WARSAW UNIVERSITY OF LIFE SCIENCES

Integrated modelling framework for evaluation of impacts of catchment-scale pressures on reach-scale habitat conditions

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Background

Environmental flows – quantity, quality and timing of water flows required to sustain freshwater (…) ecosystems (Brisbane Declaration)

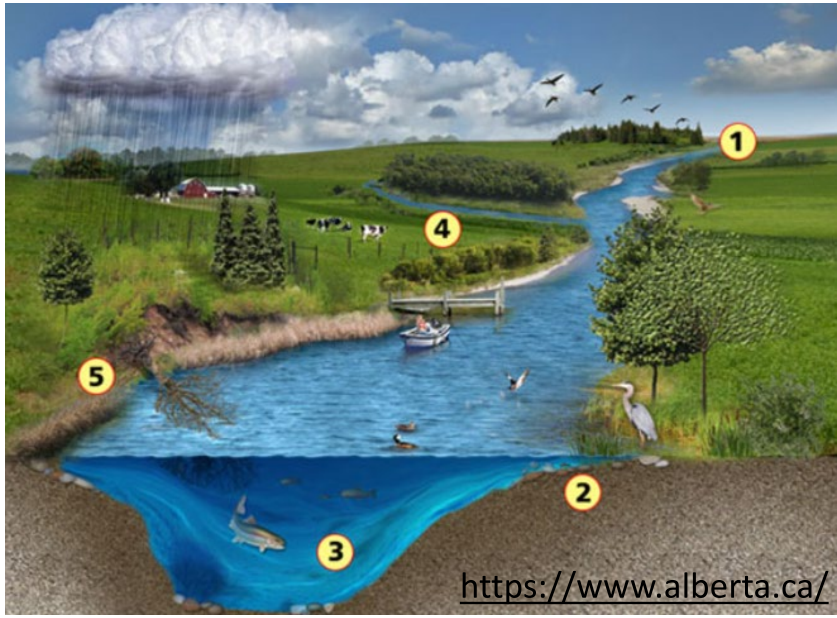
Hundreds of e-flow assessment methods developed in many countries; among them a prominent group is **hydraulic-habitat modelling**

Catchment-scale hydrological models and reach-scale hydraulic-habitat models have for a long time been applied as two separate/distinct tools with very few attempts of integration

- Hydrological models not capable of studying stream hydraulics and physical habitat of aquatic organisms
- Hydraulic-habitat models not capable of incorporating catchment-scale stressors leading to flow alteration

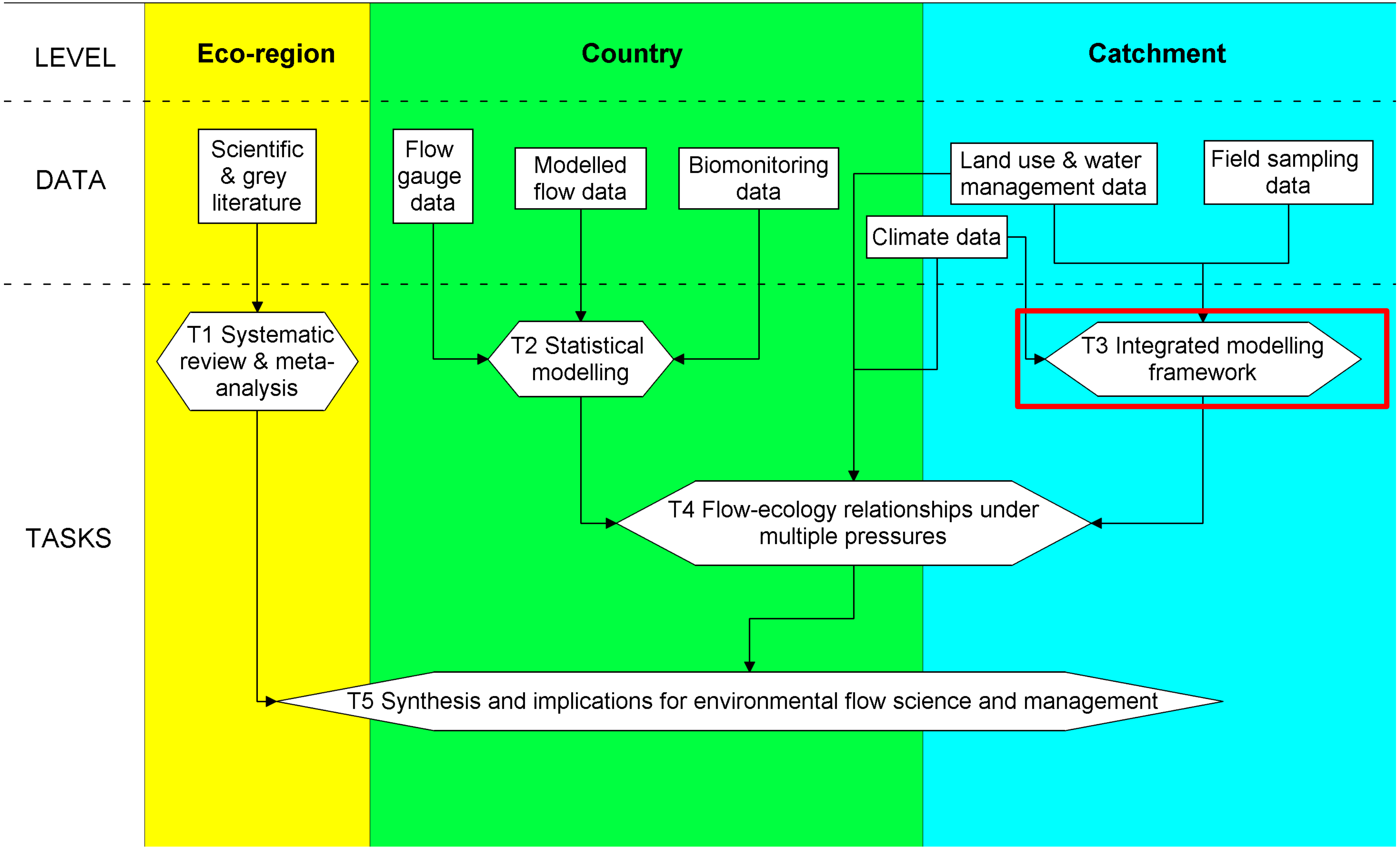
First „integrated (hydrological-hydrodynamic-habitat) modeling" / „ecohydrologic modeling cascades" developed in Europe (Germany, Greece, Austria) in 2010s

Including SWAT+ in such modeling cascades could open up new possibilities of investigating the impact of catchment-scale pressures via decision tables



1. Hydrology 2. Biology: 3. Water quality
4. Connectivity 5. Geomorphology

Wider context



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Effect of river flows on biota under multiple pressures

