Satellite-based soil moisture enhances the reliability of agro-hydrological modeling in large transboundary river basins

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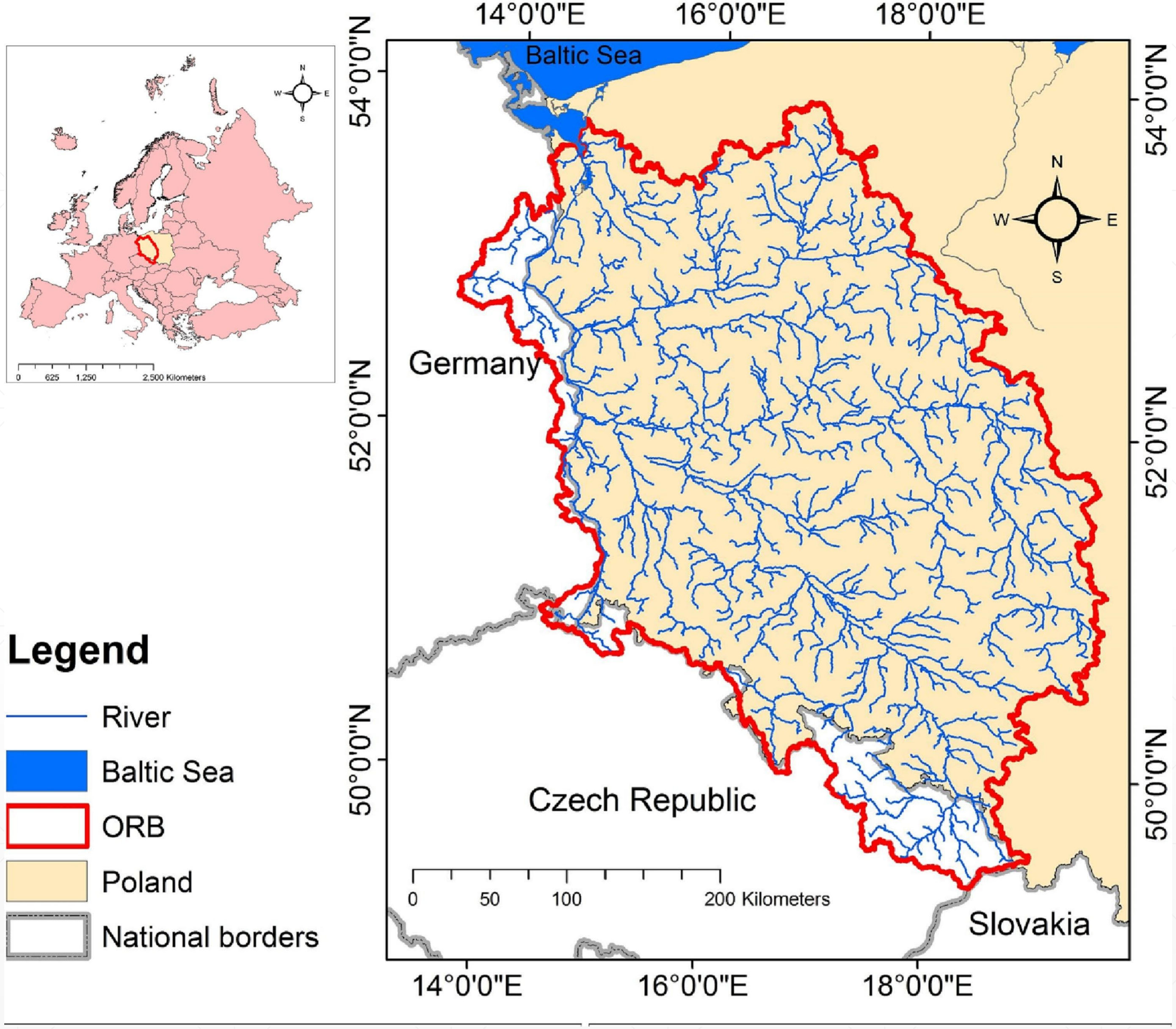
Why?

