Christian-Albrechts-Universität zu Kiel

Drought induced land use change impacts on hydrology: A SWAT+ study in the Harz mountains, Germany

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EXDIMUM

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Motivation: extreme dry conditions

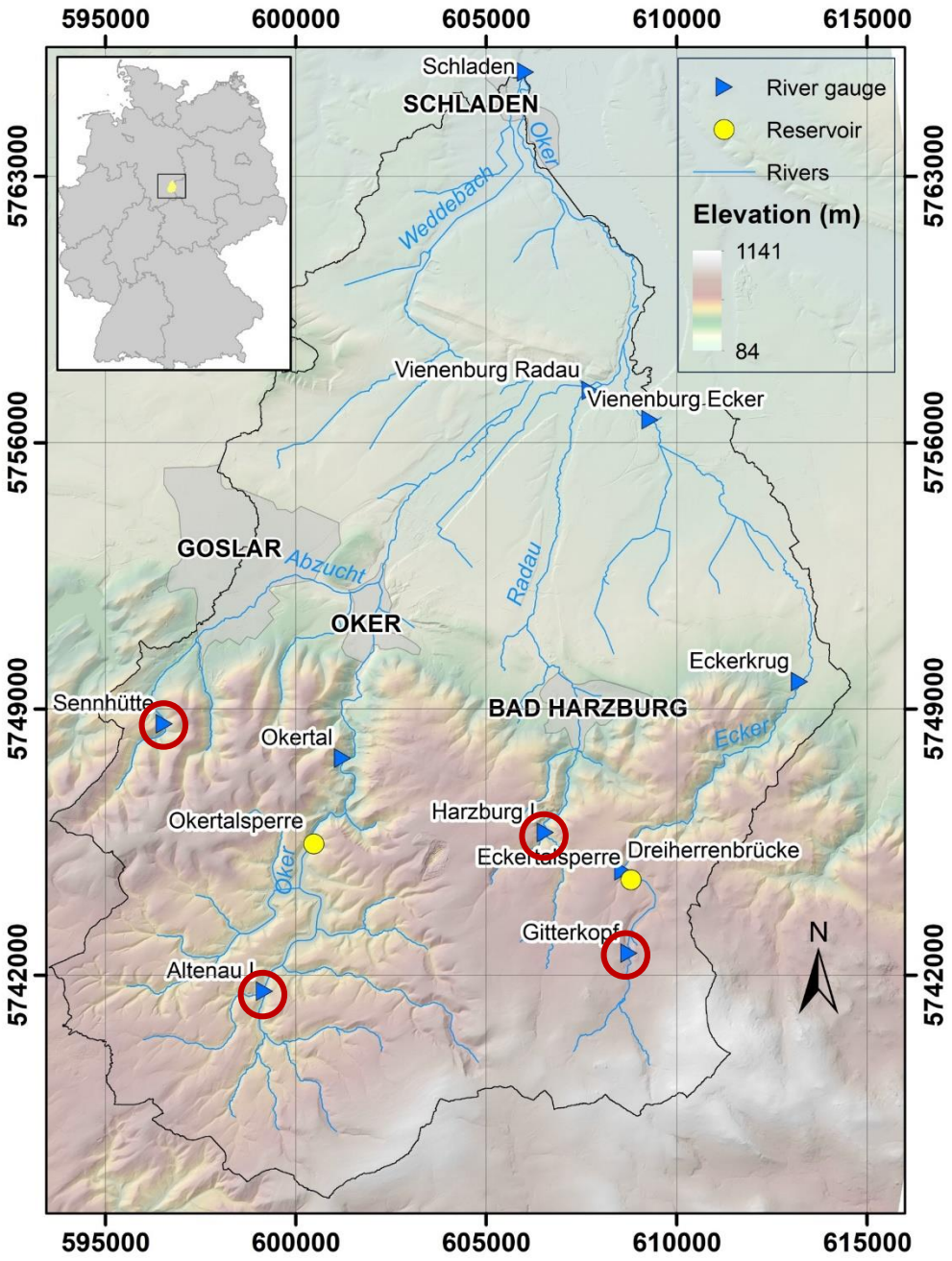
Tree mortality => soil erosion

Photos: P. Wagner 2022

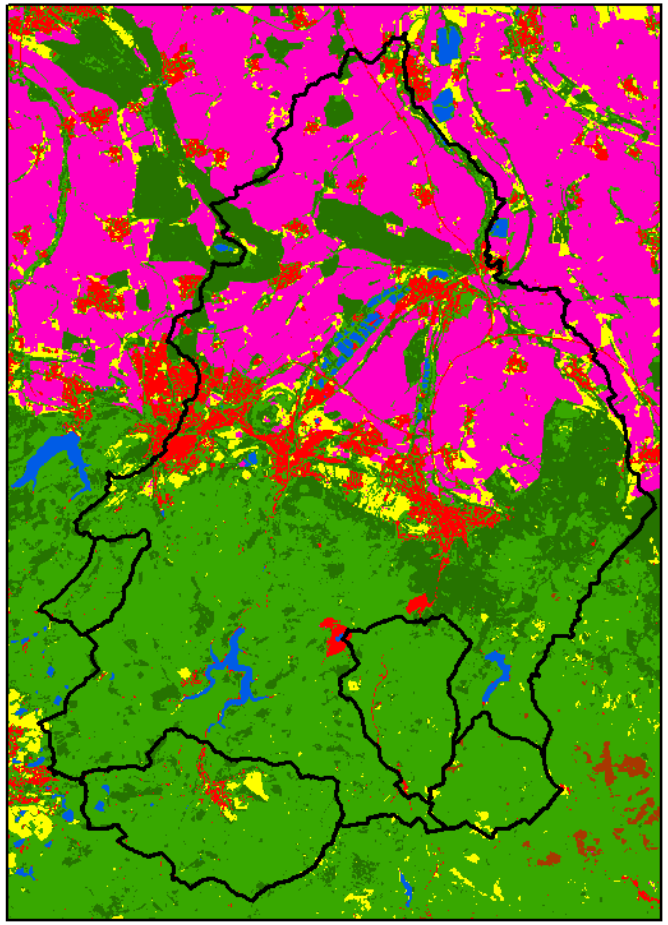
Study area

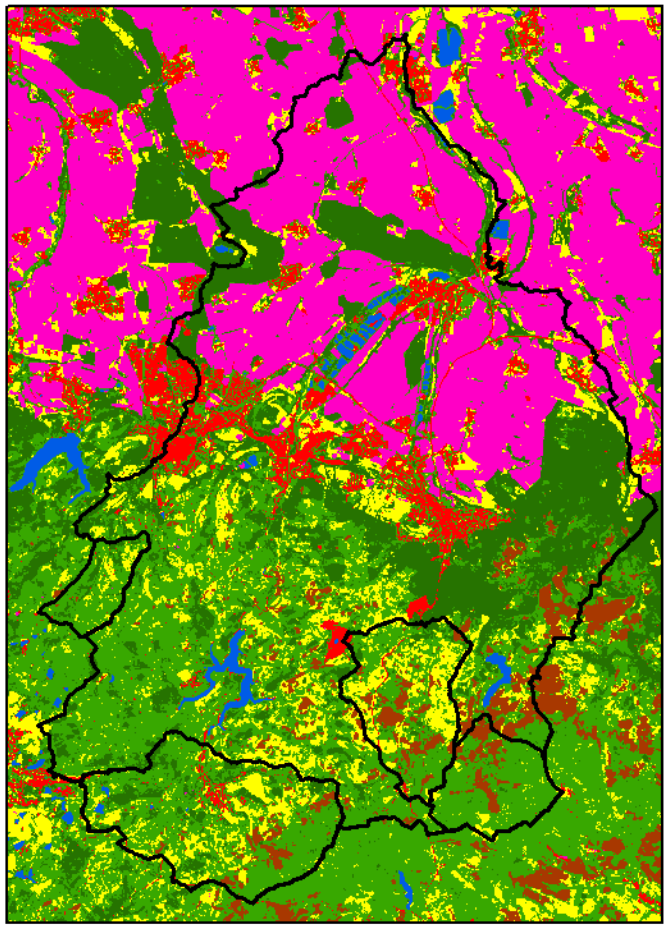
- Harz mountains, Germany
- Catchment of the Oker upstream of gauge Schladen
- Area: 361.6 km²
- Elevation: 89 m – 1141 m
- 55% forest, 28% agriculture, 8% settlements