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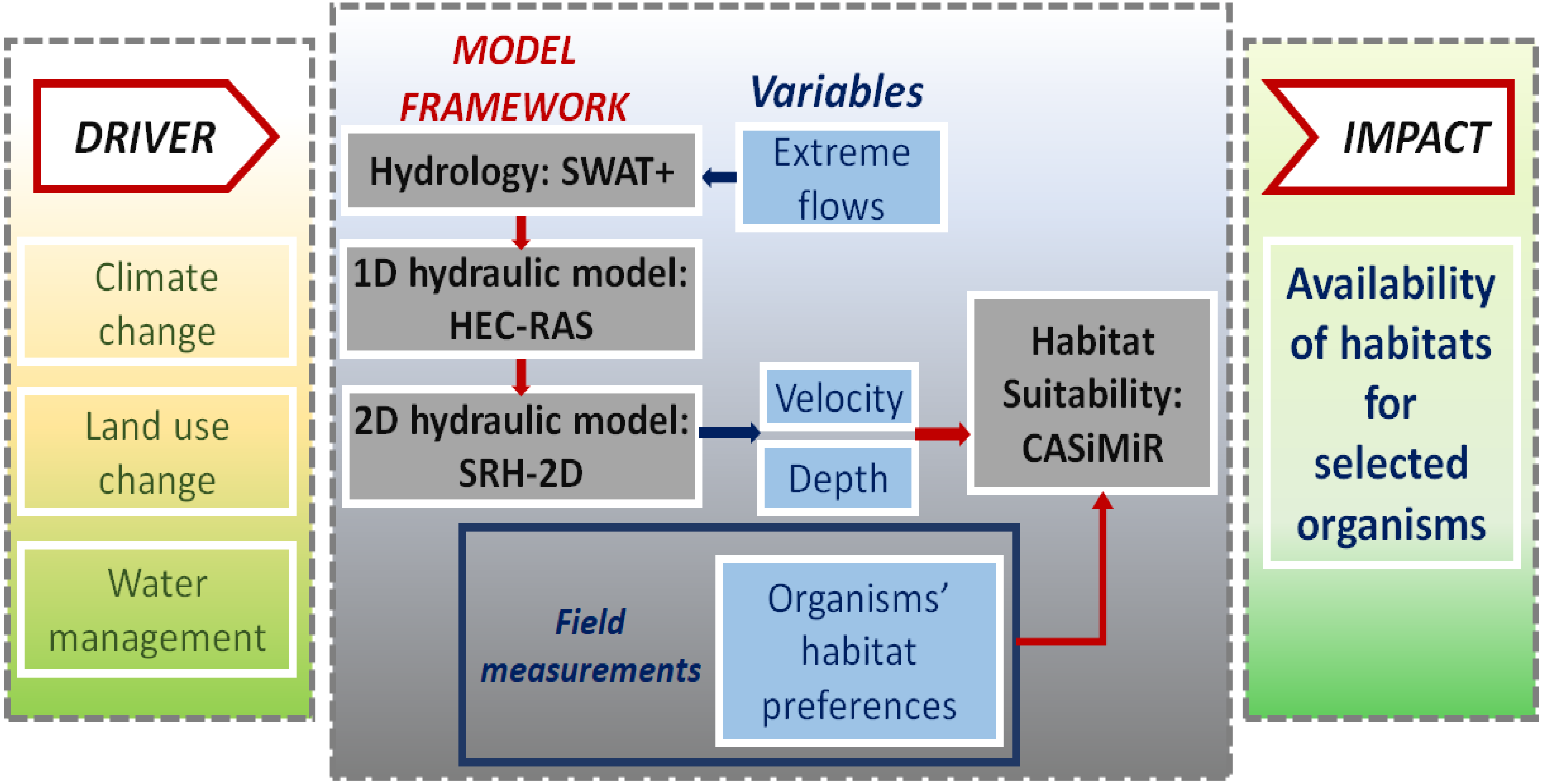
Objectives

To develop an ecohydrological modeling cascade consisting of a hydrological model, 1D/2D hydraulic models and a habitat model and test it for a case study of a medium-sized lowland river

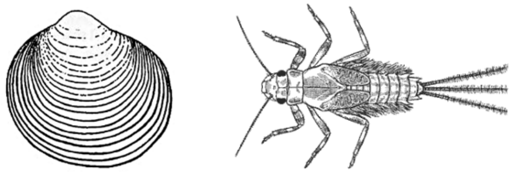
To assess performance of each individual model

To assess the effects of stressors (climate change & irrigation water withdrawals) on habitat conditions for benthic macroinvertebrates using the developed modeling cascade

Workflow



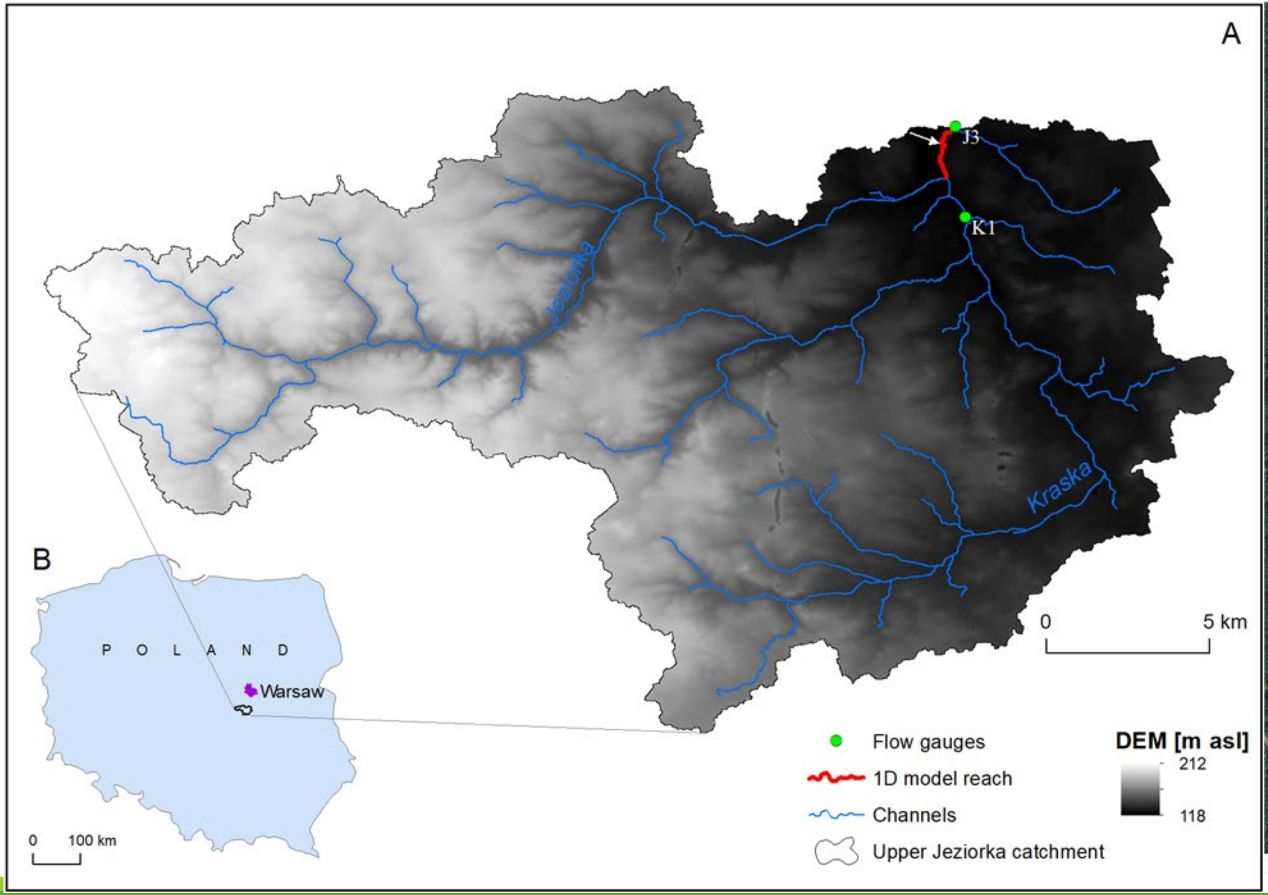
Selected organisms:
Benthic macroinvertebrates
Functional feeding group of
filter feeders

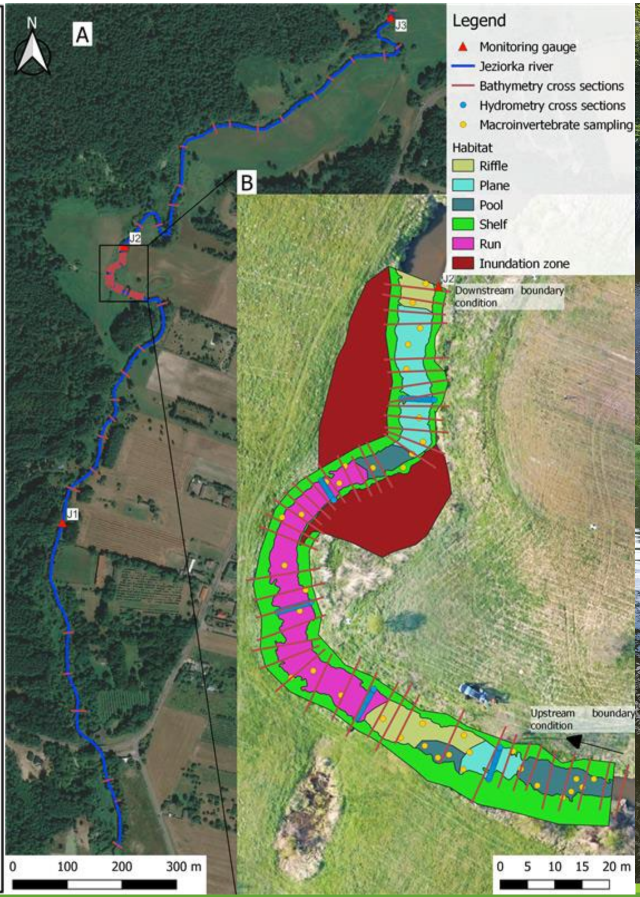


Study area & field sampling

Upper Jeziorka catchment (~380 km^2) + 140 m segment of a reach

Extensive sampling (bathymetry, mesohabitats, flow velocity & depth, discharge, macroinvertebrates)





