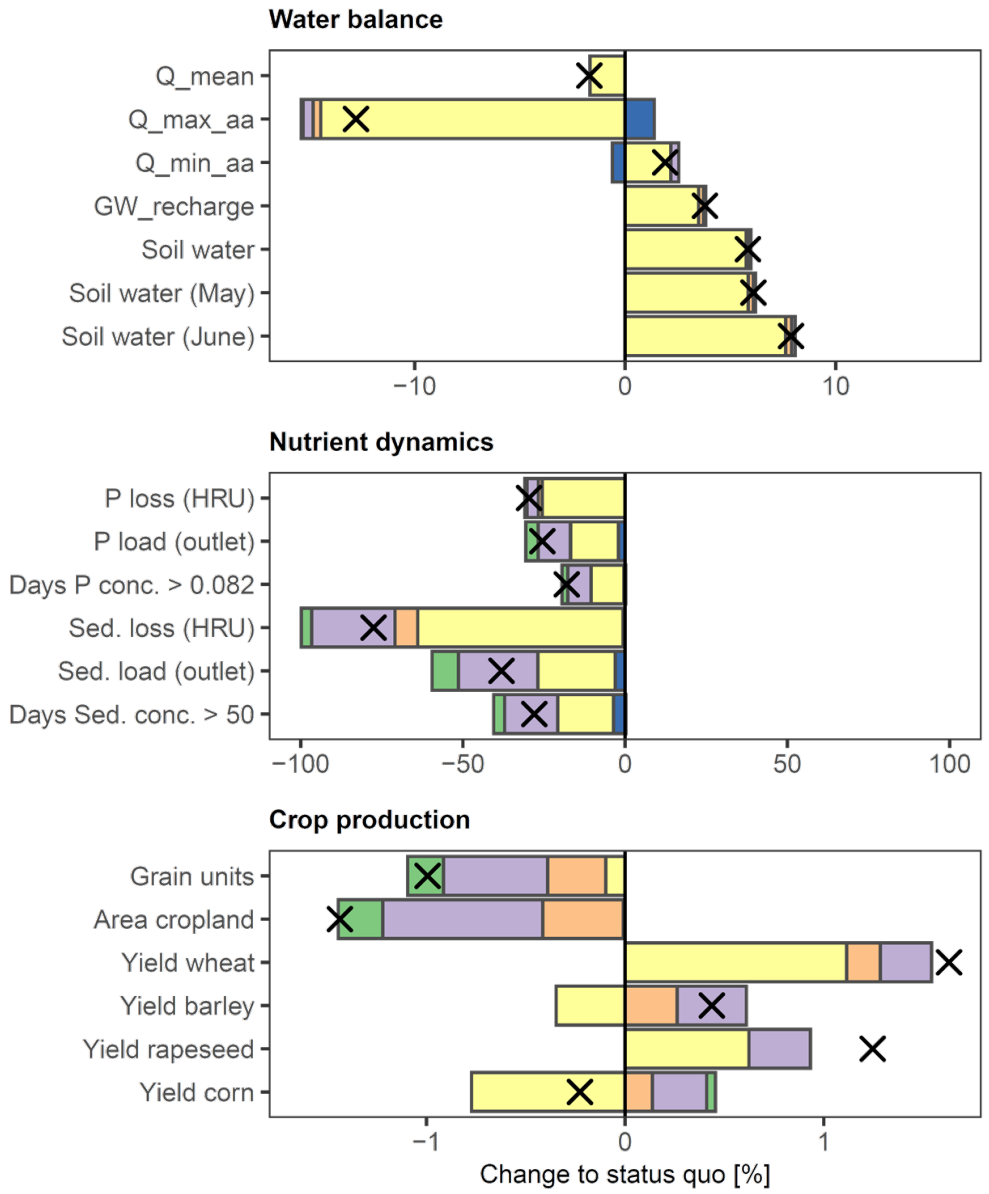
SWATmeasR

A flexible tool to implement BMPs in SWAT+ model setups



OPTAIN

Effectiveness of retention measures: Scenario 'all' and measure-specific scenarios



⇒ Significant effect on water balance only in the case of low tillage + cover crops (lt+cc)