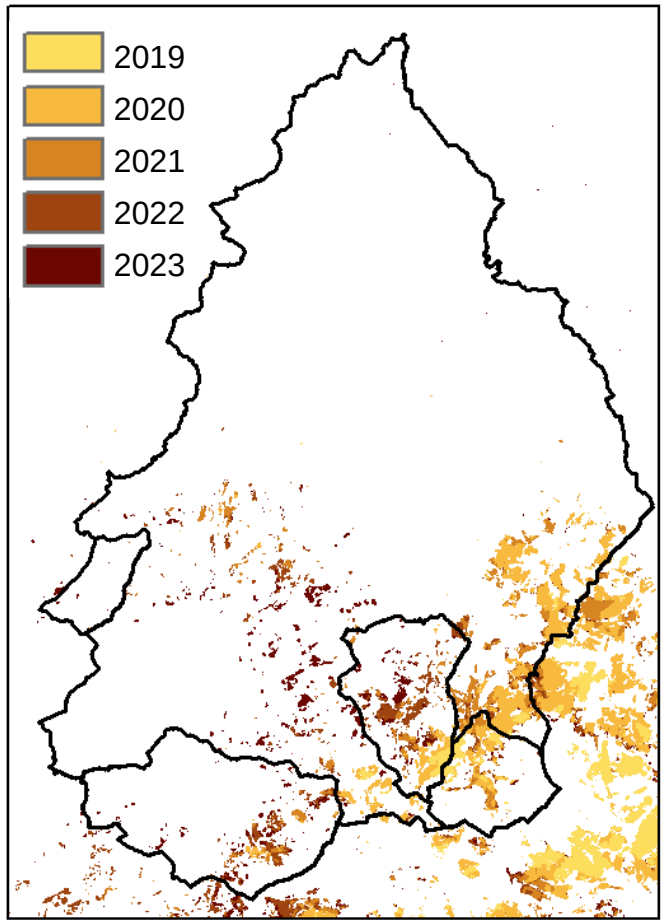
Headwater catchments



Land use change: Dead trees







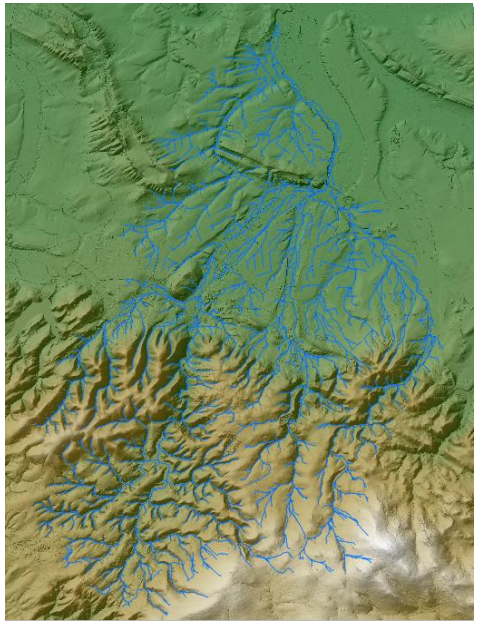
2018

2023

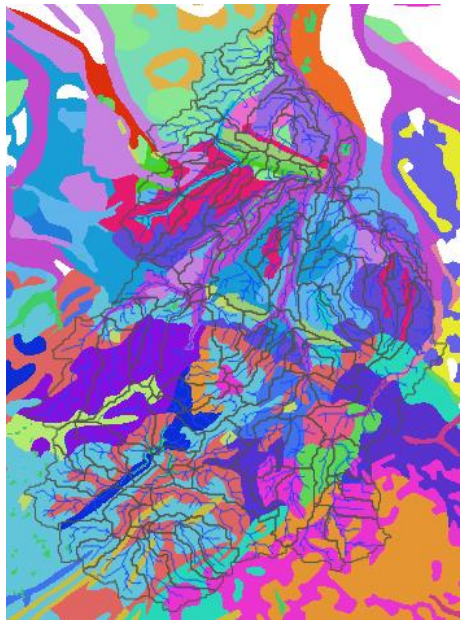
Year of first observation

Provided by F. Saba, P. Diaz & M. Gerke (TU Braunschweig)

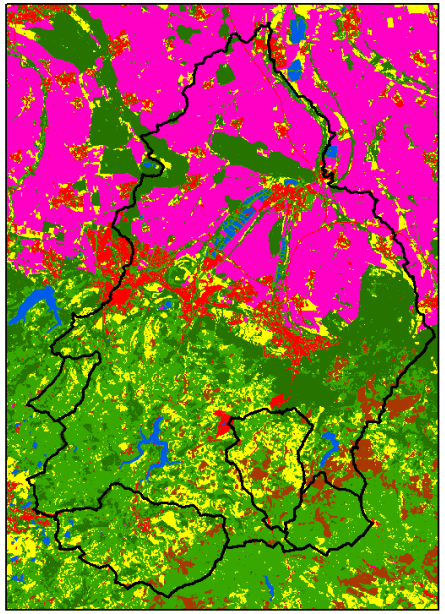
Model setup: SWAT+



DEM (5 m) +
Stream network
(LGLN 2022)



Soil map
(1:200 000)
(BGR 2022)



Land use (10 m)
(remote sensing)
(EXDIMUM)

Weather data
(interpolated)
(EXDIMUM)

=> 5253 Hydrologic response units

Initial model calibration with one land use map

Decrease in performance (example gauge Harzburg)

- when other land use map is used: -0.05 KGE
- when model is applied to period before land use change: -0.09 KGE