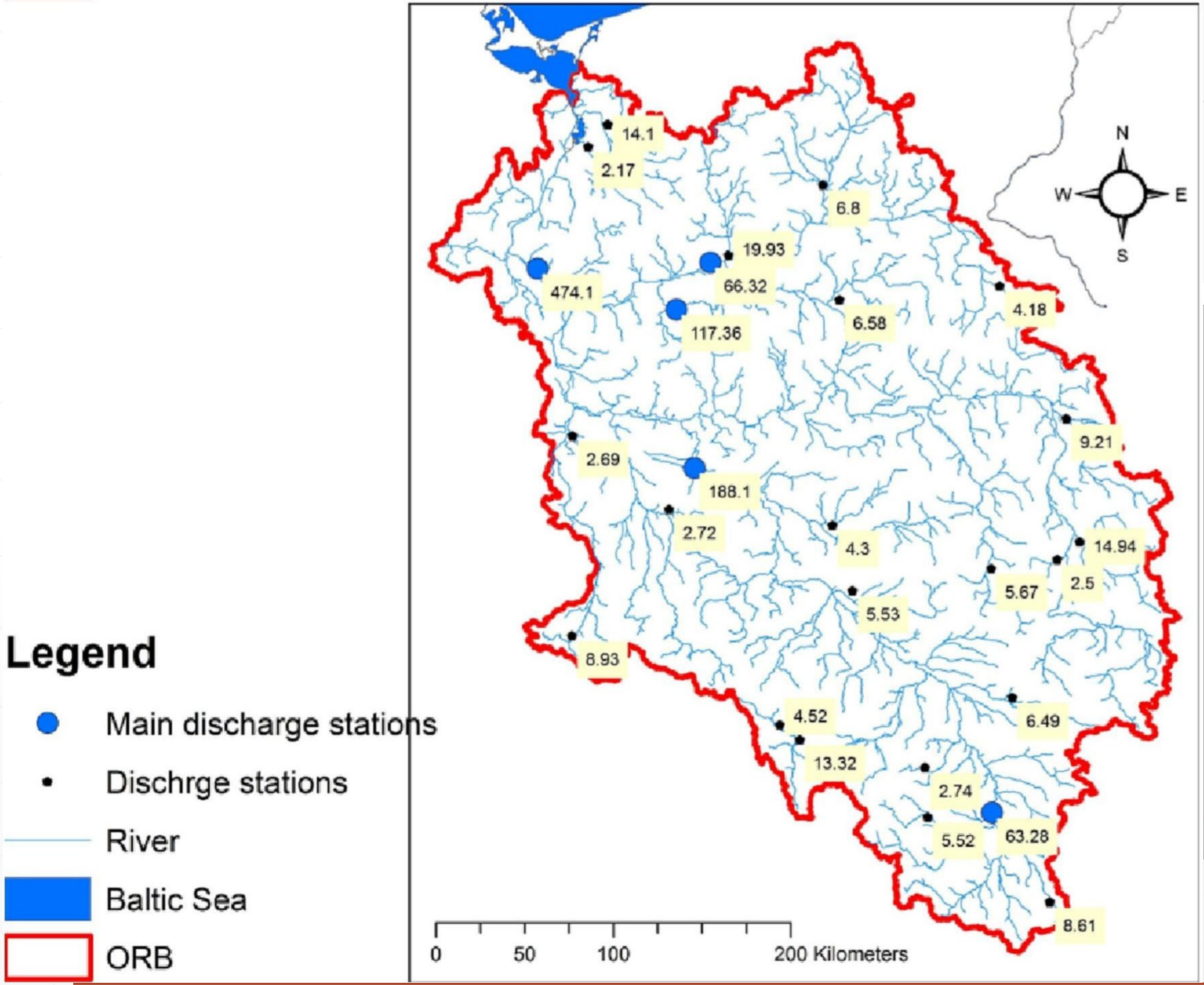
- The data issues in transboundary river basins
- A reliable model for projecting hydrological and agricultural drought indicators crop yield assessments
- Evaluating single- and multi-objective strategies in calibration

Study Area

- The Odra River Basin (ORB) – 120,000 sq-km
- Located in Central Europe
- The fifth largest river basin in EU
- 89 % is in Poland
- 4.9 % in Germany
- 6.1 % in the Czech Republic
- The longest stream is 840 km
- The annual river discharge is ~ 470 cms
- Average annual precipitation ~ 650 mm



Study Area


N
W
E
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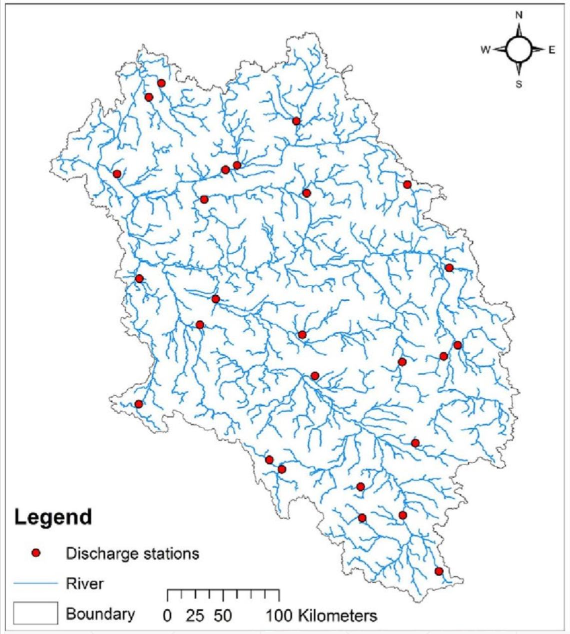
14.1
2.17
6.8
19.93
66.32
474.1
117.36
6.58
4.18
9.21
2.69
188.1
2.72
4.3
14.94
2.5
5.67
5.53
8.93
4.52
13.32
6.49
2.74
5.52
63.28
8.61
0
50
100
200 Kilometers
Legend
Main discharge stations
Dischrge stations
River
Baltic Sea
ORB


N
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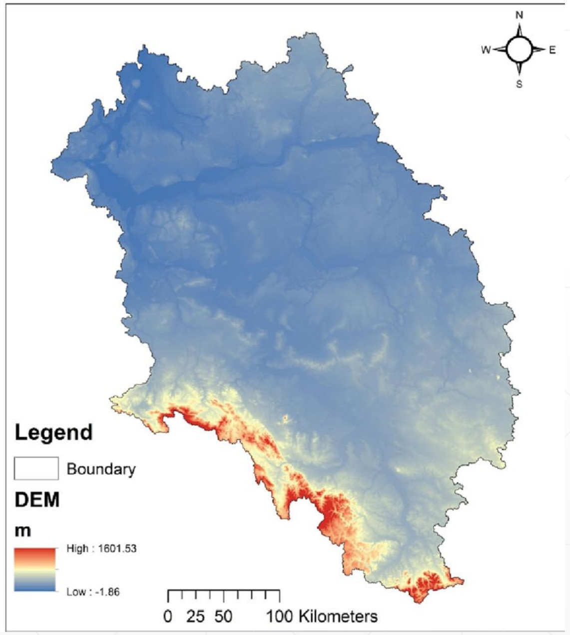
Legend
Discharge stations
River
Boundary
0 25 50 100 Kilometers


N
W
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Legend
Boundary
DEM
m
High : 1601.53
Low : -1.86
0 25 50 100 Kilometers