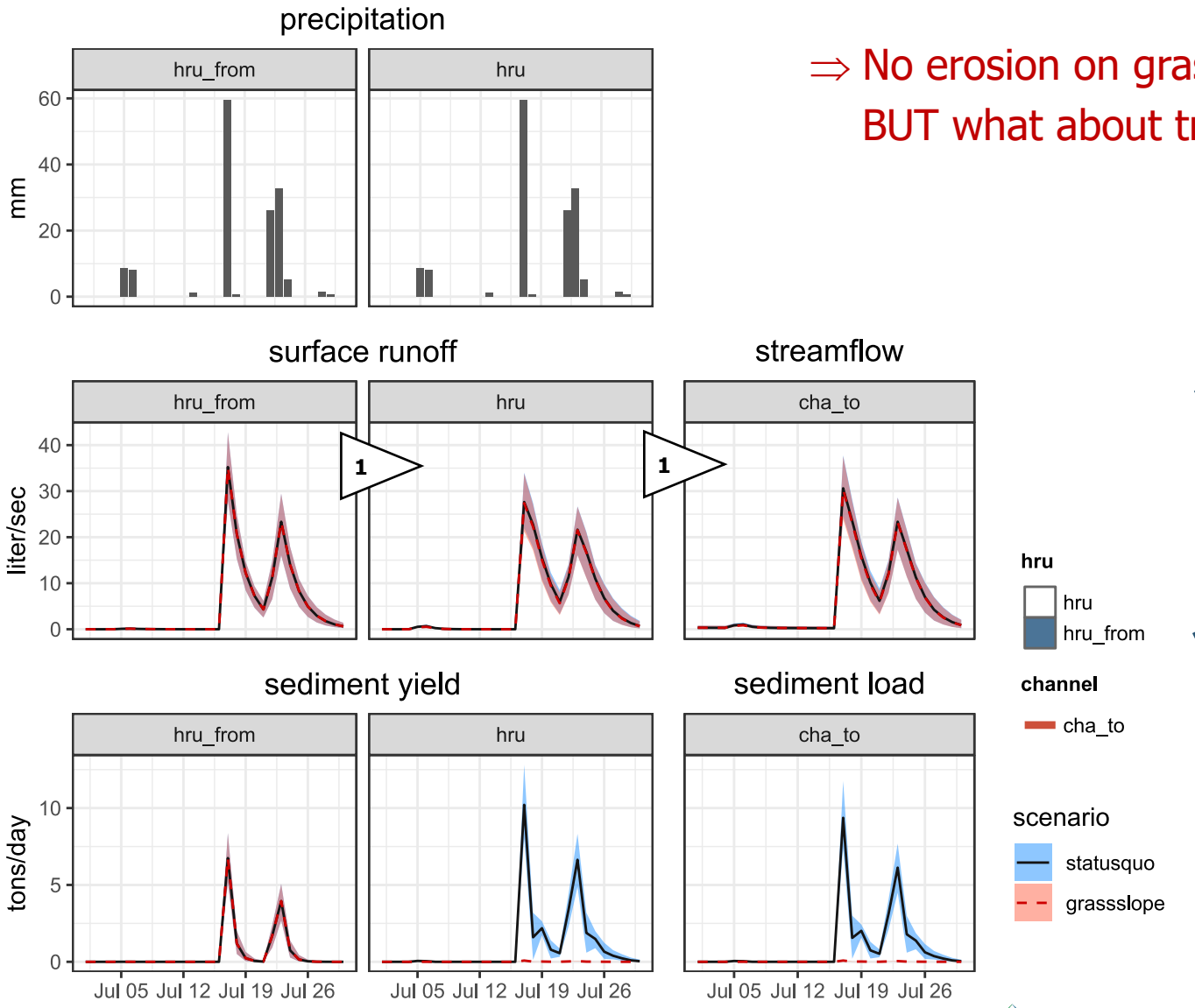
⇒ All measures retain sediment and P (but with clear differences)
...very effective: lt+cc and grassed waterways
...small effect of riparian buffer and detention ponds
...only marginal effects of hedges

⇒ Impact on crop yield at basin-level rather low
...slightly decreasing total production
...unproductive locations are often taken out of production in scenario case, resulting in slightly increasing productivity (t/ha)