Strong land use changes need to be considered in model calibration

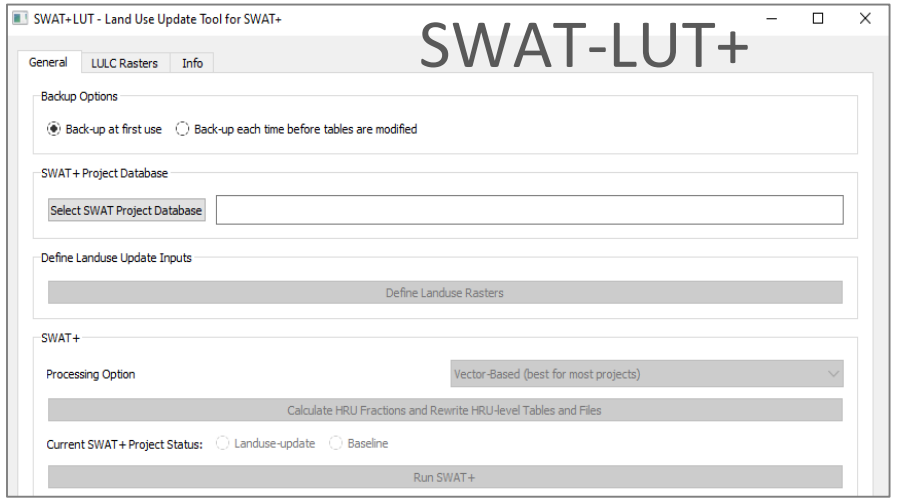
=> Dynamic land use change representation*

*__Wagner, P.D.__ et al. 2019: Static vs dynamic LUC. *Environmental Modelling & Software 122, 103987.*

Dynamic representation of land use change in SWAT+

- Land Use Update Tool for SWAT+ (SWAT-LUT+)*
  - Writes scen_dtl.upd, **scen_lu.dtl**, ru_unit_upd001-005, ls_unit_upd001-005
  - Updates hru.con, hru-data.hru, hydrology.hyd, ls_unit.ele/.def, rout_unit.ele/.def, object.cnt, topography.hyd, file.cio
- Available for QSWAT+ 2.2.5, SWAT+ Editor 2.1.3, Revision 60.5.4
- Works for Revision 61.0 with a few workarounds

SWAT-LUT+



=> +1064 HRUs

- Model setup: constant land use (2014-2018)
  annual land use updates (2019-2023)

*__Moriasi, D.N.__ et al. 2019: SWAT-LUT: A Desktop Graphical User Interface for Updating Land Use in SWAT. *JAWRA, 1102–1115.*

Dynamic representation of land use change in SWAT+

scen_lu.dtl - Editor

Datei Bearbeiten Format Ansicht Hilfe

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scen_lu.dtl: written by SWAT+ editor v2.3.1 on 2024-06-26 18:26 for SWAT+ rev.60.5.4
1

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jday                       null         0              null                -       1.00000         -         =         -         -         -         -         -        !
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year_cal                   null         0              null                -    2019.00000         -         -         =         -         -         -         -        !
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jday                       null         0              null                -       1.00000         -         -         -         -         -         =         -        !
year_cal                   null         0              null                -    2022.00000         -         -         -         -         -         =         -        !
jday                       null         0              null                -       1.00000         -         -         -         -         -         -         =        !
year_cal                   null         0              null                -    2023.00000         -         -         -         -         -         -         =        !
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hru_fr_update              null         0  lu_change_2013-001  ls_unit_upd002.ele        0.00000        0.00000  ru_unit_upd002.ele  n   y   n   n   n   n   n
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hru_fr_update              null         0  lu_change_2021-001  ls_unit_upd005.ele        0.00000        0.00000  ru_unit_upd005.ele  n   n   n   n   y   n   n
hru_fr_update              null         0  lu_change_2022-001  ls_unit_upd006.ele        0.00000        0.00000  ru_unit_upd006.ele  n   n   n   n   n   y   n
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```

Model calibration and application

Latin Hypercube Sampling:
500 parameter sets
for 11 parameter

Calibration period:
2019 – 2023
annual land use changes

10% best model runs
based on Kling-Gupta
efficiency

Visual analysis
(3 runs)