SWAT+ model configuration

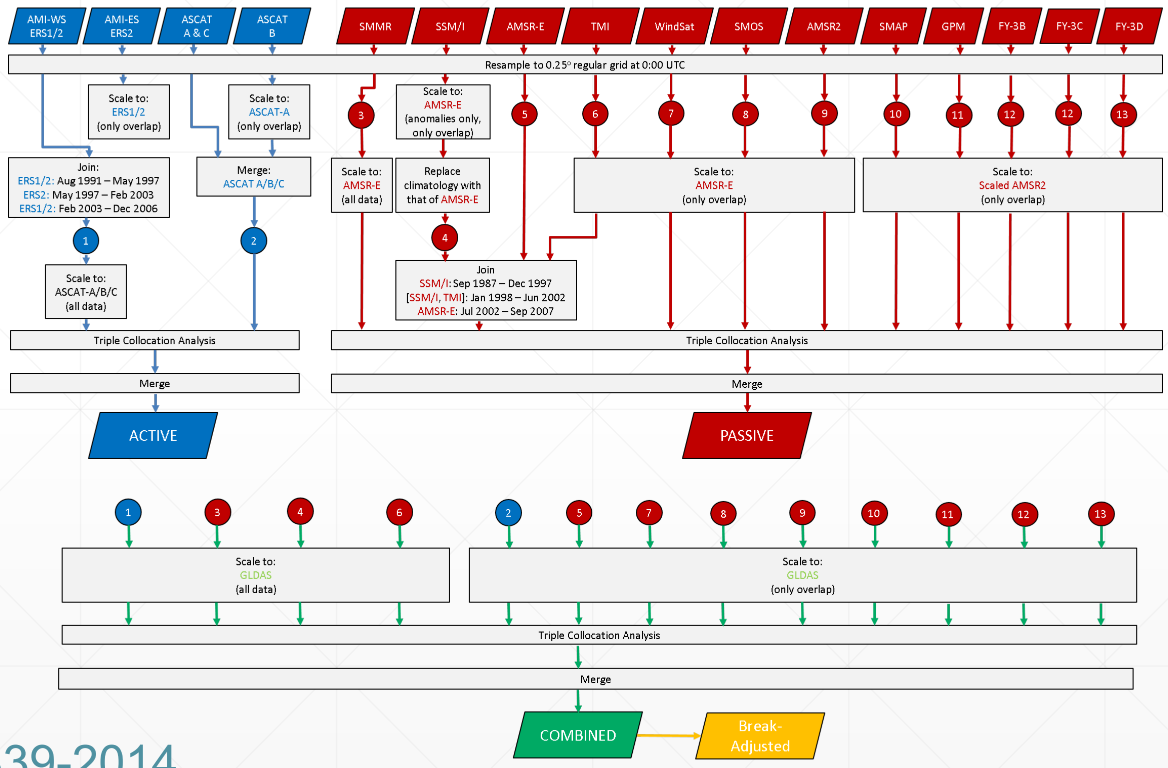
SWAT+
SOIL & WATER ASSESSMENT TOOL

- 1476 subbasins (pre-defined watersheds)
- 20,000 hydrologic response units (HRUs)
- 176 lakes (natural lakes and reservoirs)
- 11 major crops
- Management plans (fertilizer, planting date, harvesting,…)
- Drainage system
- Weather datasets (G2DC-PL+ and ERA5 (solar radiation))
- Penman-Monteith method for PET
- Period: 1997-2019

An extensively revised version of SWAT+: https://github.com/andrejstmh/SWATplus
Microsoft Visual Studio and Intel Fortran Compiler

Satellite-based Soil Moisture

- ESA (European Space Agency) CCI (Climate Change Initiative) SM version 07.1
- Combined product
- The resolution of this product is 0.25° and has daily time step
- The Soil Water Index (SWI) was used for corrections of SM
- Due to the large-scale resolution and irregular time intervals on surface and depth



SWI: Massari et al (2014) https://doi.org/10.5194/hess-18-839-2014
Ceballos et al (2005) https://doi.org/10.1002/hyp.5585

Source: esa-soilmoisture-cci.org

Objective functions and calibration strategies

- Kling–Gupta efficiency (KGE) for river discharge
- SPAtial EFficiency (SPAEF) for Soil Moisture (compares two maps)

- The single-objective (SO) calibration of river discharge
- The multi-objective (MO) calibration of river discharge and soil moisture