SWAT+ model setup

Developed with QSWAT+

93 channels & 5,391 HRUs

Geomorphic baseflow option with a single aquifer used

Limitation: availability of discharge data only for 2020-2022 (own flow gauges set up during the project) + downstream gauge used for extrapolation before 2020

SWATdoctR: SWAT+ model setup verification tool

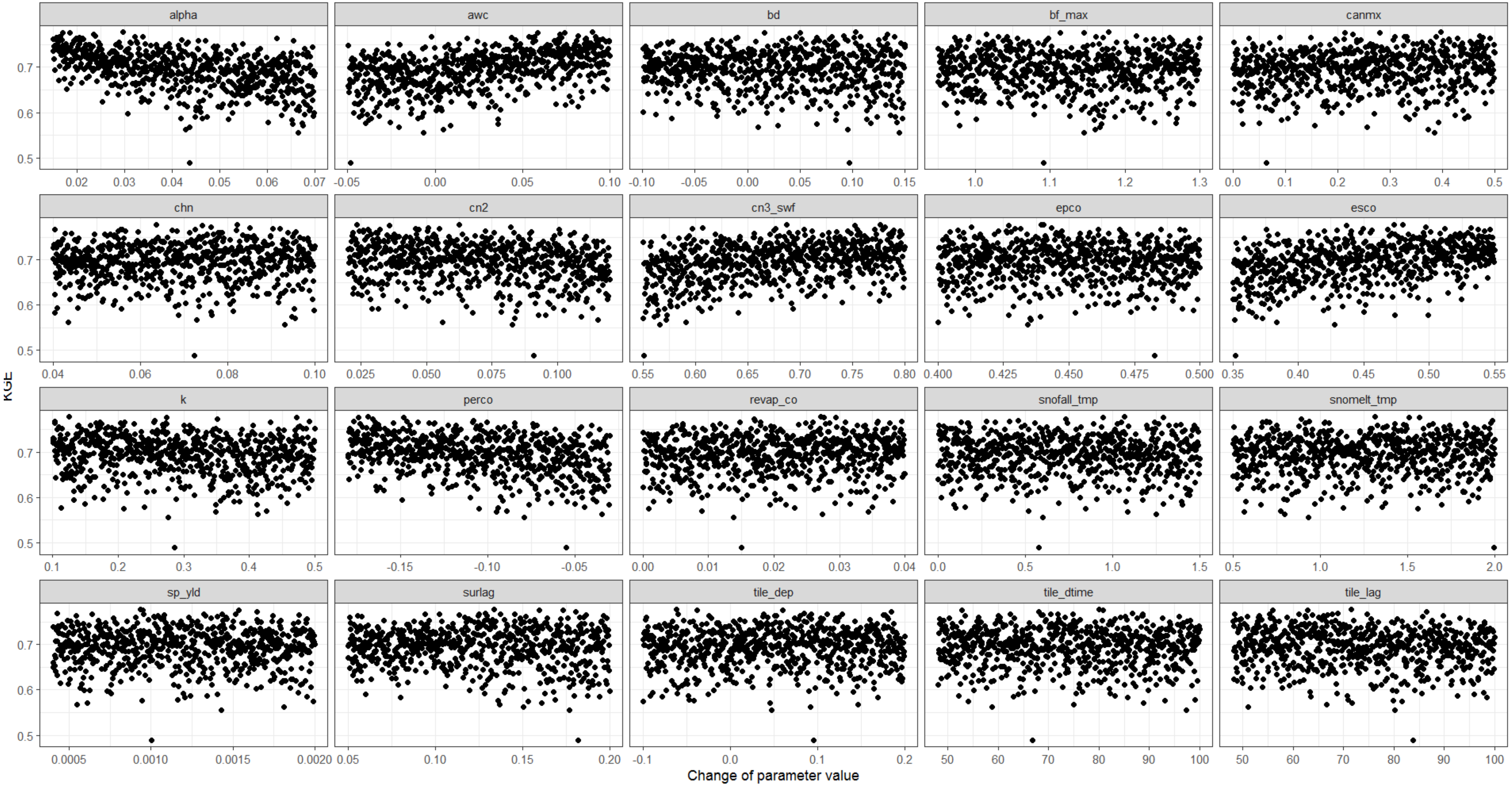
SWATrunR: R tool for executing SWAT+ model

Simple discharge calibration workflow with the Latin Hypercube Sampling, 20 parameters, KGE & PBIAS as performance criteria + spatial/temporal model validation

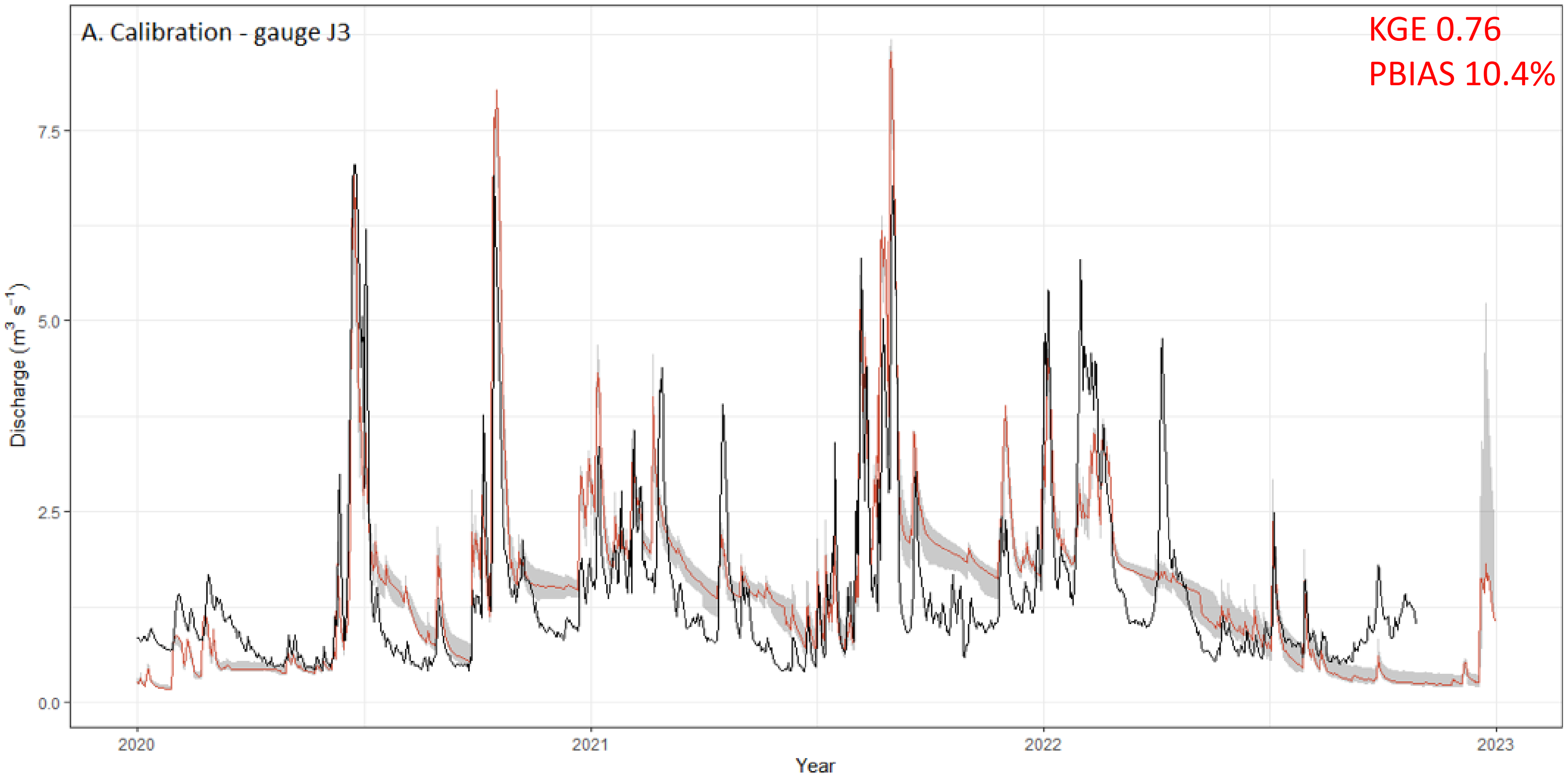
10:30 - 12:00	**Session A1: Model Development** Stakladen, Building 1423	Moderated by Ryan Bailey, Colorado State University, USA
10:30 - 10:50	**Ryan Bailey** Coupled surface/subsurface hydrologic modeling with SWAT+ and the new groundwater flow module: current approaches and applications	
10:50 - 11:10	**Natalja Čerkasova** Integrated SWAT+ soft-calibration procedure for water balance and crop yields	
11:10 - 11:30	**Jaehak Jeong** Modeling framework for rice paddy water management and climate impact assessment: Progresses in SWAT+ development	
11:30 - 11:50	**Christoph Schürz** Harmonized SWAT+ modeling workflows in R: An overview of R packages and workflows for input data preparation, model setup, and model verification and calibration	