NSWRM
- Riparian buffer
- Grassed waterways
- Hedges
- Low tillage + cover crops
- Detention ponds
- × All at the same time

OPTAIN

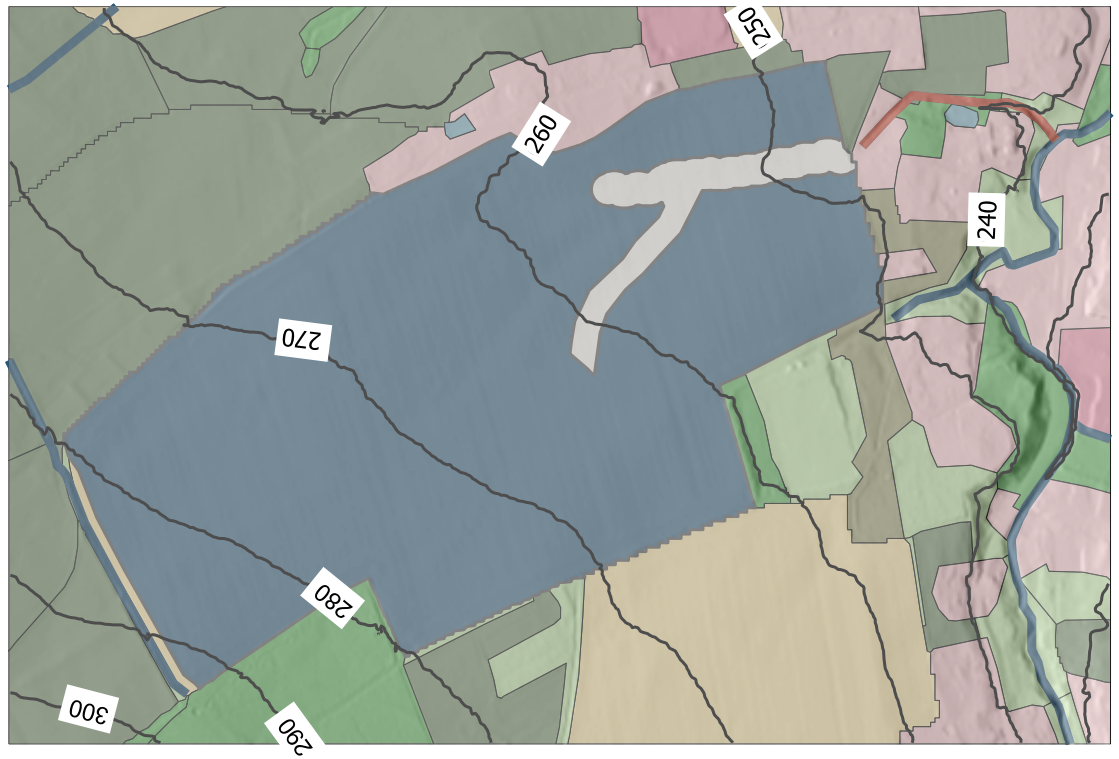
A closer look to individual implementation sites…



⇒ No erosion on grassed hru (usle_p = 0.012)