Evaluation of
selected model
run

Validation period:
2014 – 2018
static land use

Model run with land
use change

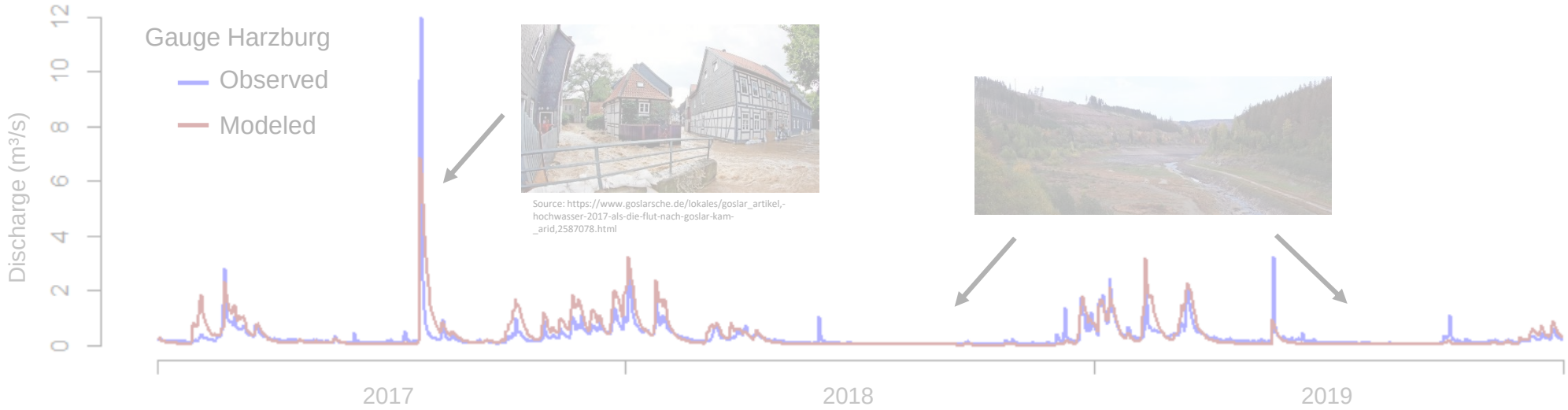
Model run without
land use change

Assessment of
differences in water
balance components

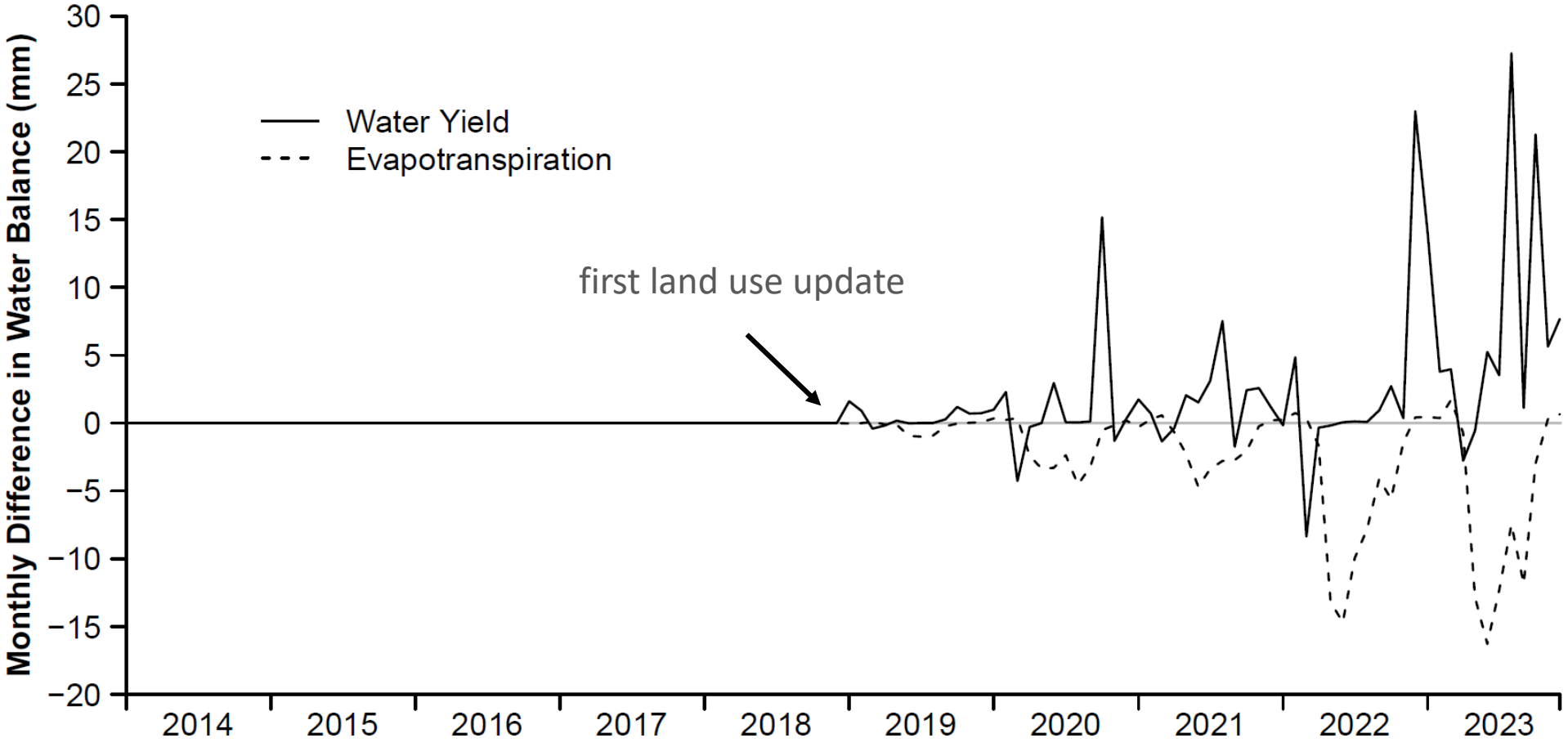
Model evaluation

Gauge	Kling-Gupta efficiency Calibration	Validation	Difference
Sennhütte	0.67	0.66	-0.01
Altenau	0.70	0.66	-0.04
Gitterkopf	0.41	0.53	+0.12
Harzburg	**0.75**	**0.69**	**-0.06**

Model suitable for dynamic land use change (2018-2023) and static land use (validation: 2014-2017).



Temporal land use change impacts on water yield and evapotranspiration

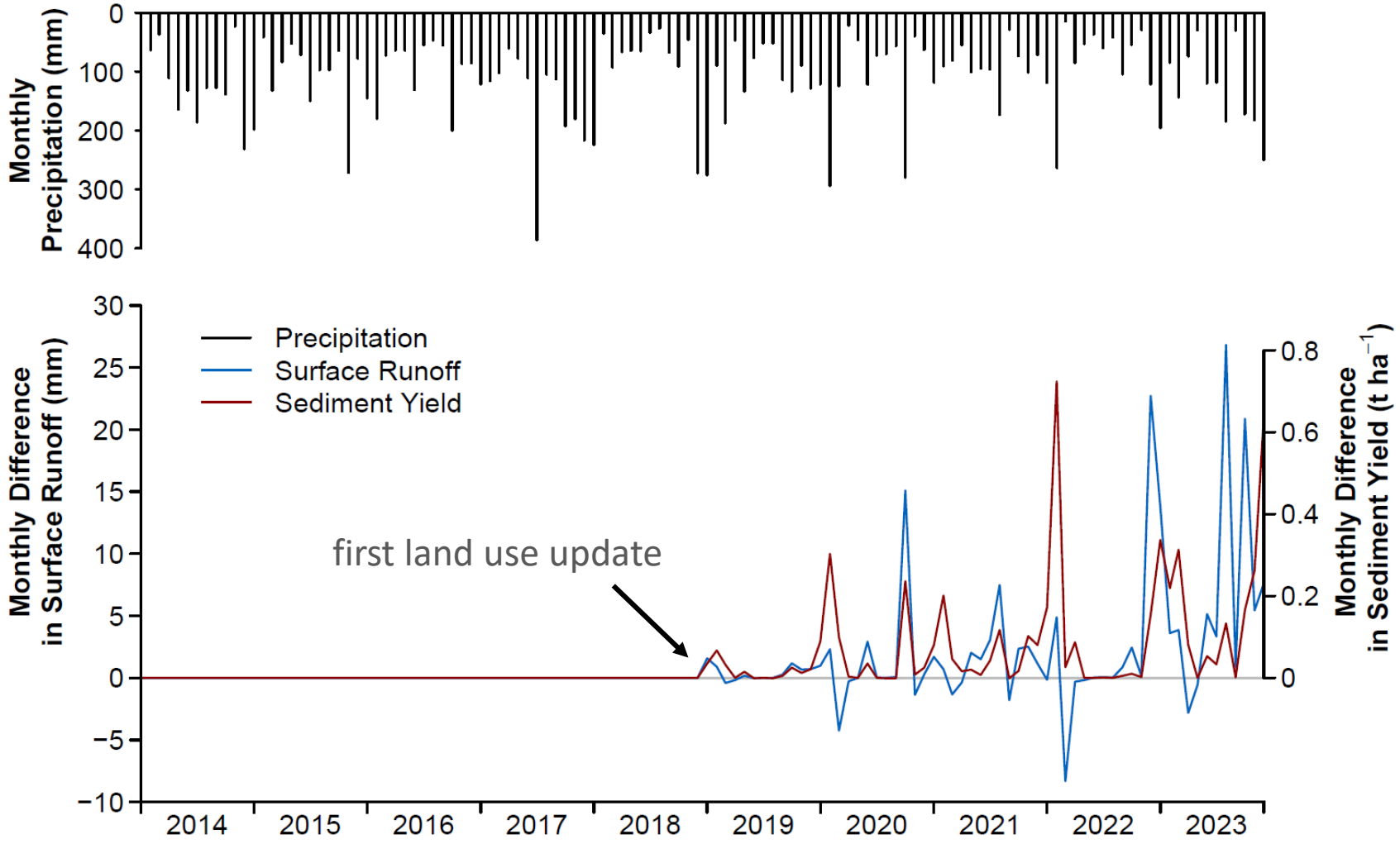


Forest loss:

Increase in water yield (surface runoff)