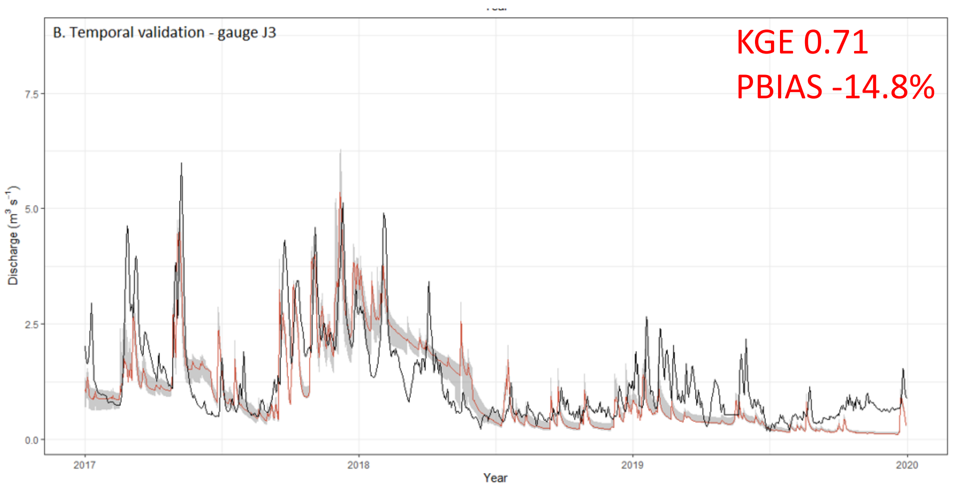
09:00 - 10:30	**Session G2: SWAT+ Model Applications** Mogens Zieler Stuen, Building 1422
09:00 - 09:20	**Dennis Trolle** ASAP Platform: making hydrological forecasting with SWAT+ easy
09:20 - 09:40	**Mauricio Zambrano-Bigiarini** Multi-period and multi-variable calibration of SWAT+ using gridded input datasets and a novel R package
09:40 - 10:00	**Svajunas Plunge** SWAT+ model setup verification tool: SWATdoctR
10:00 - 10:20	**Edward Smit** Remote Examining the value of hydropedological insight on hydrological modelling in the Sabie catchment, South Africa

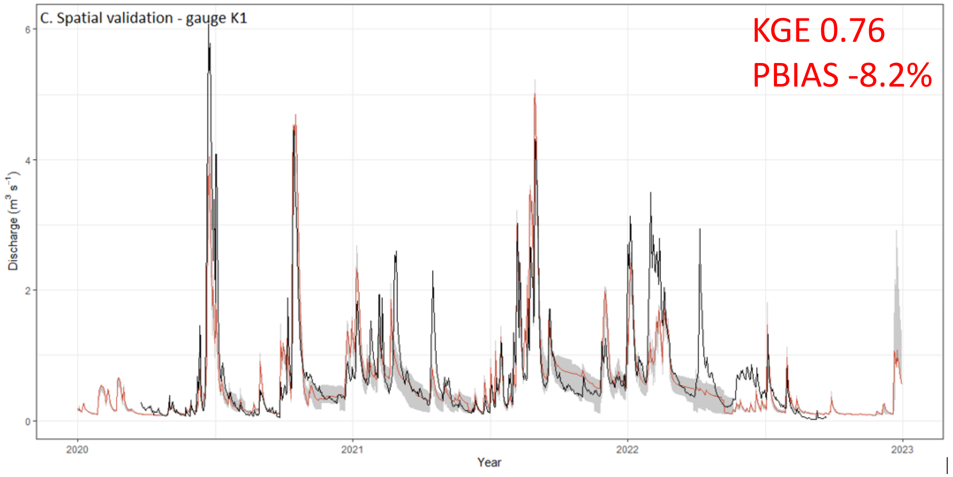
Calibration – dotty plots



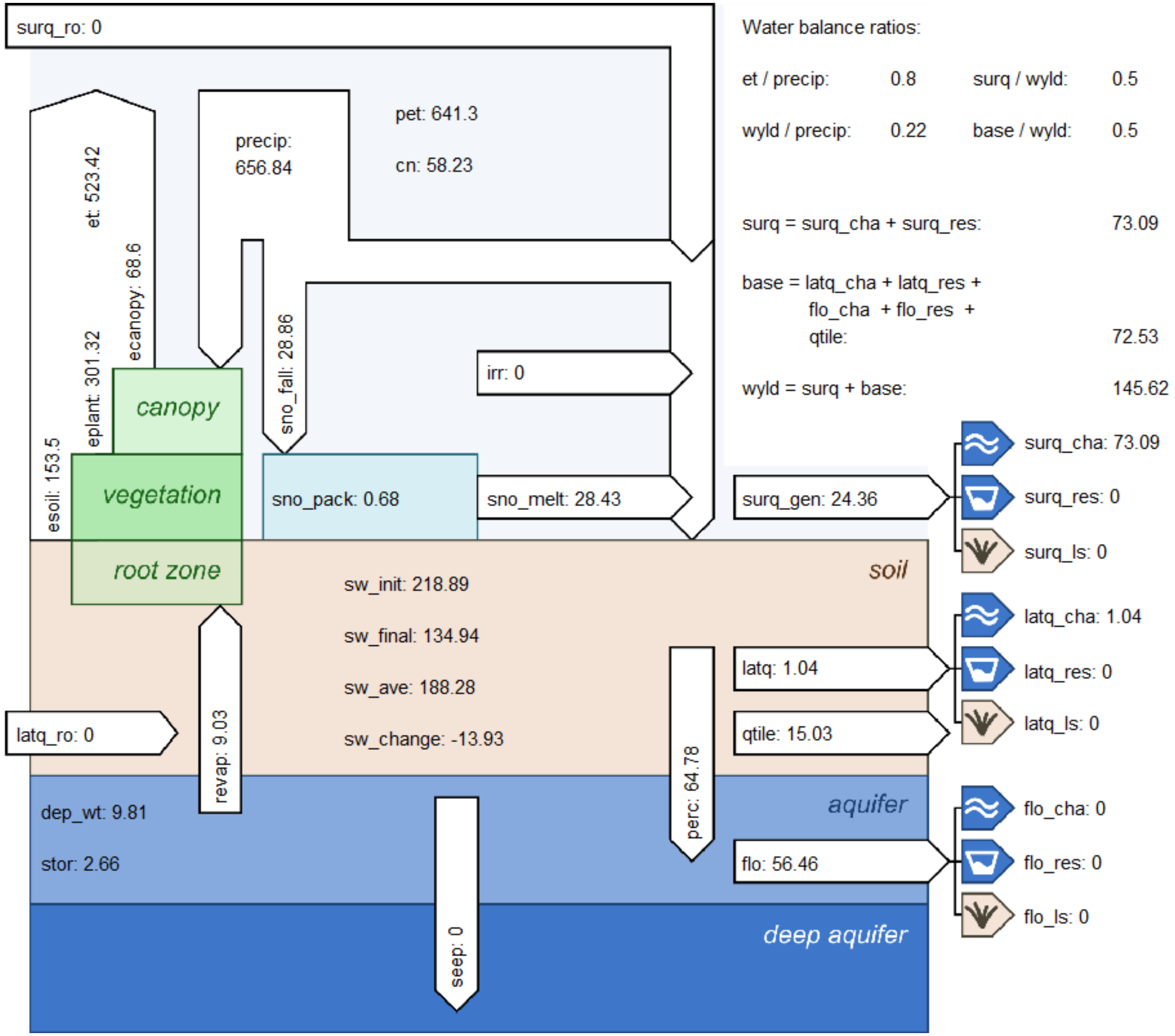
Calibration/validation – SWAT+ discharge