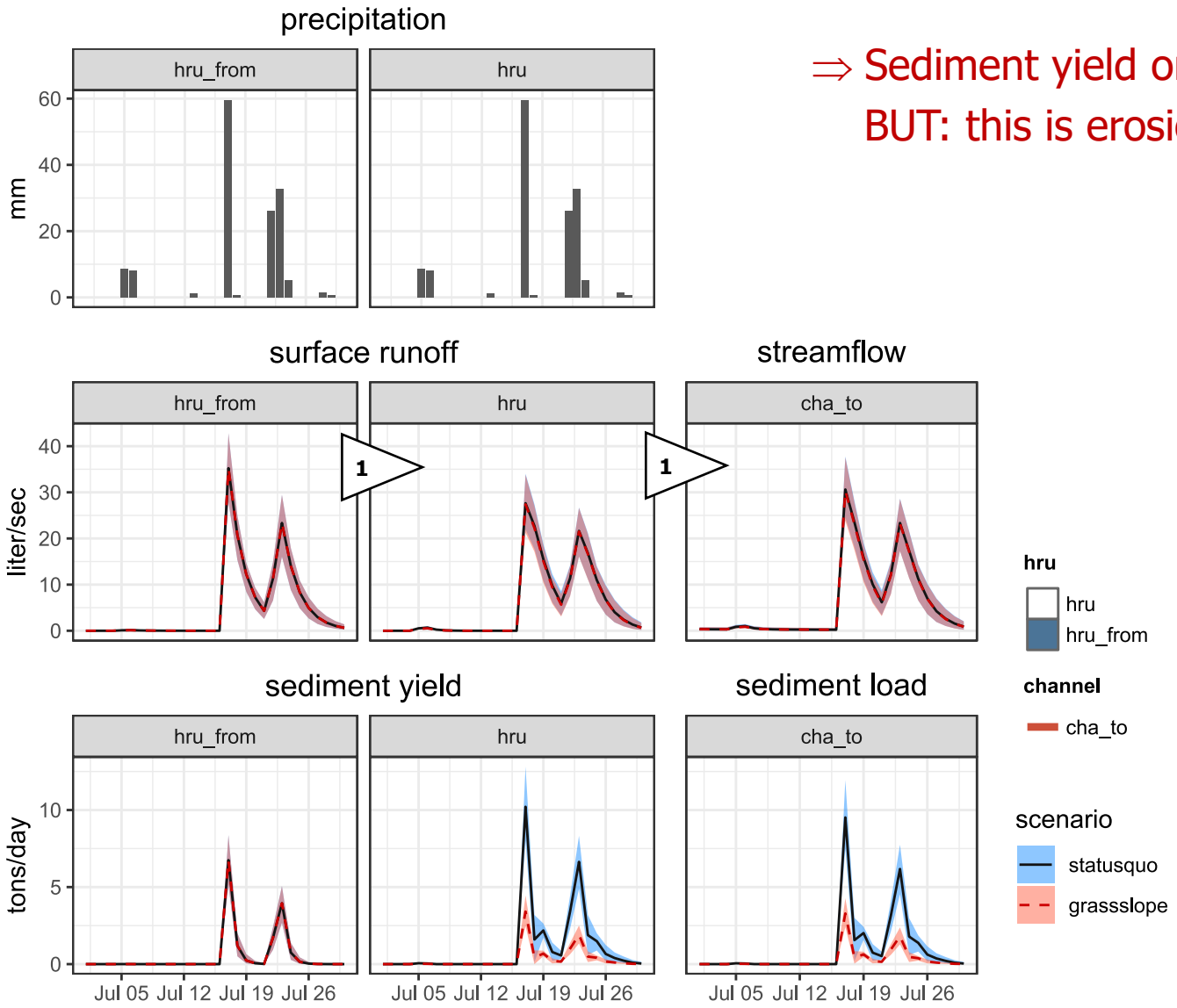
BUT what about transport of incoming sediments?

Grassed waterway directly connected with downstream channel



OPTAIN

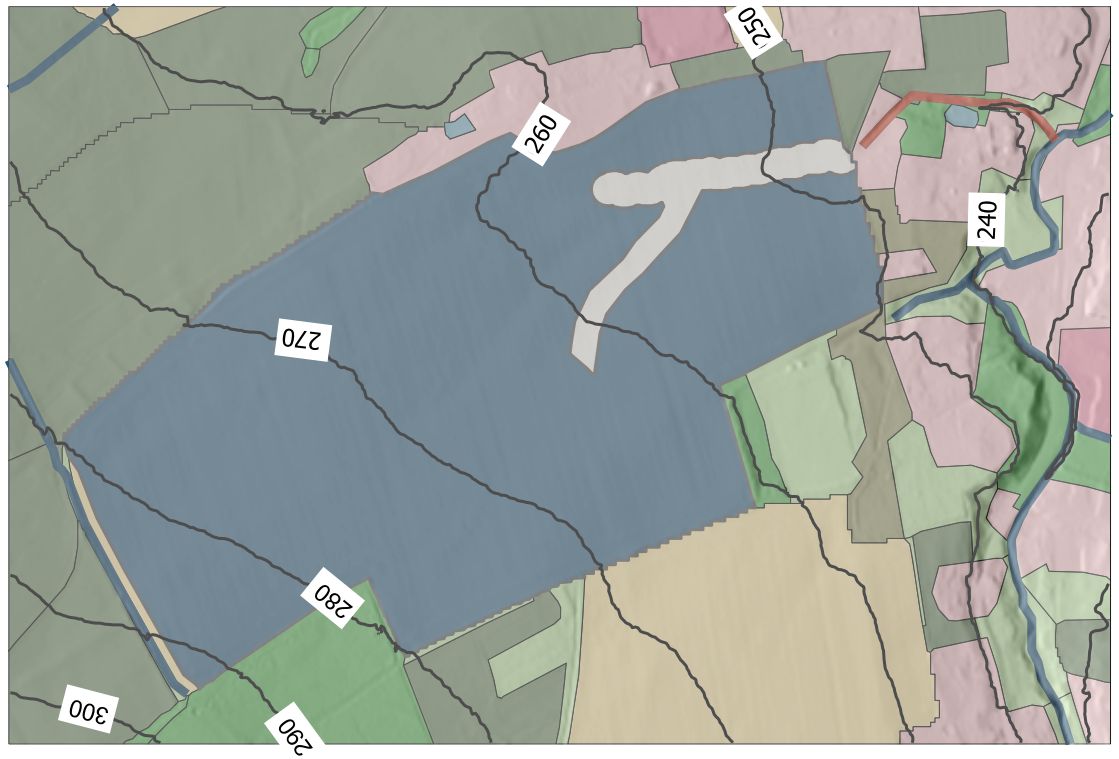
A closer look to individual implementation sites…