- Effect of SO and MO on river discharge, soil moisture and crop yields

Results

Calibrated parameters

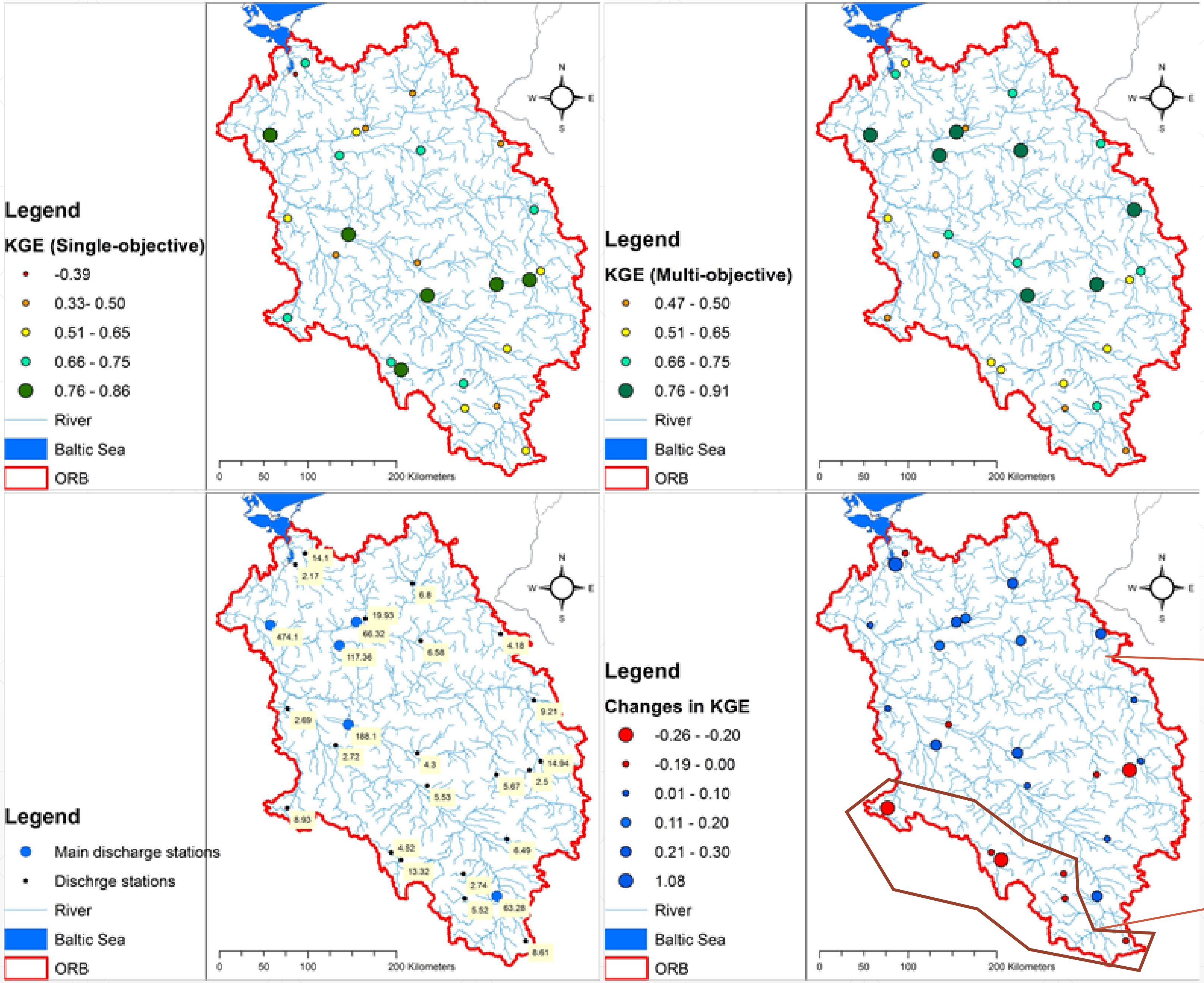
26 discharge stations were classified into 6 groups based on land use and soil of the drainage area
Selected model parameters were calibrated for 6 groups

Change method	Parameter	Initial range of parameters		Final value	
		Lower band	Upper band	Single-objective	Multi-objective
Absolute value	alpha.gw	0.01	0.1	0.06	0.04
	bf_max.gw	0.01	1	0.29	0.61
	chn.rte	0.05	0.2	0.18	0.08
	deep_seep.gw	0.001	0.2	0.05	0.14
	epco.hru	0	0.3	0.07	0.05
	esco.hru	0.5	1	0.94	0.95
	flo_min.gw	1	5	3.31	3.27
	lat_time.hru	0.5	2	1.04	0.93
	perco.hru	0.85	0.99	0.96	0.96
	revap_co.gw	0.02	0.1	0.023	0.04
	revap_min.gw	4	10	7.05	5.76
	sp_yld.gw	0	0.2	0.09	0.04
Relative value	awc.sol	-0.2	0.2	-0.155	0.14
	bd.sol	-0.3	0.3	0.29	0.02
	cn2.hru	-0.2	0.2	-0.02	0.11
	cn3_swf.hru	-0.5	0.5	-0.29	-0.35
	k.sol	-0.2	0.2	-0.195	-0.02

Calibration results at main discharge stations

River and discharge station name	Q (m^3/s)	KGE			
		Single objective		Multi objective	
		Calibration	Validation	Calibration	Validation
Odra at Gozdowice	474.1	0.77	0.78	0.81	0.83
Odra at Cigacice	188.1	0.86	0.81	0.75	0.79
Warta at Skwierzyna	117.36	0.73	0.78	0.84	0.85
Noteć at Nowe Drezdenko	66.32	0.56	0.63	0.81	0.88
Odra at Racibórz-Miedonia	63.28	0.45	0.53	0.67	0.65

Calibration results



KGE:

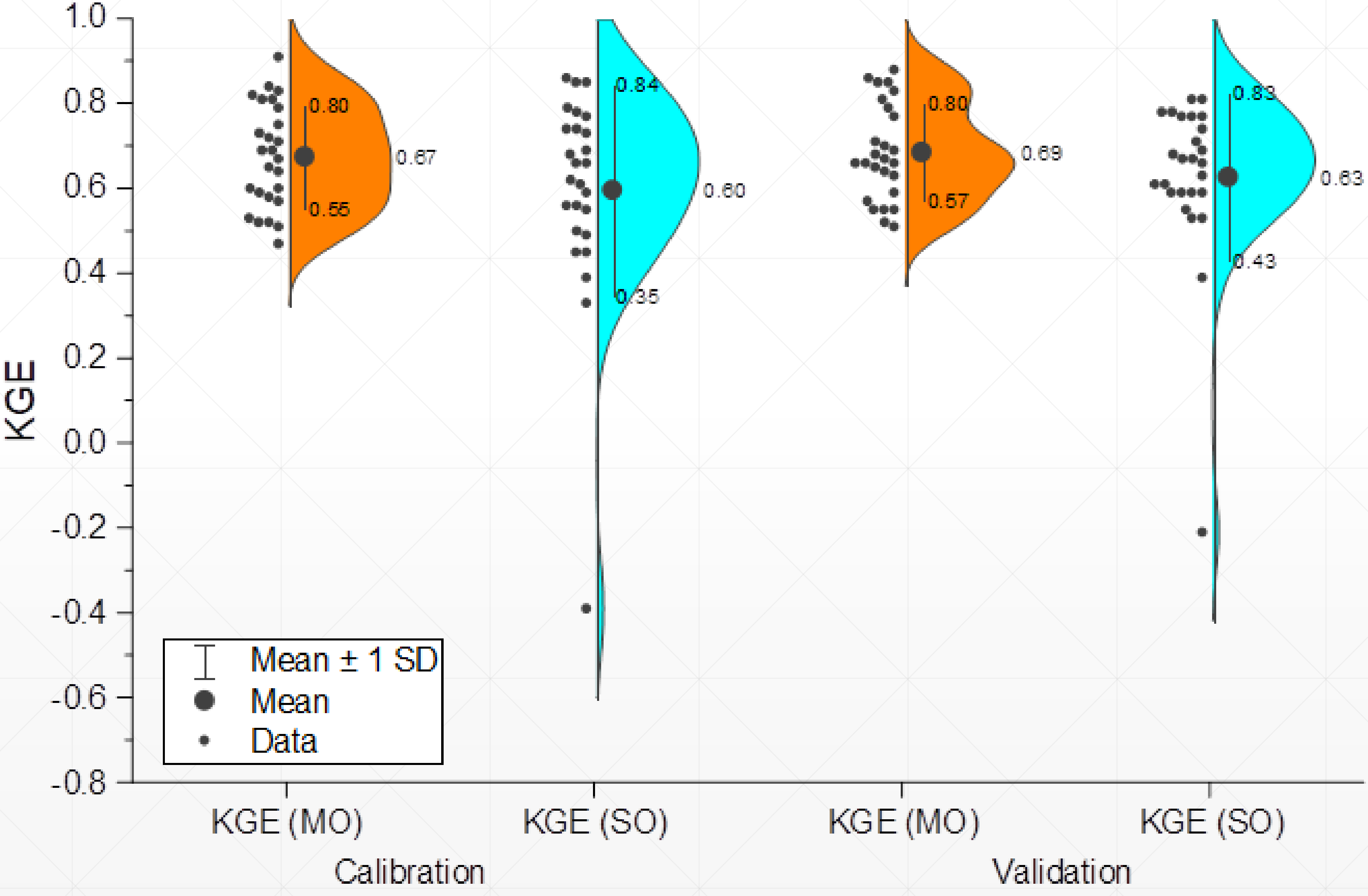
SO: ~0.60 and ~0.63 in the calibration and validation periods