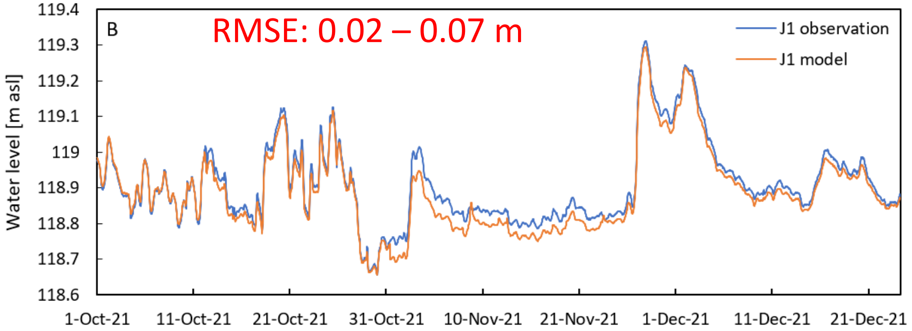


Simulated water balance (SWATdoctR)

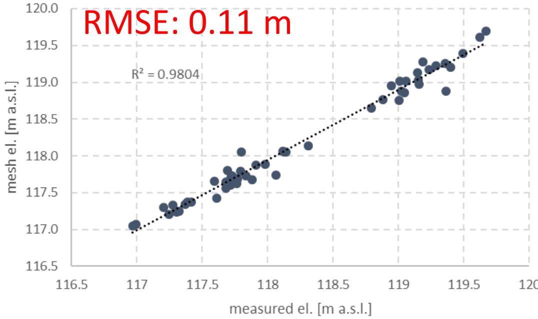


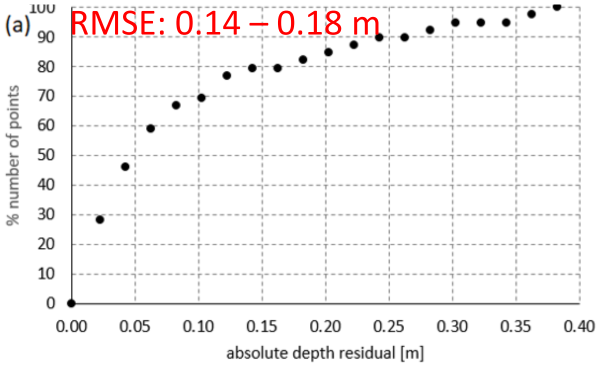
Calibration/validation – other models

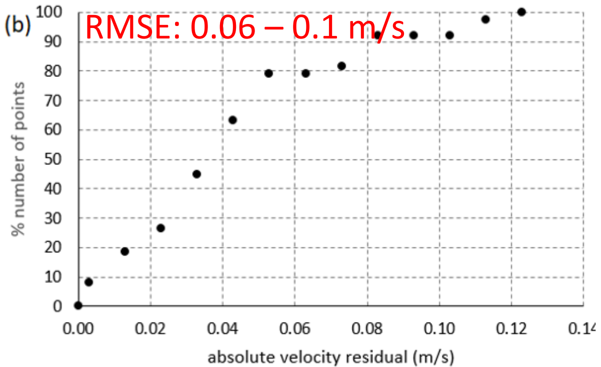
1. HEC-RAS 1D: Surface water elevation



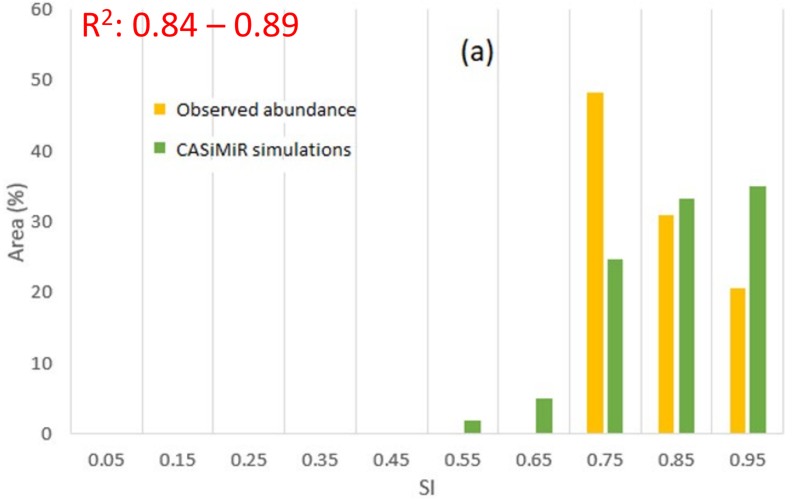
2. SRH-2D: computational mesh, flow depth and velocity







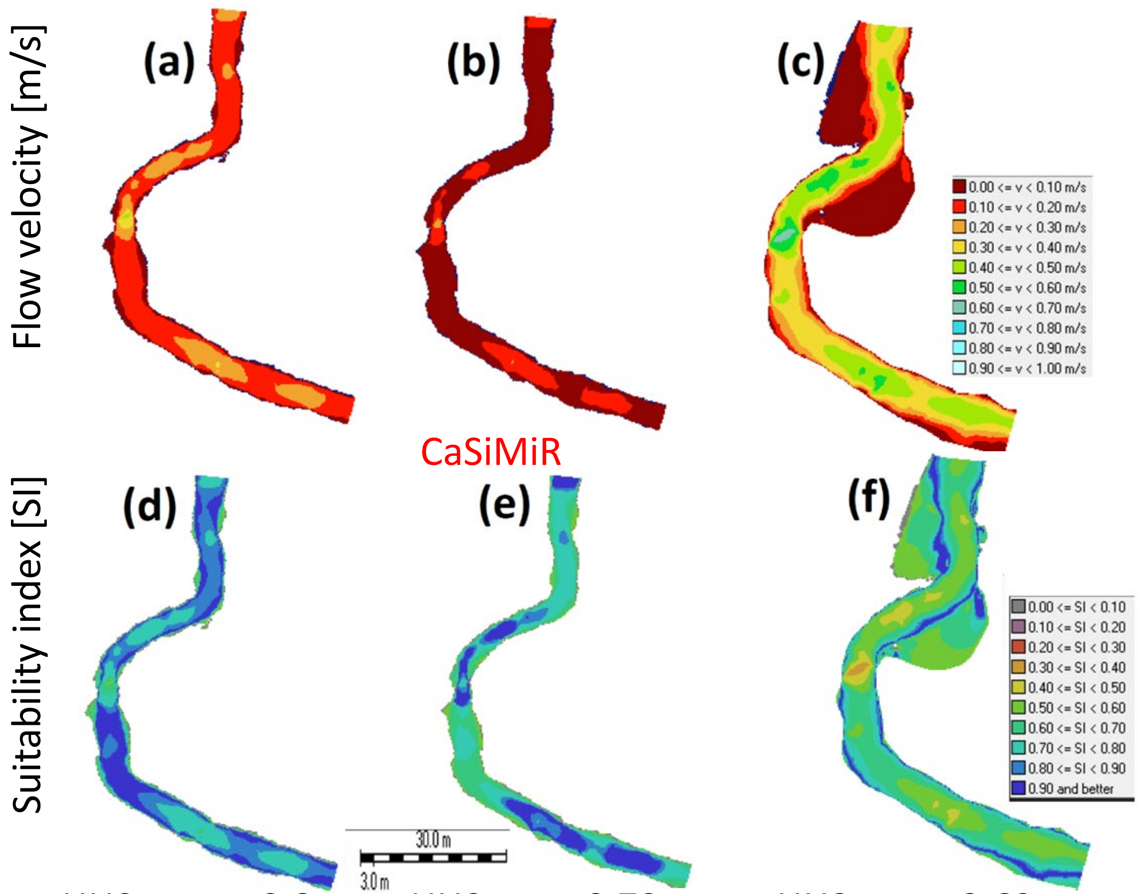
3. CaSiMiR: Habitat Suitability Index (HSI) vs species abundance



Example application of the modeling cascade

SWAT+ => Q_{mean} = 1.24 m^3/s Q_{low} = 0.29 m^3/s Q_{high} = 4.74 m^3/s

SRH-2D



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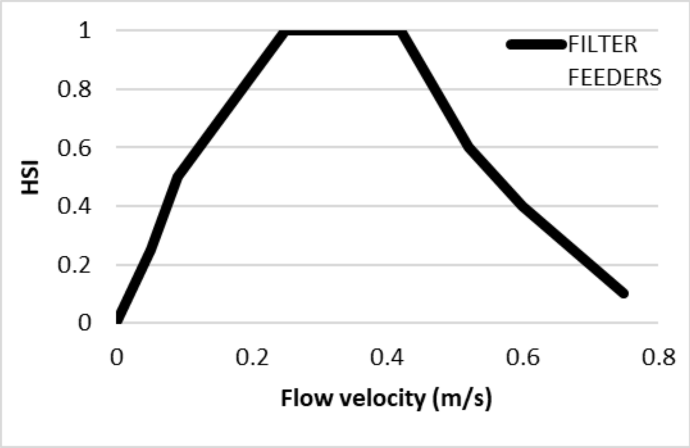