⇒ Sediment yield on grassed hru can be simulated (with usle_p = 0.5)

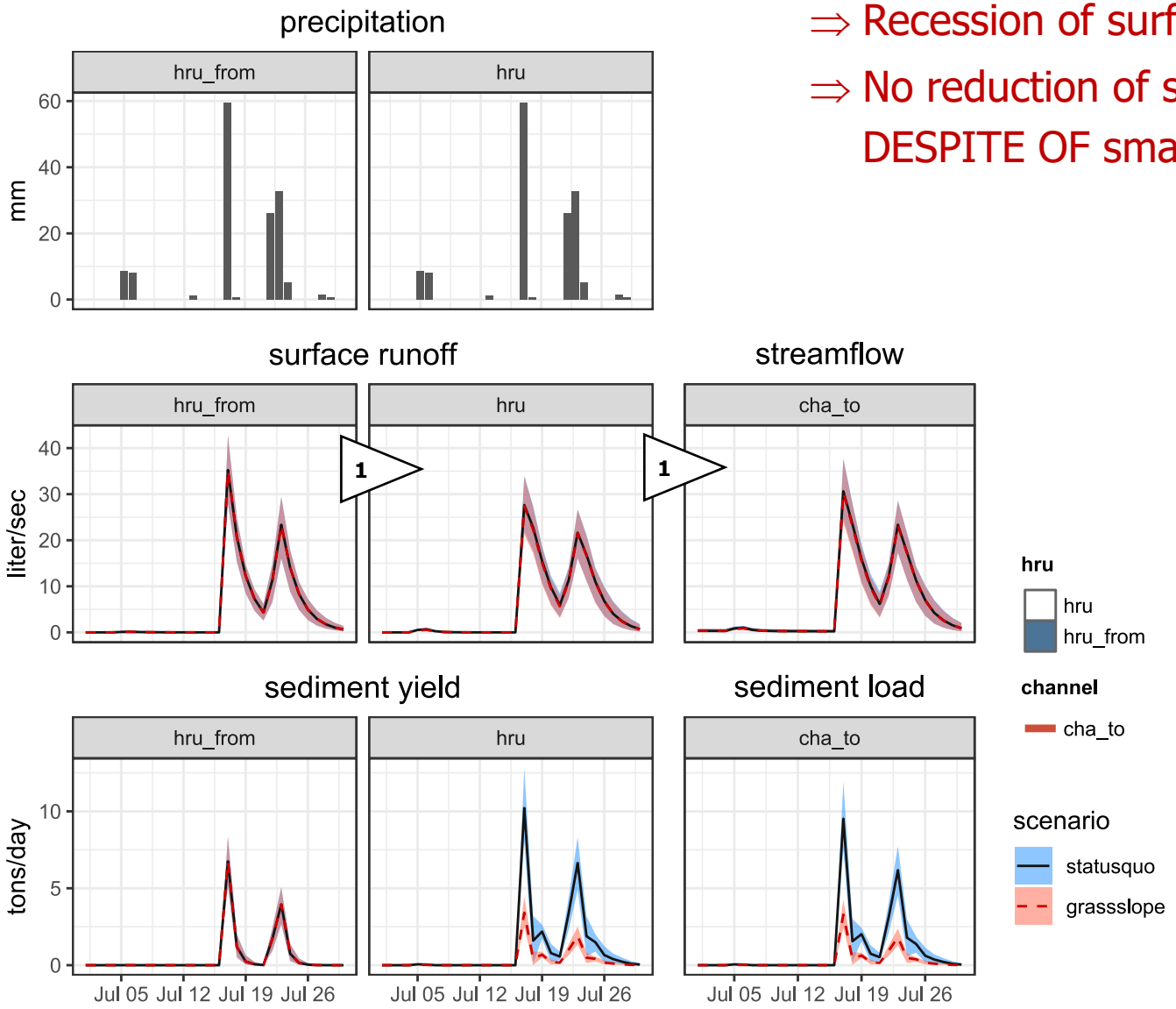
BUT: this is erosion, not sediment transport!