MO: ~0.67 and ~0.69 in the calibration and validation periods

Major improvements in lowlands

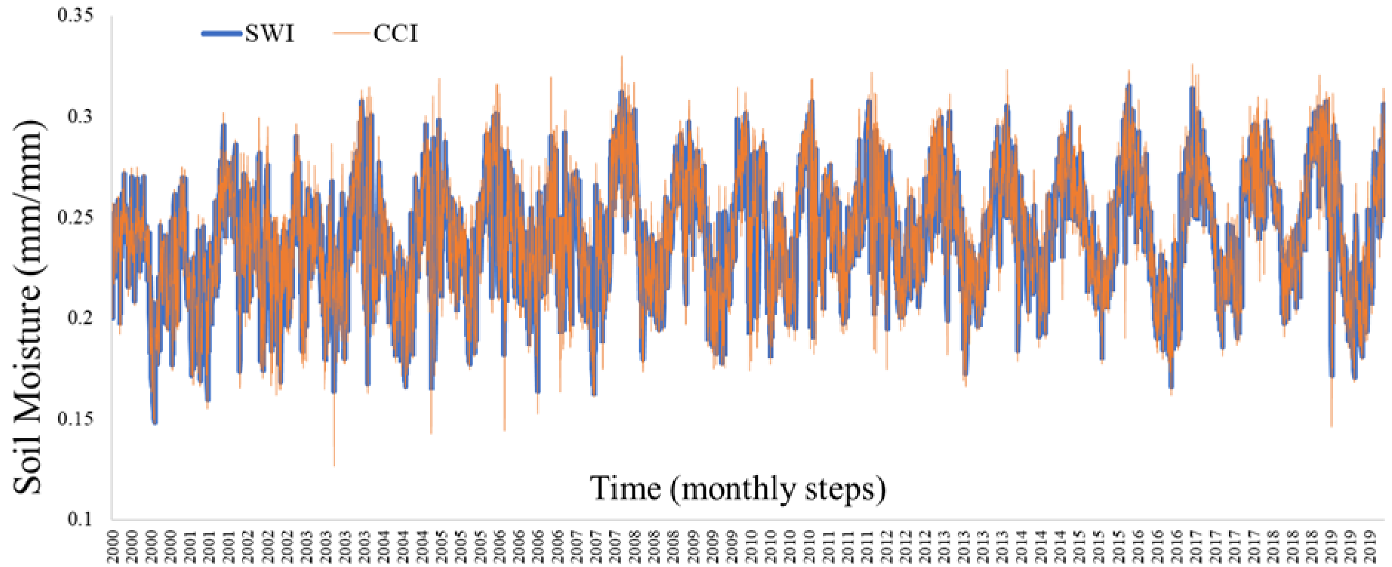
Not useful for here
We can exclude mountains