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*HHS – Weighted Usable Area (WUA) divided by total inundated area

WUA [m^2] – integrating suitability index over wetted area

Output: HHS_{Qmean} = 0.8 HHS_{Qlow} = 0.72 HHS_{Qhigh} = 0.62

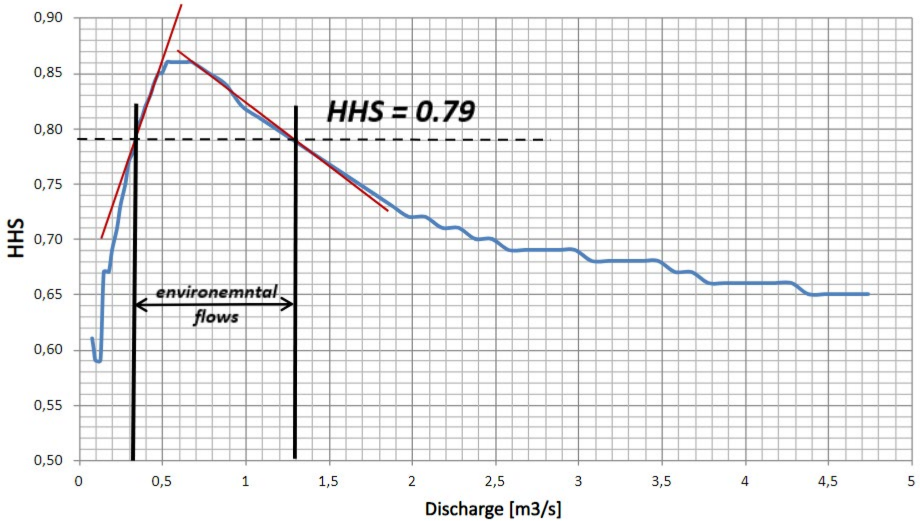
Propagation of flow scenarios through the modeling cascade

Incremantal flow values 0.08 – 4.7 m^3/s

SRH-2D (flow velocity field)

CaSiMiR (Hydraulic Habitat Suitability HHS)

Q-HHS relationship



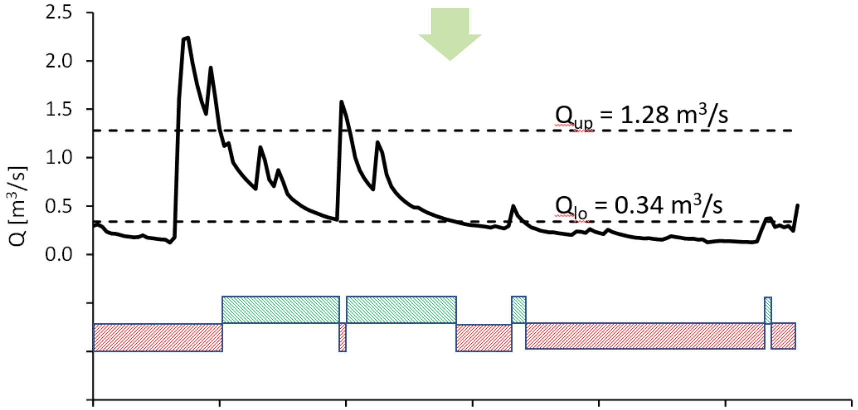
HHS > 0.79 => E-flow range 0.34 – 1.28 m^3/s

Combined scenarios

Climate change scenarios

Water use scenarios

SWAT+ (daily flows)



Trends in HHS

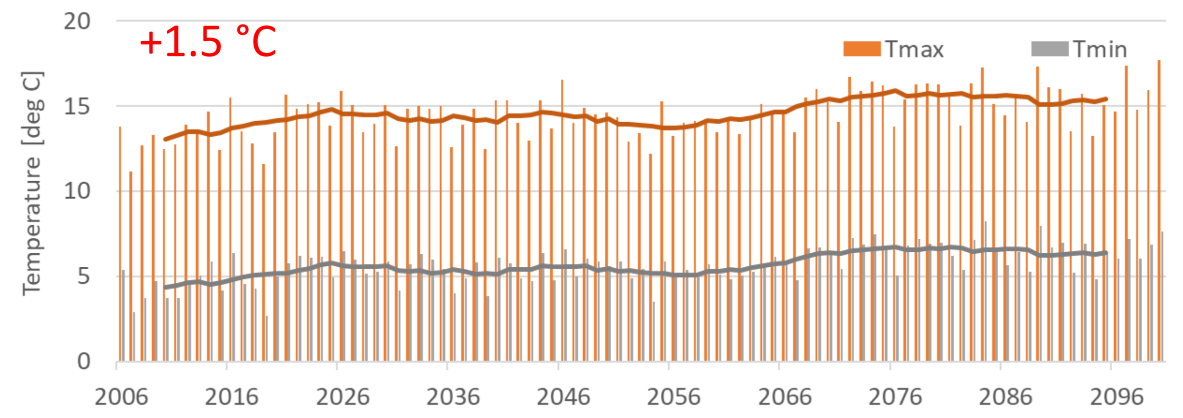
Frequency of meeting e-flow range

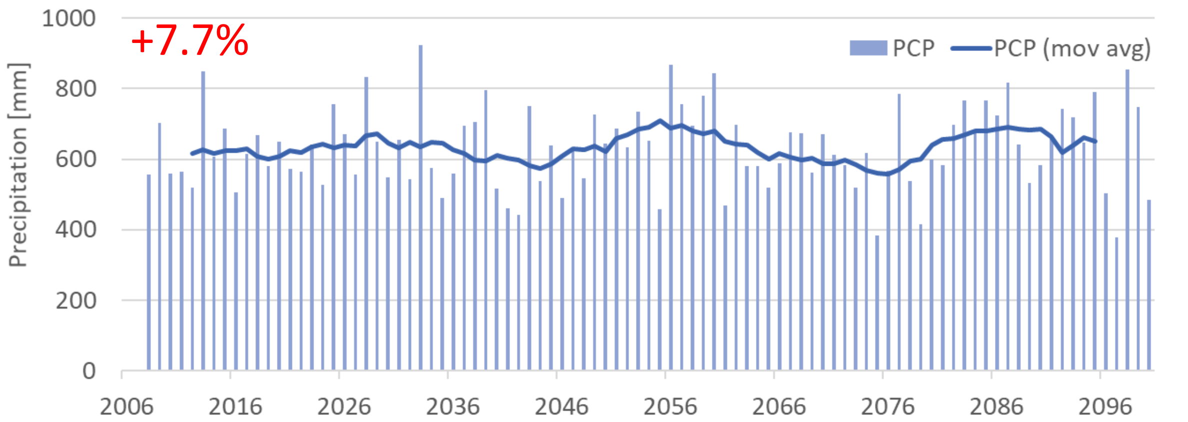
Statistics of periods with e-flow and non e-flow condition

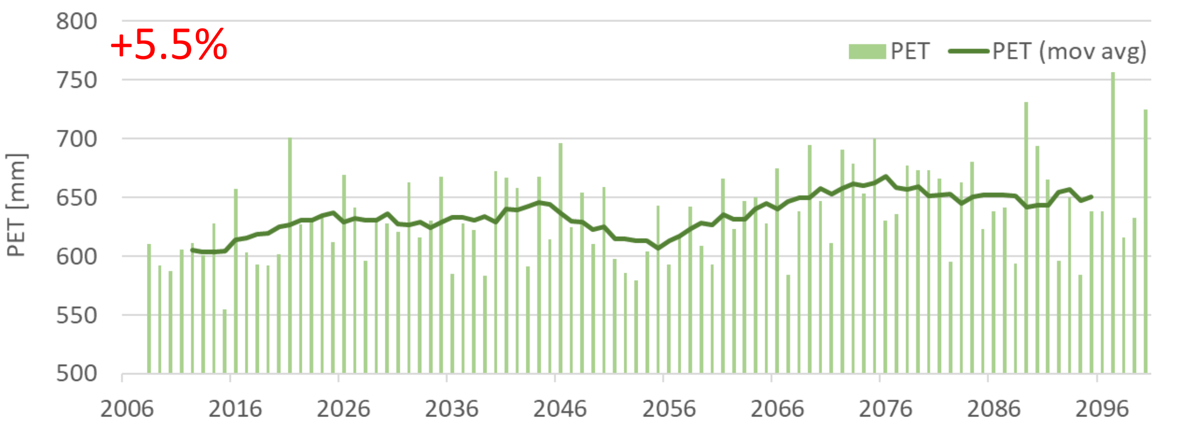
Example application: a climate change scenario