Grassed waterway directly connected with downstream channel



OPTAIN

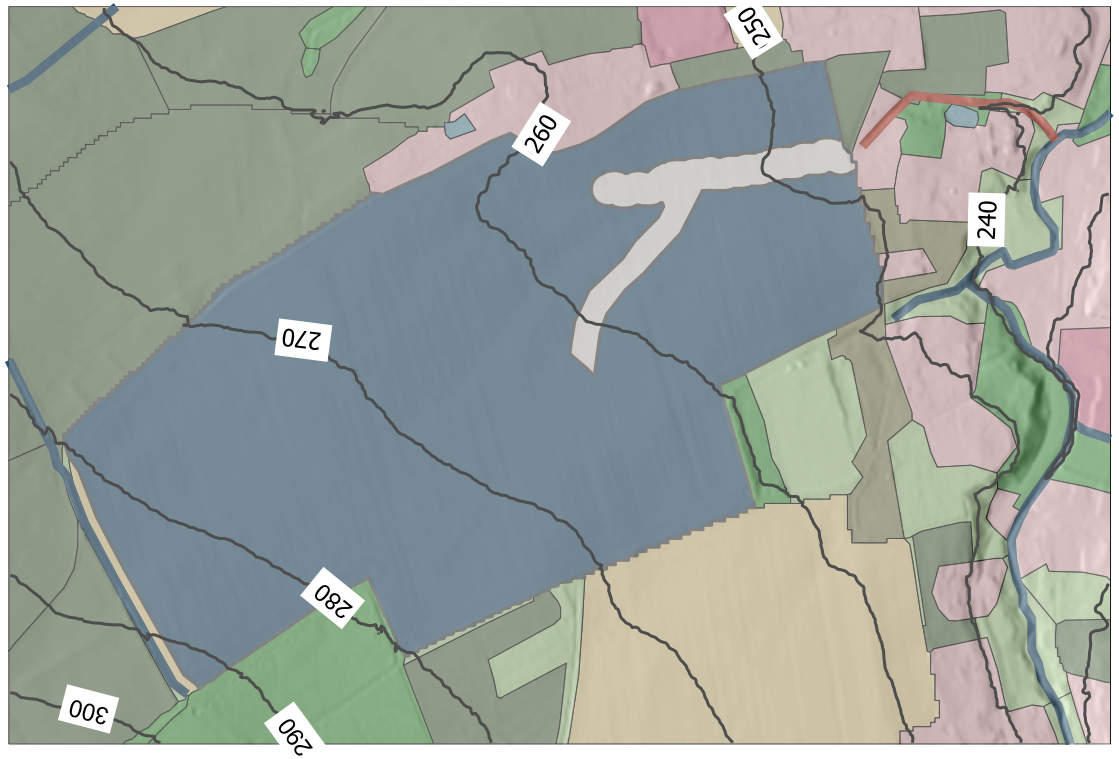
A closer look to individual implementation sites…