Decrease in ET in vegetation period

Temporal land use change impacts on surface runoff and sediment yield

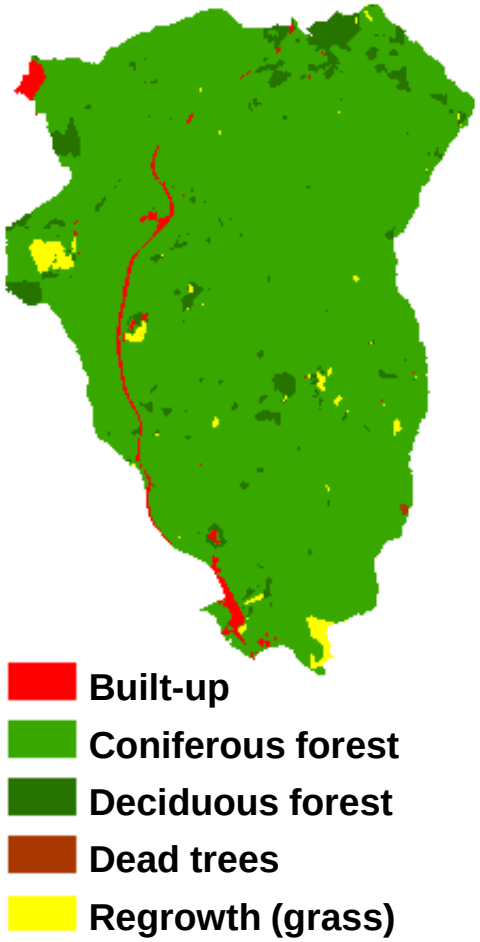


Increase in sediment yield due to:

- forest loss
- surface runoff (r=0.40)
- precipitation (r=0.69)

Spatial land use change impacts Harzburg: 2018

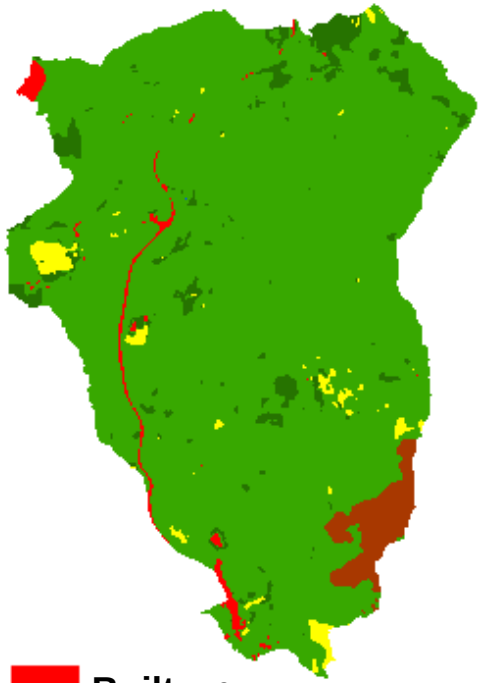
Land use | Evapotranspiration | Surface runoff | Percolation | Sediment yield



No land use change, no impacts

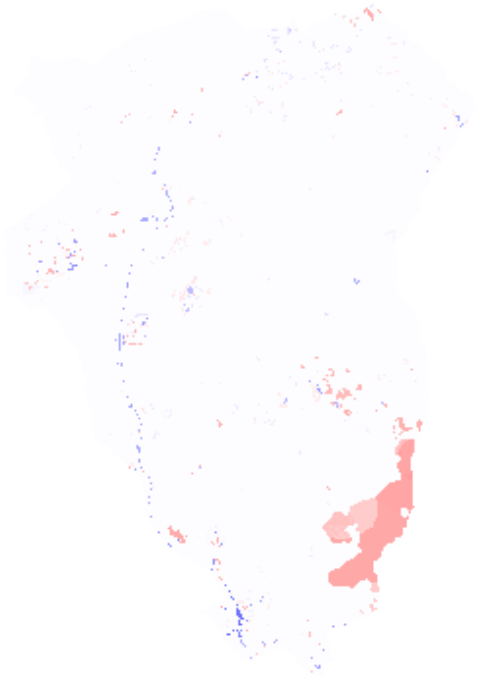
Spatial land use change impacts Harzburg: 2019

Land use

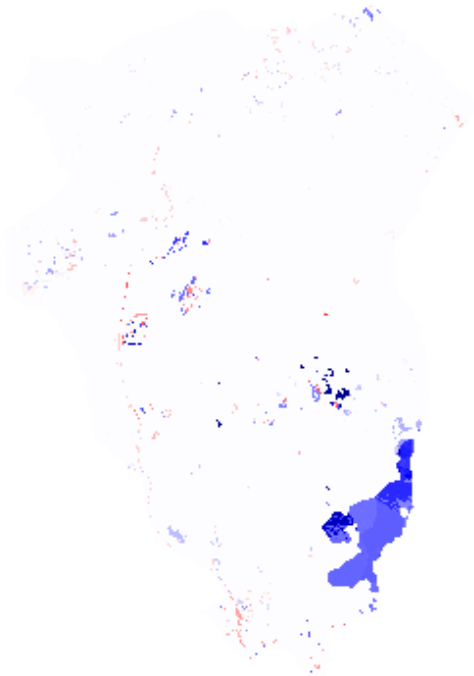


Built-up
Coniferous forest
Deciduous forest
Dead trees
Regrowth (grass)