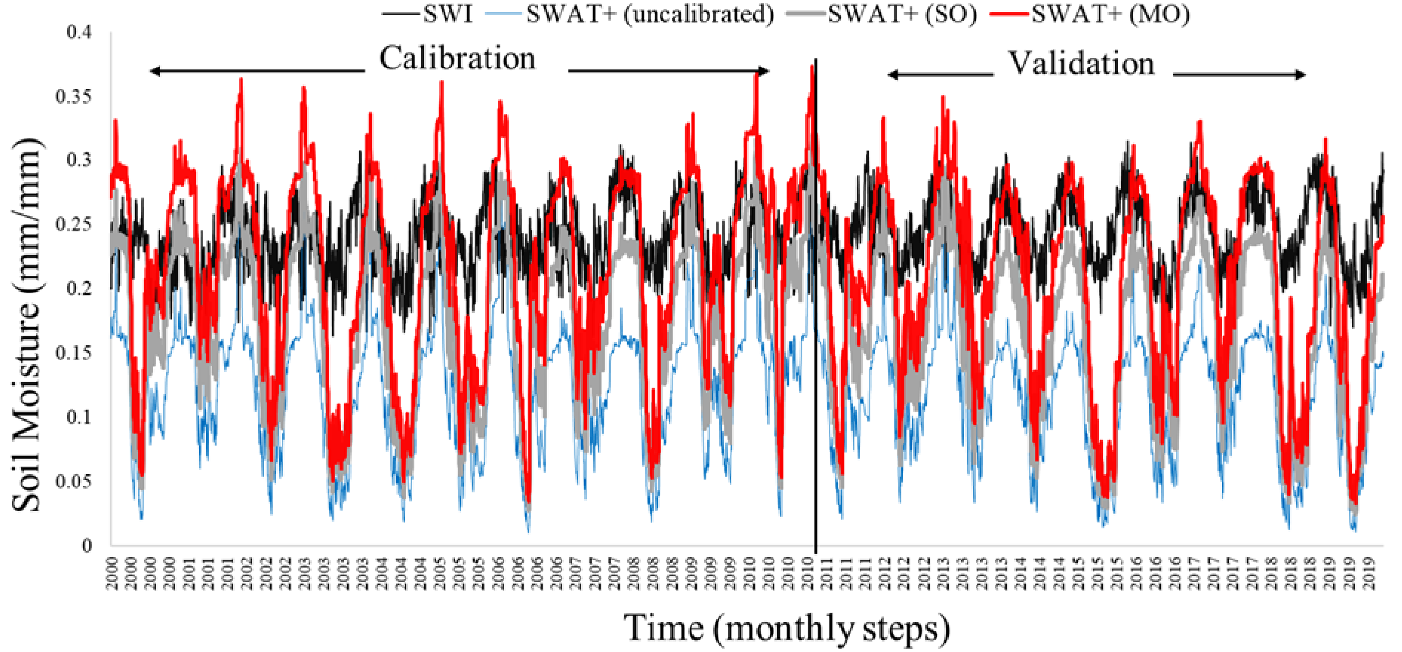
Calibration results



Distribution of KGE for river discharge in SO and MO approaches

Calibration results





What happens if we apply SWI?

Soil moisture was calibrated for topsoil (300 mm) and entire soil profile!