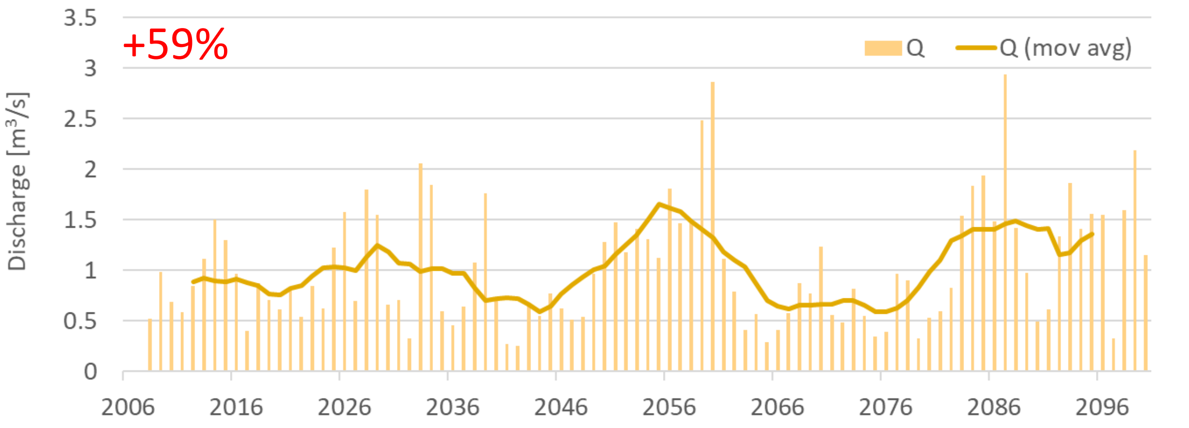
Bias-corrected EURO-CORDEX model KNMI-ICHEC-EC-EARTH-KNMI-RACMO22E for RCP4.5

Transient simulation for 2008-2100 used as SWAT+ forcing (temperature & precipitation)