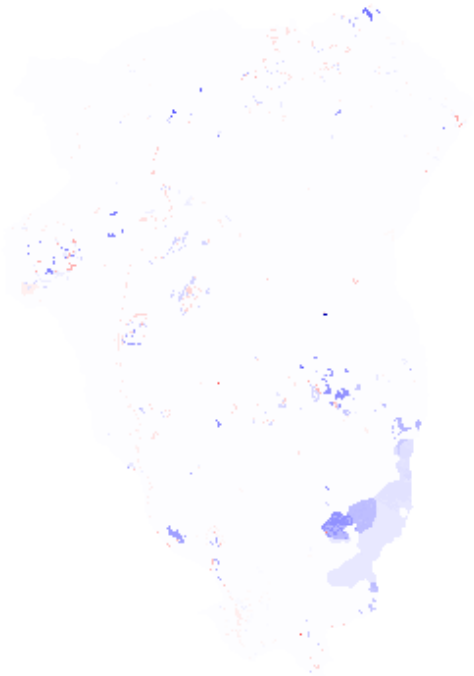
Evapotranspiration



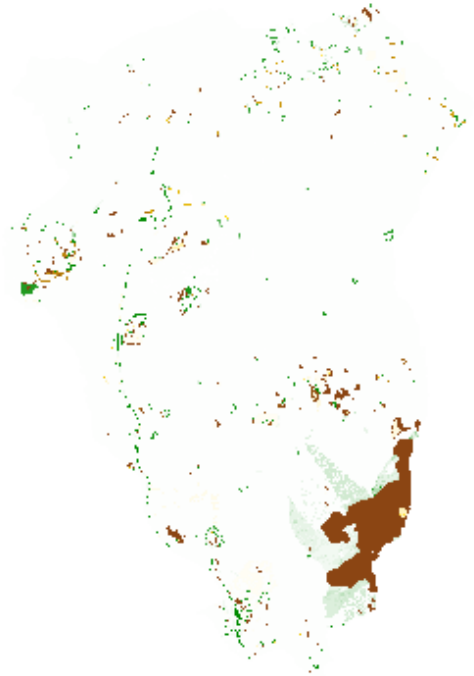
Surface runoff



Percolation



Sediment yield



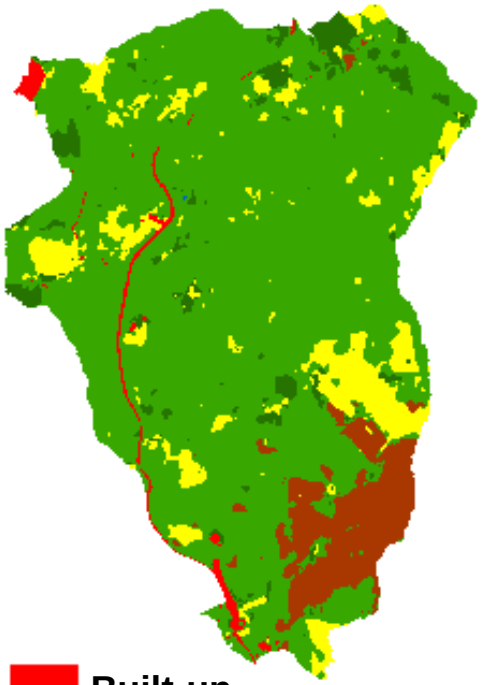
-100% 0 >200%

-100% 0 >1000%

Spatial land use change impacts Harzburg: 2020

EXDIMUM

Land use



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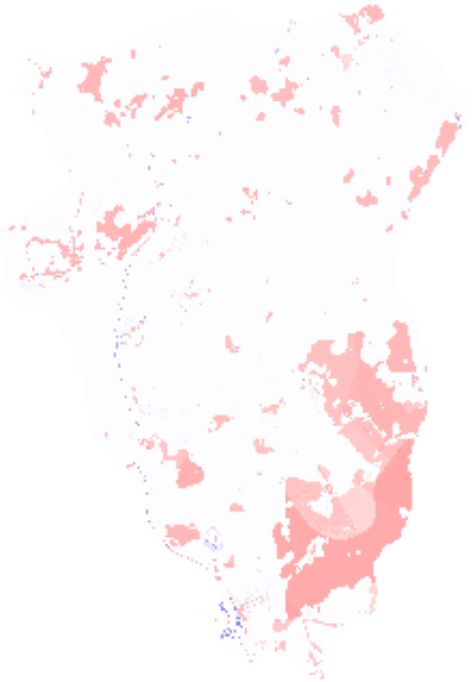
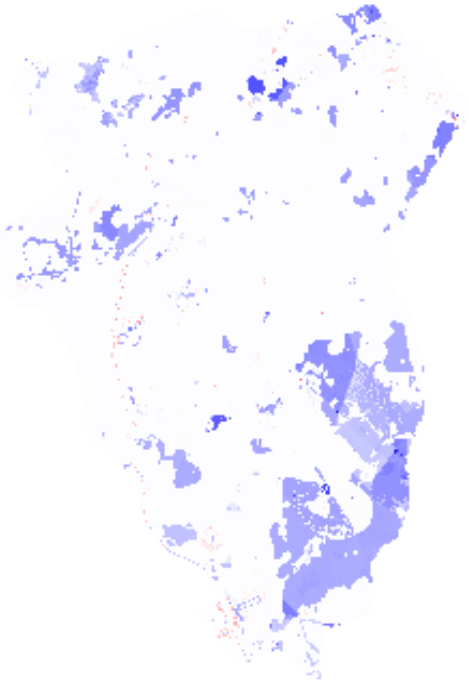
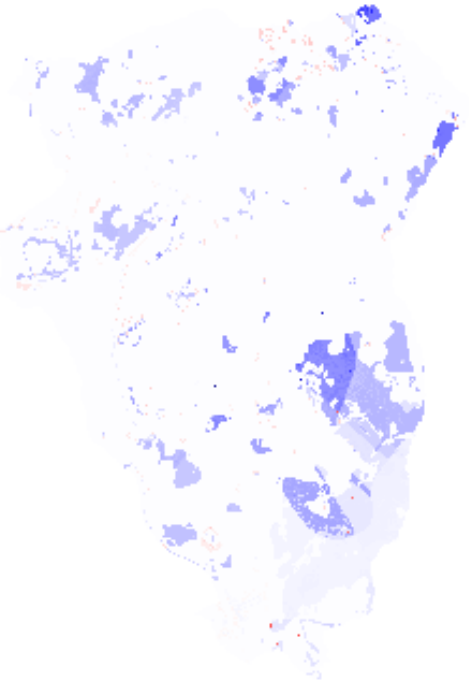
Evapotranspiration



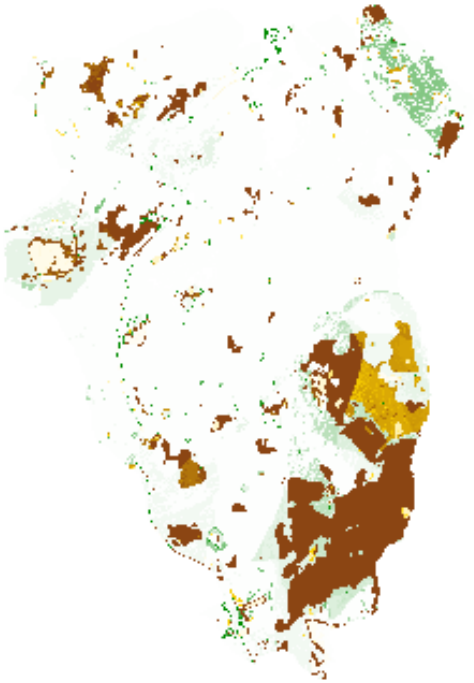
Surface runoff



Percolation



Sediment yield



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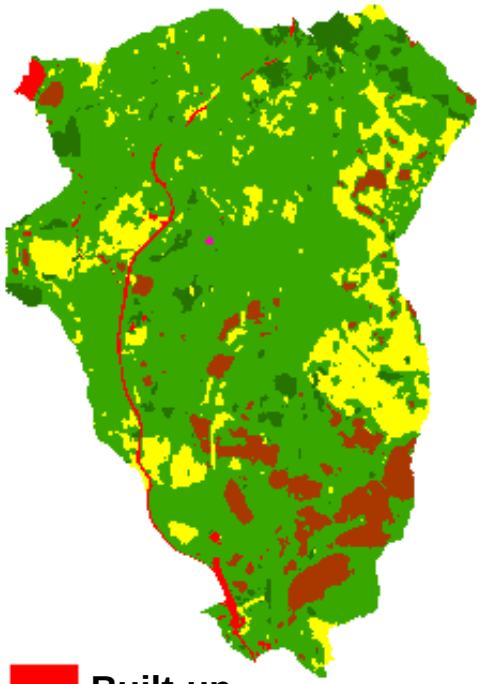
-100% 0 >1000%