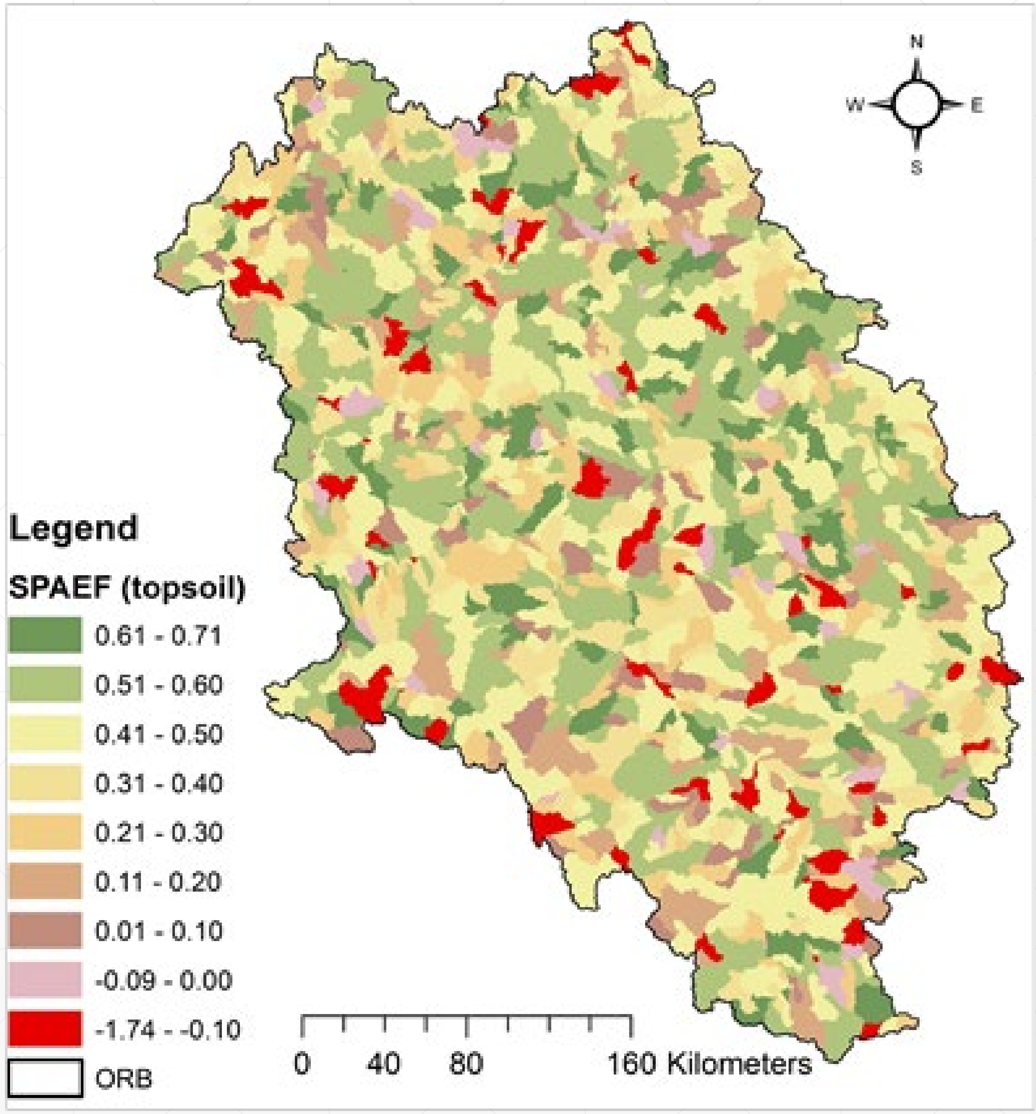
In SWAT and SWAT+ models soil moisture

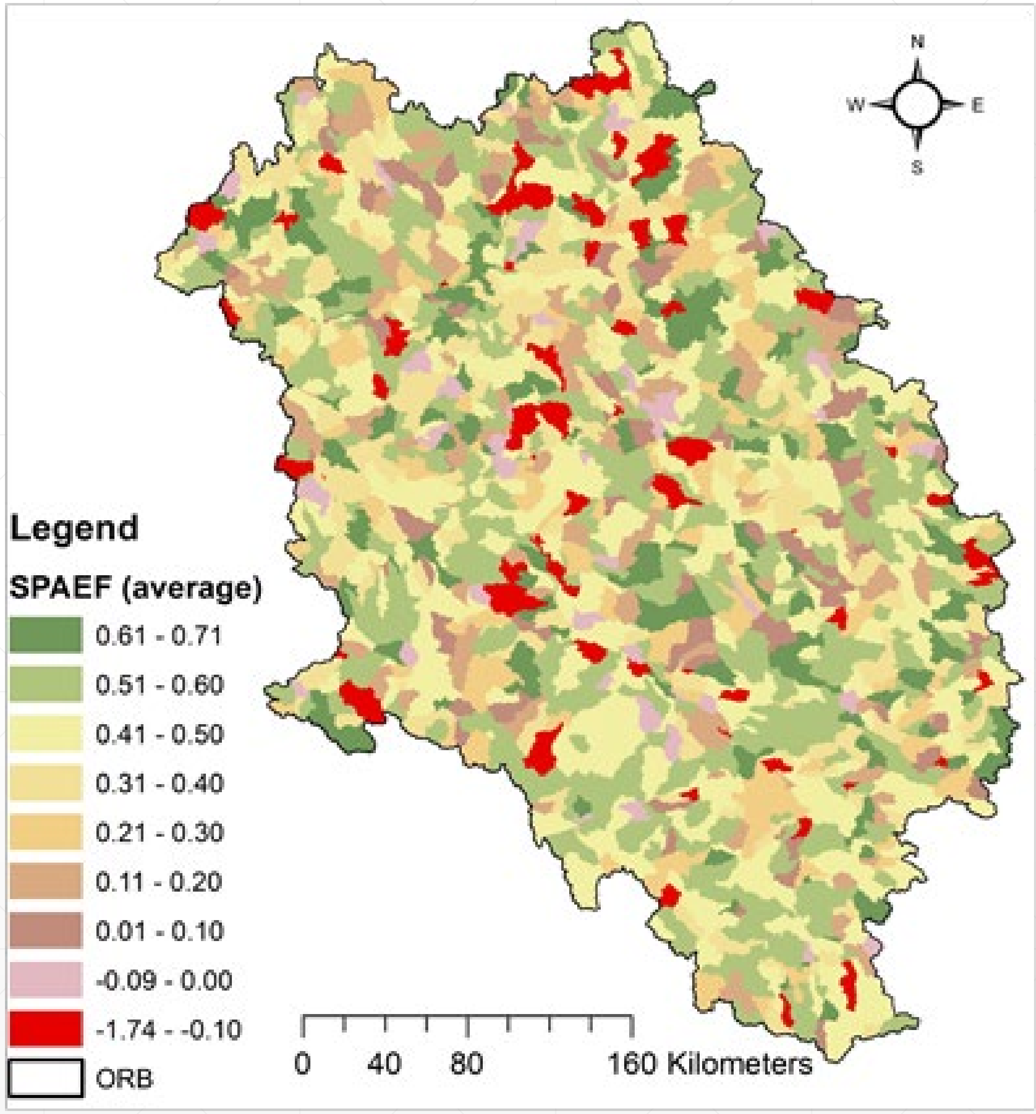
is not soil moisture

It shows water content above wilting point

After three months in SWAT2022 conference!