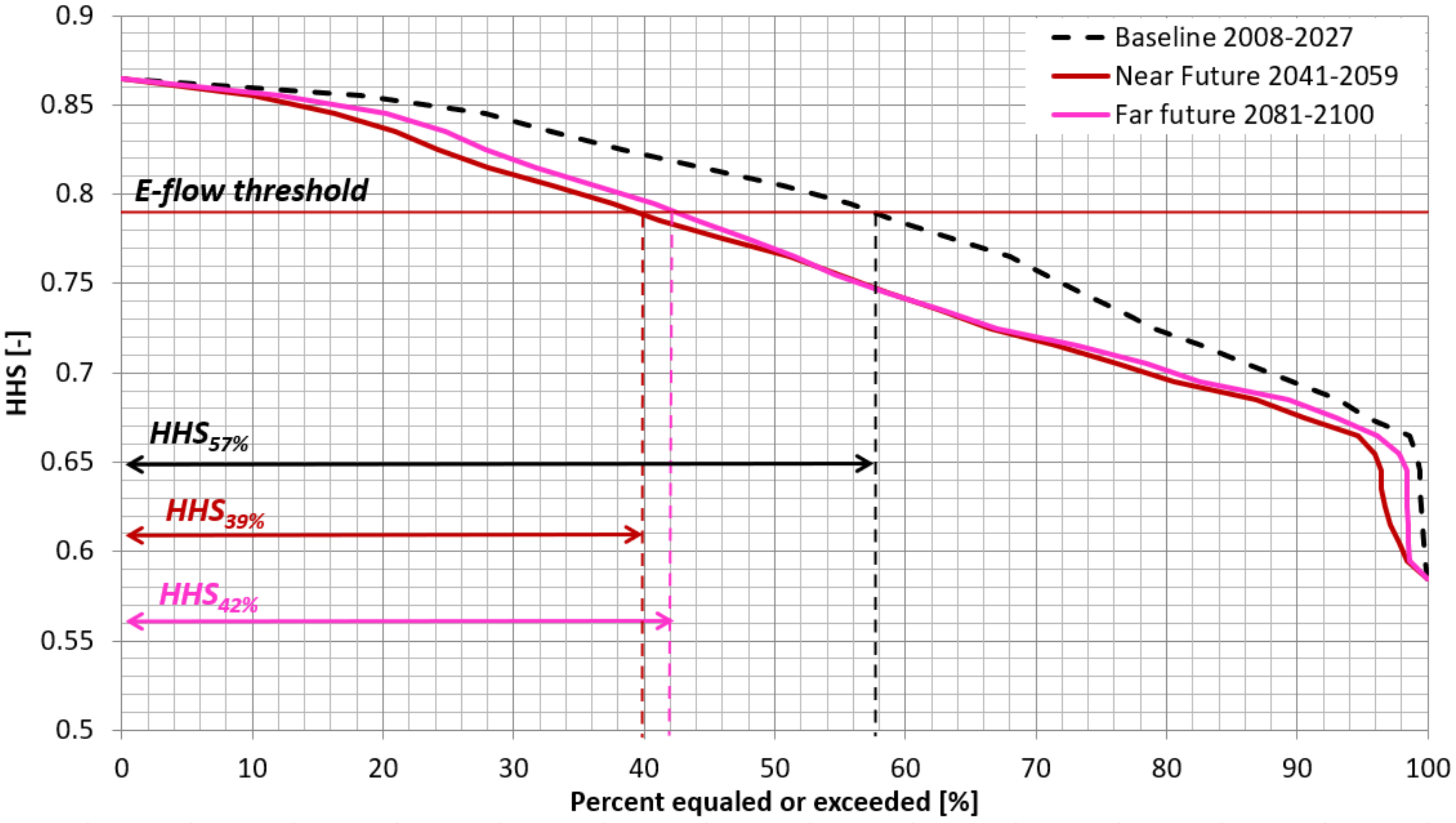






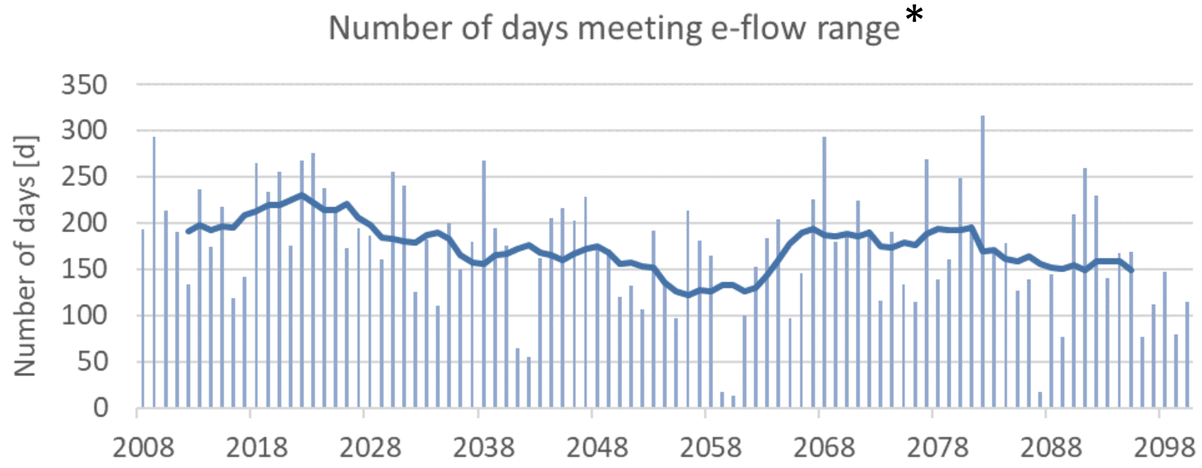


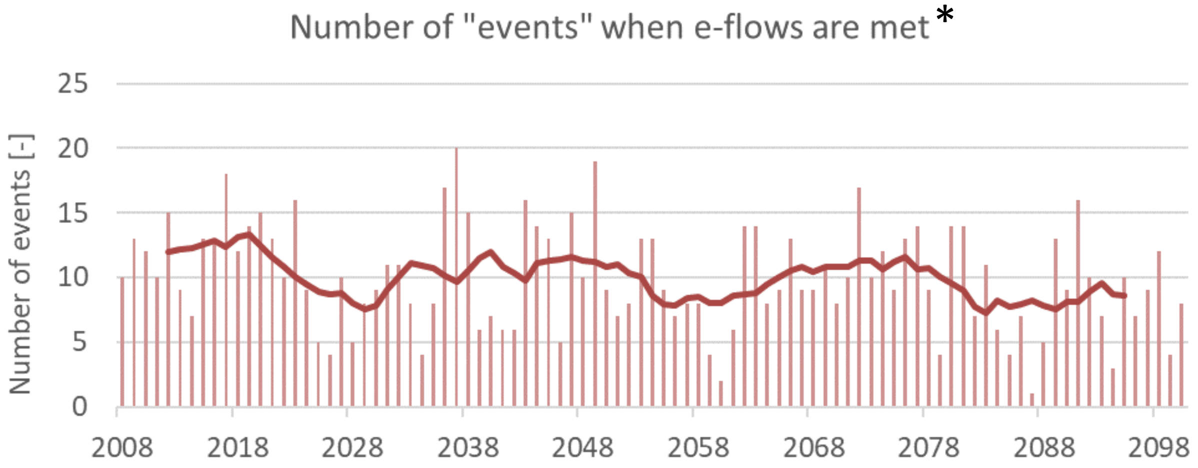
Frequency of meeting e-flow range

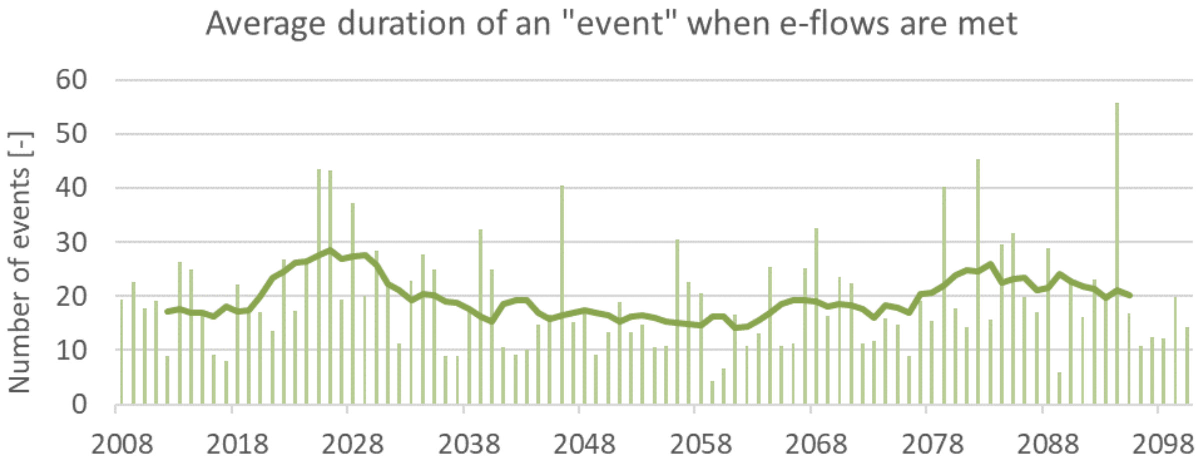


Frequency of time that the e-flow range is met drops from 57% in the baseline to 39-42% in two future horizons

Trends in meeting e-flow range







* statistically significant decrease ($p<0.05$)

Conclusion

Successful integration of hydrological, hydraulic and habitat models for studying the effects of external pressures on benthic macroinvertebrates

Estimated e-flow range for maintainig optimal habitat conditions for filter feeders in medium-sized lowland rivers

Pros: approach is flexible and versatile (e.g. for other groups of organisms, other preference criteria, other types of scenarios)

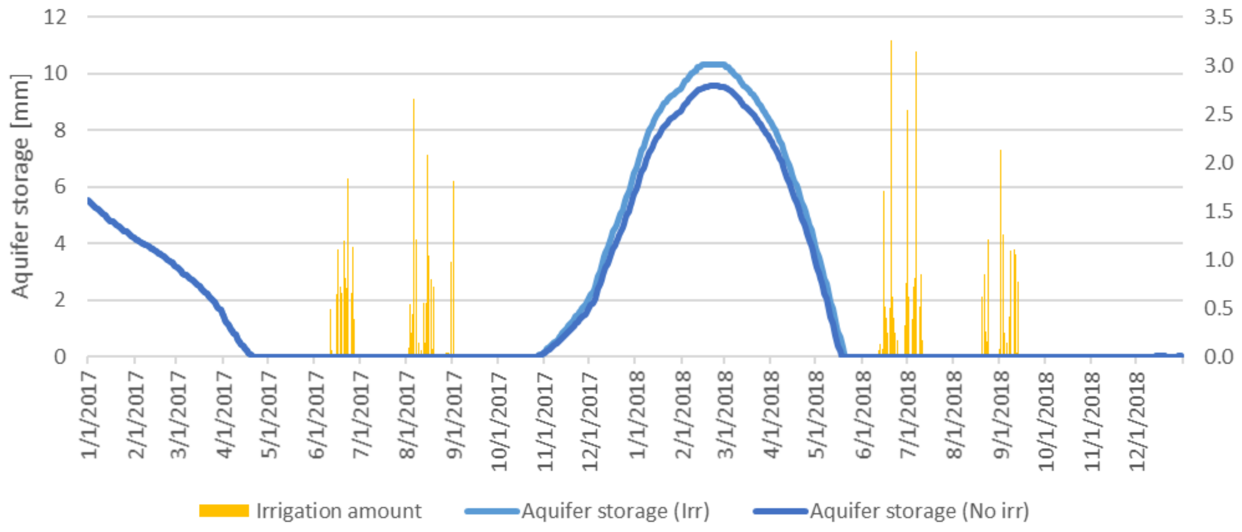
Cons: intensive field data collection, data processing and significant modeling effort + broad expertise needed

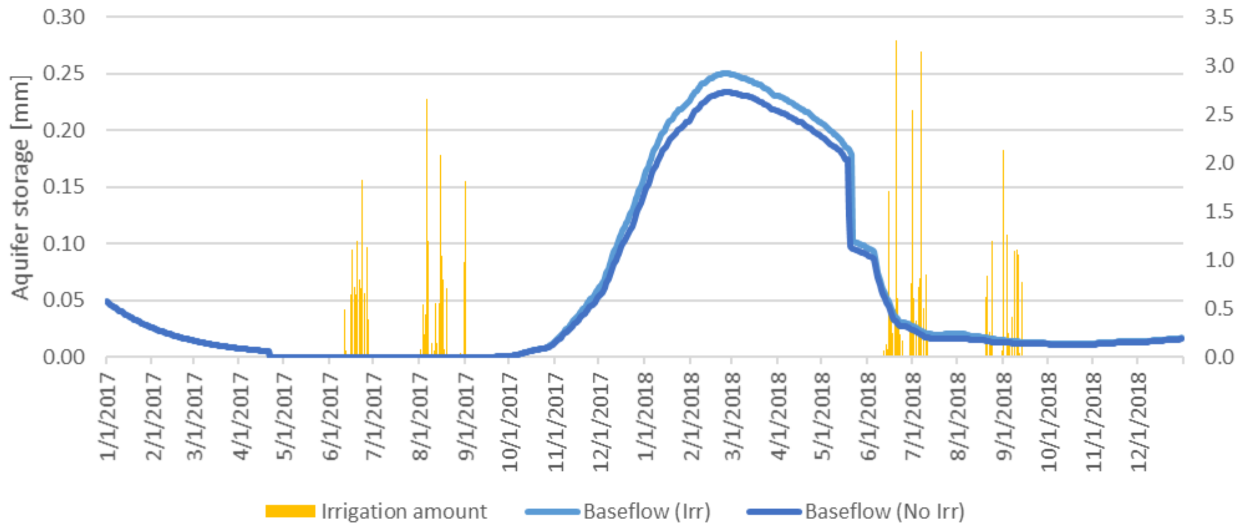
Uncertainty propagation – a remaining challenge

Post scriptum – decision tables mysteries

Why is irrigation from the aquifer (single source) set up using a decision table possible when aquifer storage is zero?

Why is baseflow increasing after setting up irrigation from the aquifer (single source) via decision tables?





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Thank you!

Chattopadhyay, S., Szałkiewicz, E., Dytkiewicz, M., Marcinkowski, P., Mirosław-Świątek, D., Oglęcki, P., Piniewski, M. Development of an integrated modelling framework to evaluate impacts of pressures on habitat conditions and riverine biota. Ecohydrology (under review)