Spatial land use change impacts Harzburg: 2021

Land use



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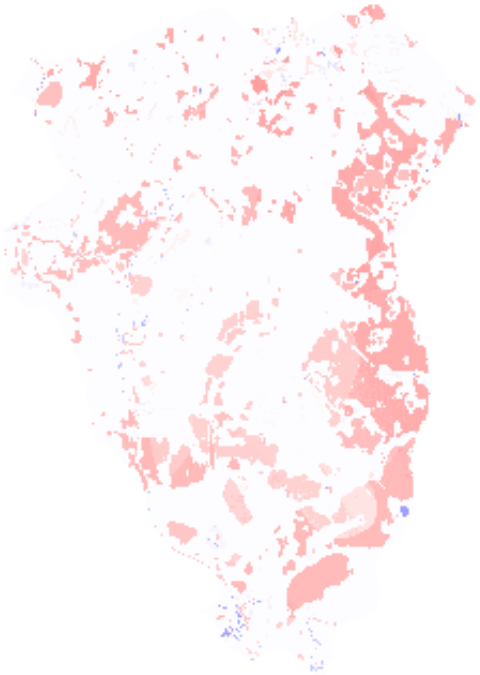
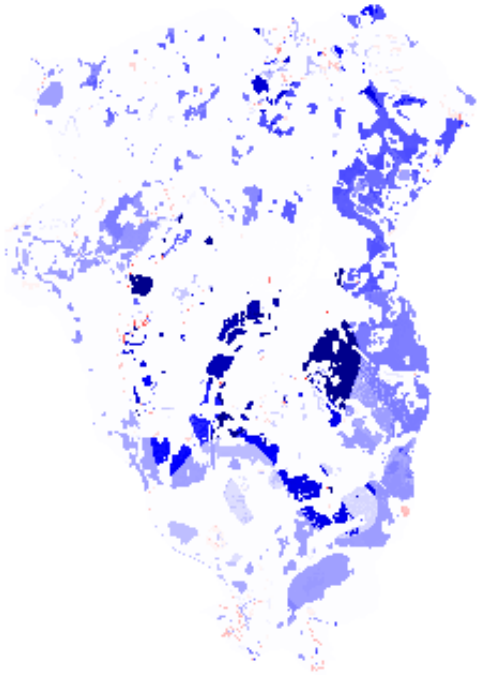
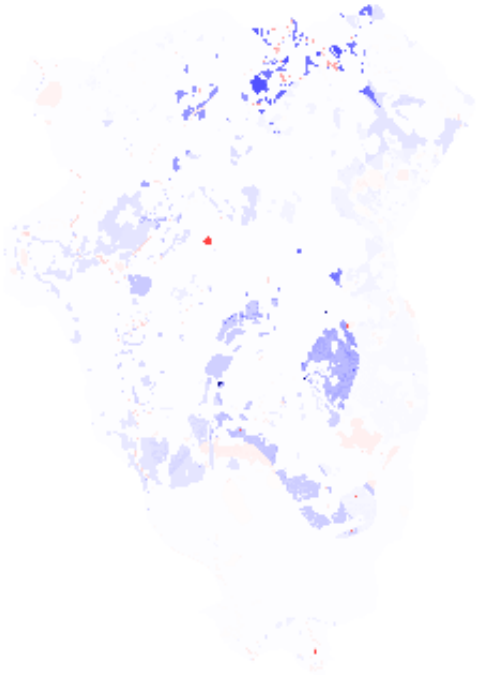
Evapotranspiration



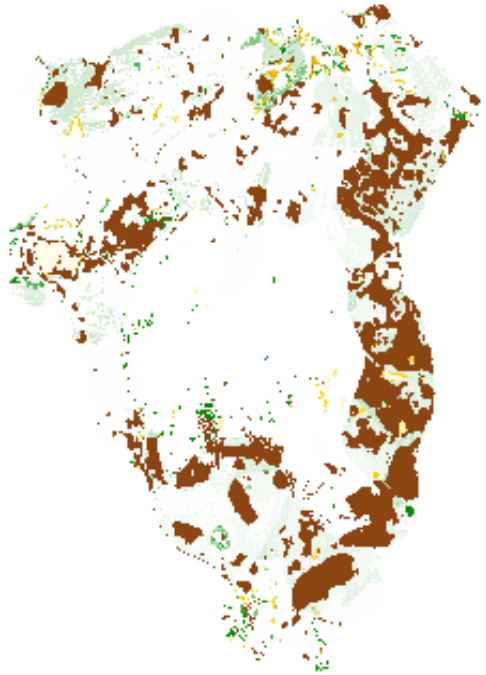
Surface runoff



Percolation



Sediment yield

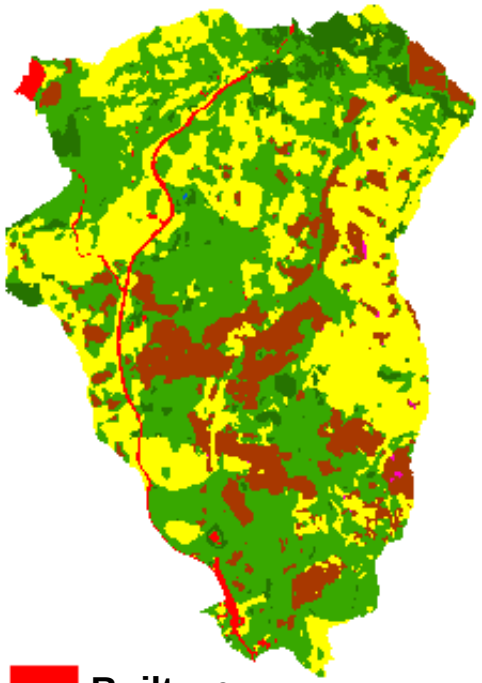


-100% 0 >200%

-100% 0 >1000%

Spatial land use change impacts Harzburg: 2022

Land use



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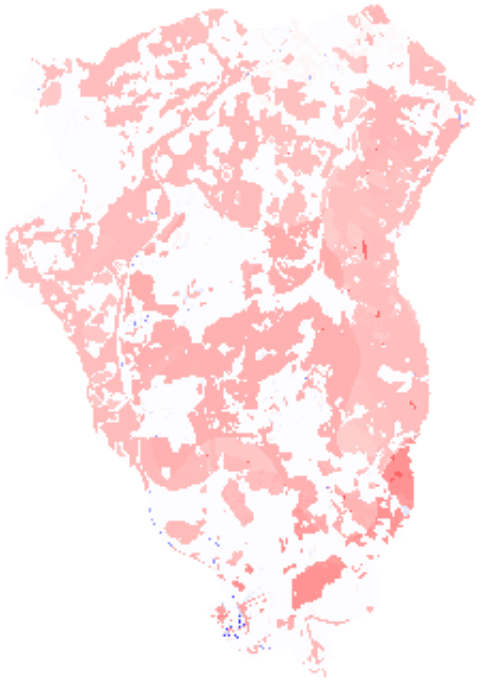
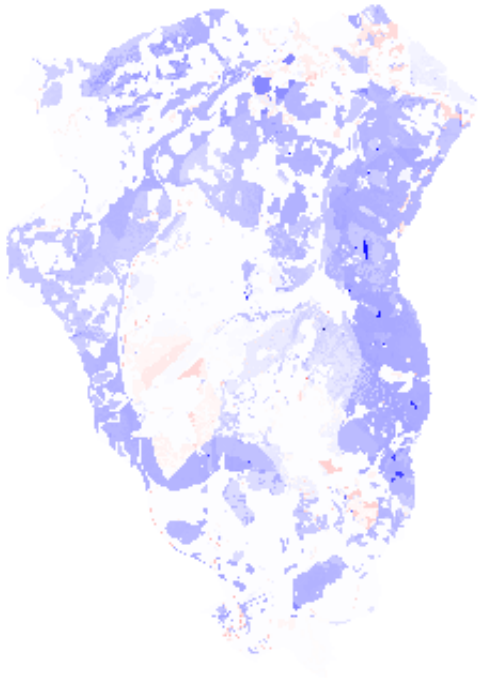
Evapotranspiration