⇒ Recession of surface runoff is too long

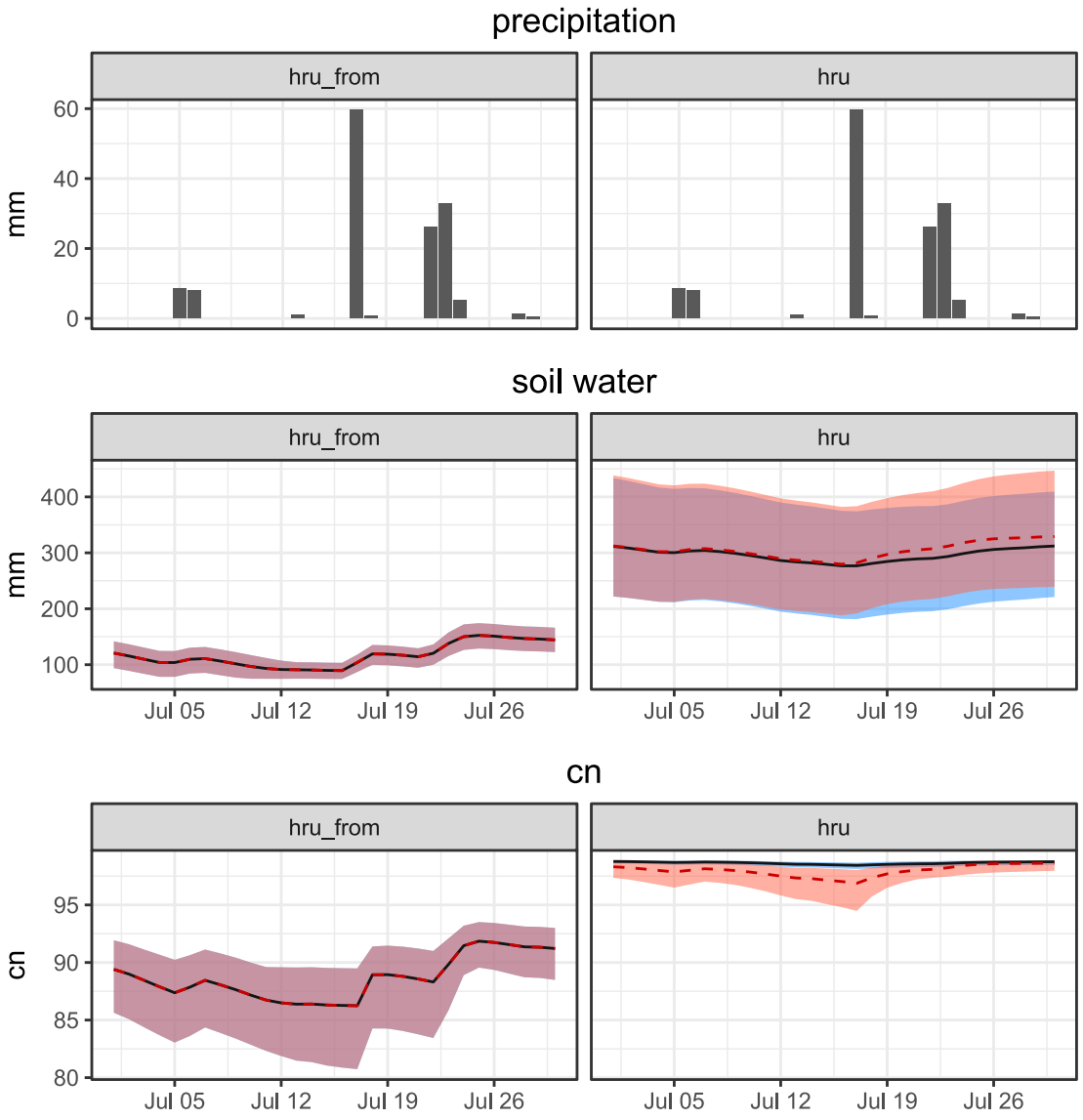
⇒ No reduction of surface runoff when hru is converted to grassed ww. DESPITE OF smaller cn input values (78 vs. 85.2)