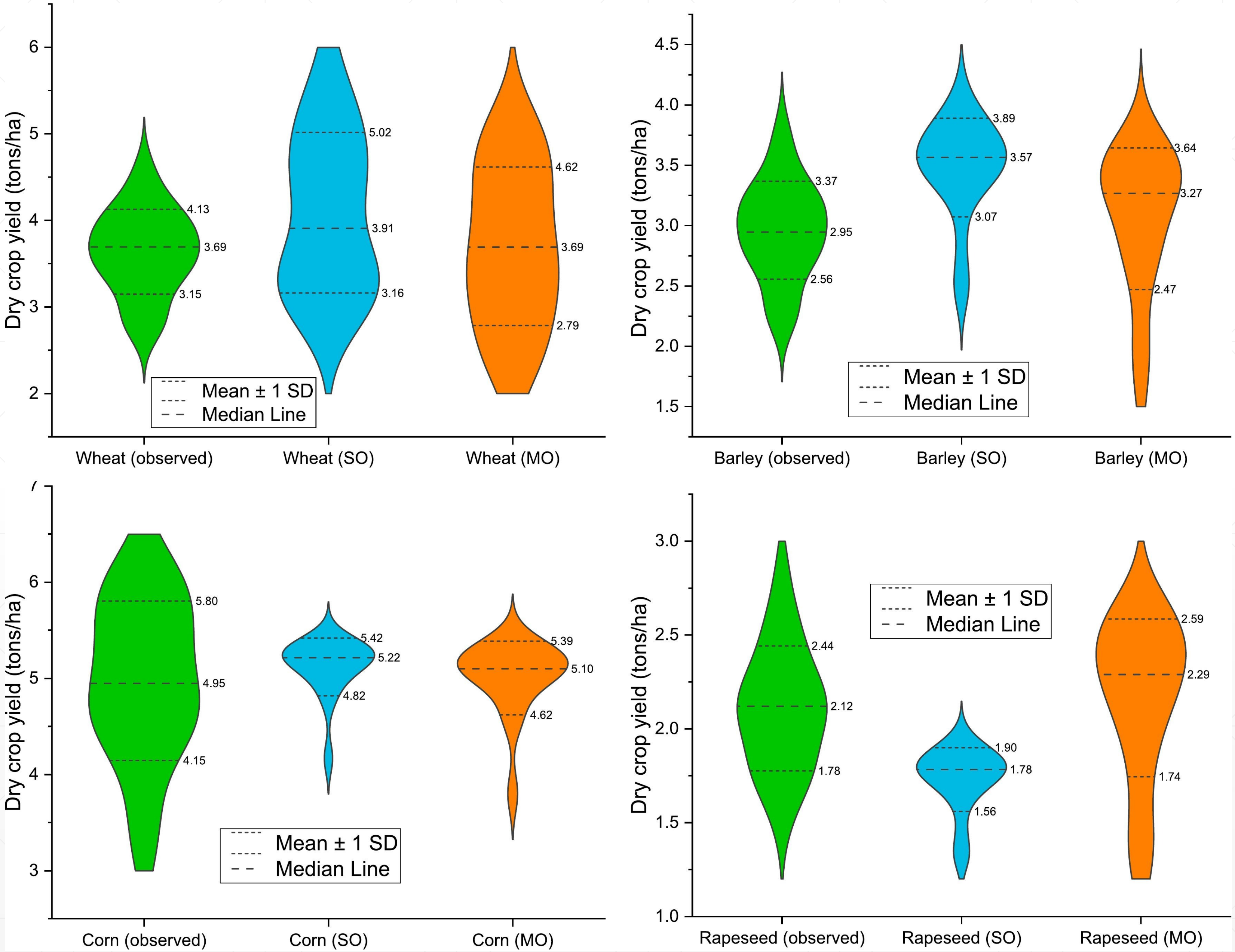
Calibration results





SPAEF distributions at subbasin levels: average = 0.37 topsoil and 0.31 entire soil profile

Calibration results

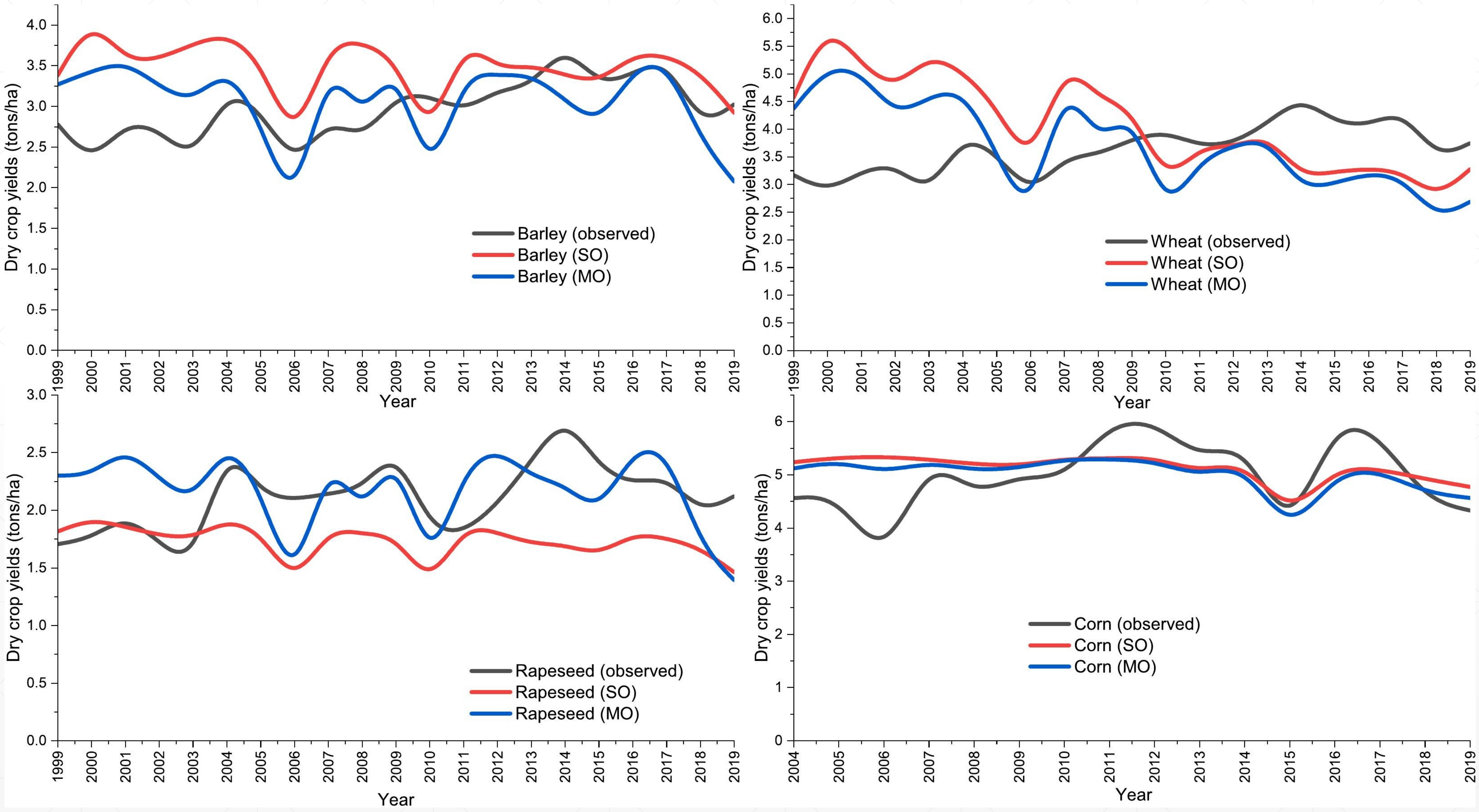


Effect of SO and MO on crop yields

- Winter wheat
- Spring barley
- Corn
- Rapeseed

Calibration results

Effect of SO and MO on crop yields



Winter wheat
Spring barley
Corn
Rapeseed

Future works

- **The difference of SO and MO approaches in projections**
- **Water accounting for historical and future based on the MO approach**
- **Projecting hydrological and agricultural droughts and crop yields**
- **Assessing the possibility of supplemental irrigation for this region**

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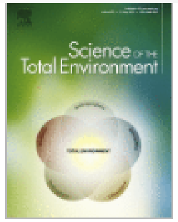

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Thanks for your attention