-100% 0 >200%

Surface runoff



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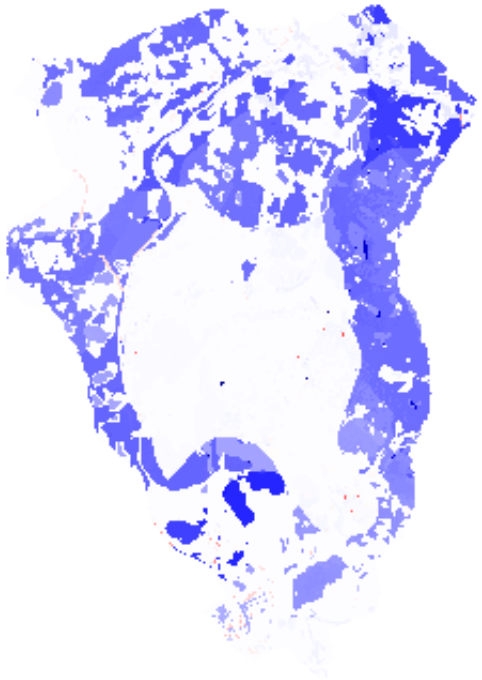
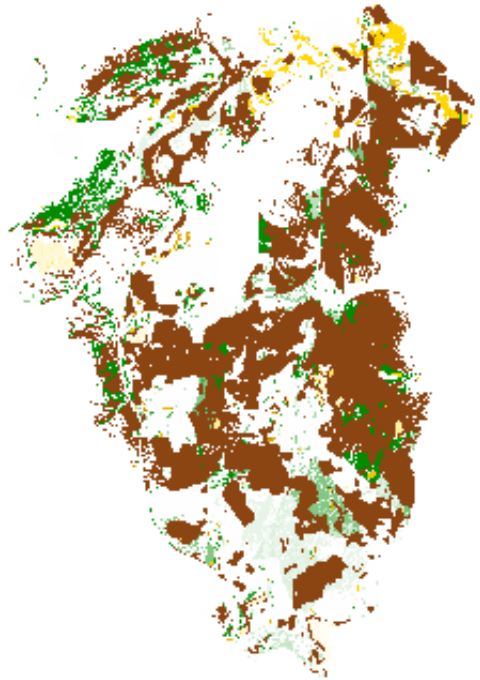


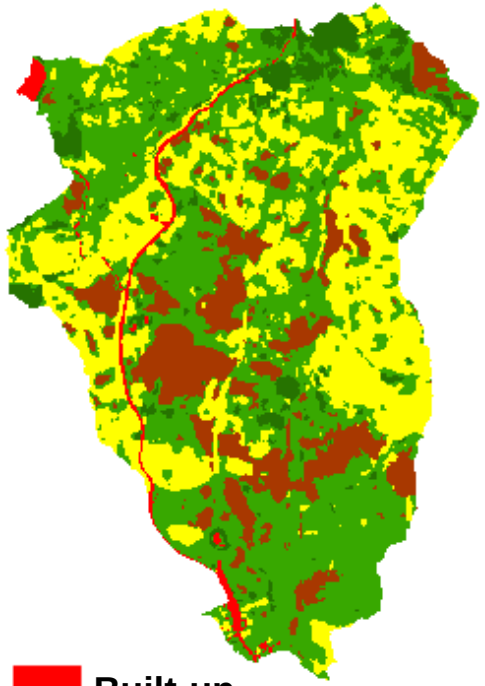
Sediment yield



-100% 0 >1000%

Spatial land use change impacts Harzburg: 2023

Land use



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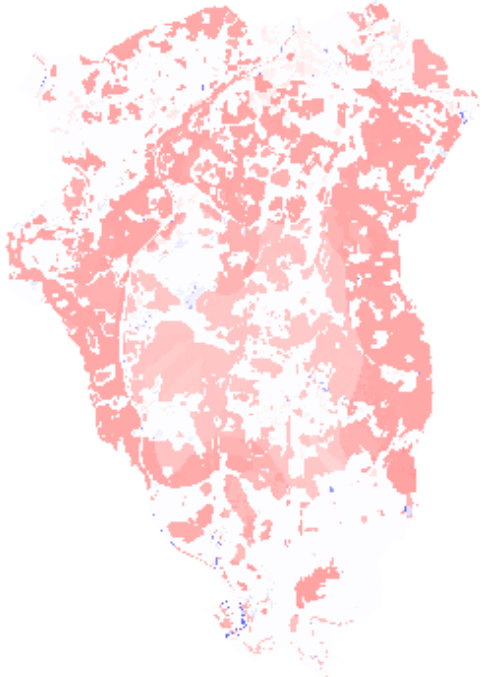
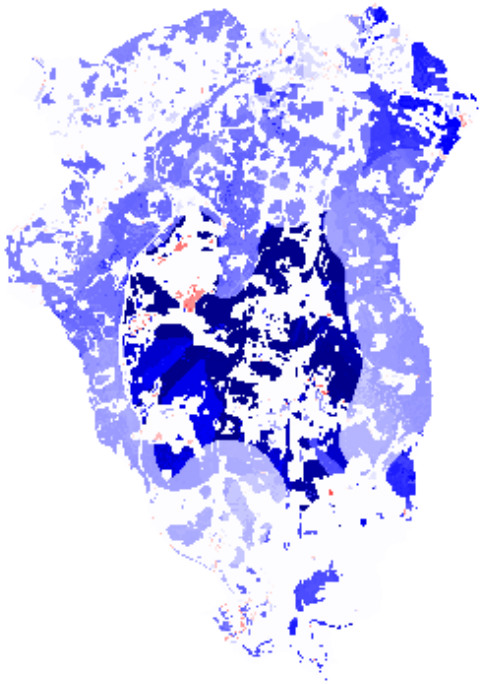


Surface runoff



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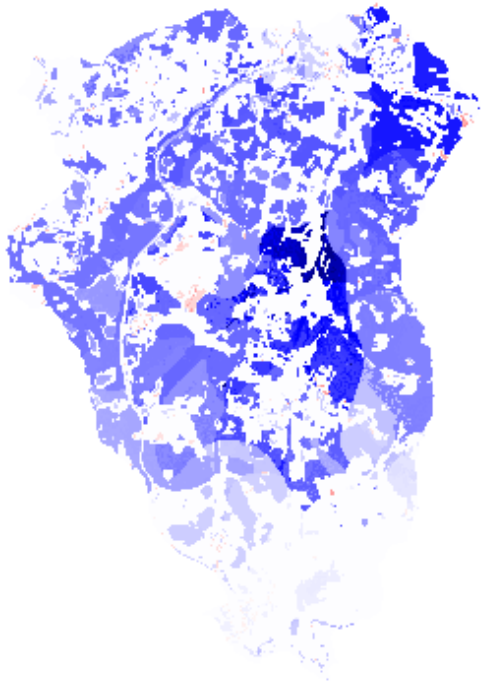

Sediment yield

=> faster response

Conclusion

Modeling:

- Successful implementation of dynamic land use changes in SWAT+
- Calibration for dynamic land use representation
- Necessary improvement of multi gauge calibration

Impacts:

- Strong impacts of tree mortality on water balance components
- Decrease of ET, increase of surface runoff, percolation and erosion
- Improve drought and flood resilience by afforestation with climate resilient trees

Thank you very much for your attention!

EXDIMUM

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

FONA
Forschung für Nachhaltigkeit

WaX
Wasser-Extremereignisse

Data sources:
BGR 2022: Bodenübersichtskarte 1:200.000 (BÜK200).
LGLN 2022: Auszug aus den Geodaten des Landesamtes für Geoinformation und Landesvermessung Niedersachsen 2022.

Contact: pwagner@hydrology.uni-kiel.de