Grassed waterway directly connected with downstream channel



OPTAIN

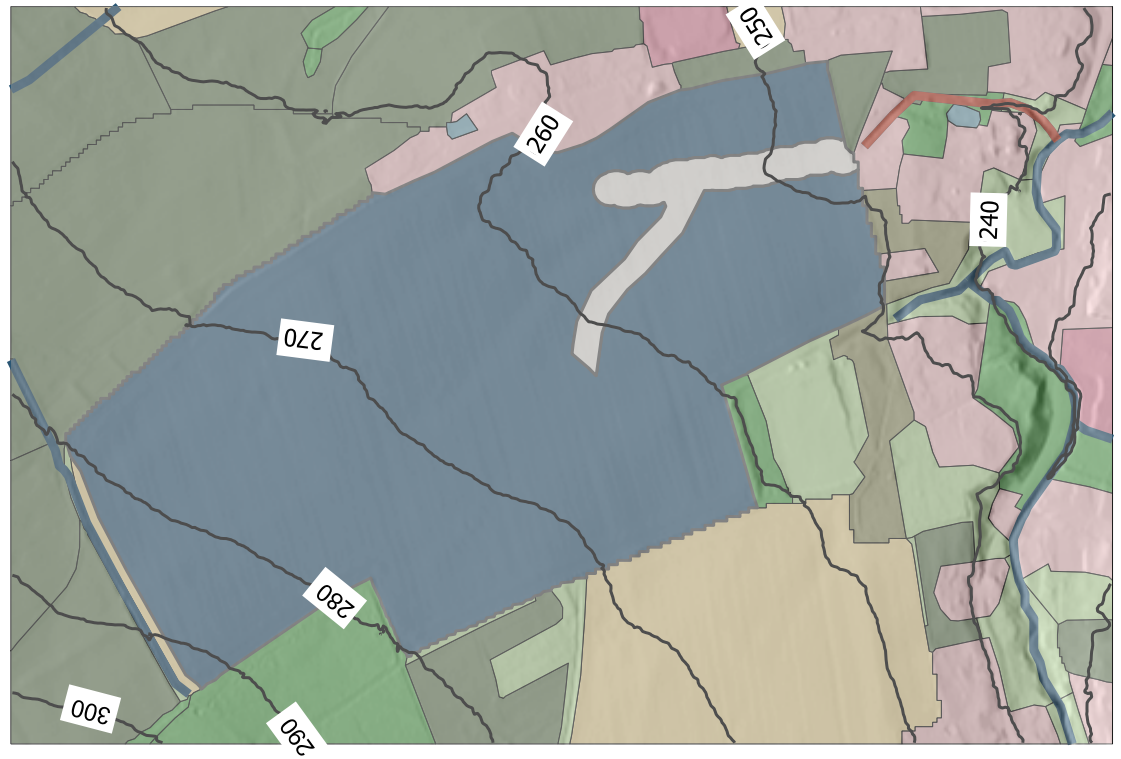
A closer look to individual implementation sites…

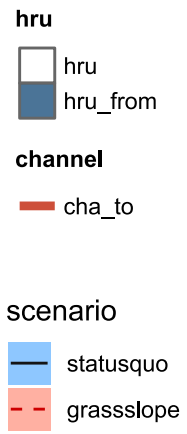


⇒ Soil moisture consistently high in (receiving) hru

⇒ Internally calculated cn values are extremely large CAUSING high surface runoff (indepedent from scenario)

Grassed waterway directly connected with downstream channel





OPTAIN

Summary and conclusion

- OPTAIN aims to model the site-specific effectiveness of retention measures
- SWATbuildR models connect all individual land units with their neighbor units and contained channels according to surface flowpaths
- Problematic:
  - ➢ Surface runoff is always sheet flow and therefore fully infiltrates into the receiving land unit (which may then be too wet!)
  - ➢ There appears to be no sediment transport between land units (i.e. the channel only receives material eroded in the connected land unit – to be confirmed…)
- Possible solution (to be discussed): Connecting land units also with ‚virtual' channels and activating this additional connection depending on rainfall intensity and topography

Thank you

michael.strauch@ufz.de

For more details:

- Media center on OPTAIN website
- project repository: zenodo
  https://zenodo.org/communities/optain-h2020-project/records
- OPTAIN Webinar on Modeling and Optimization: 3.9.2024, 15:00 CET

@H2020_OPTAIN

@H2020OPTAIN

WWW.OPTAIN.EU

OPTAIN