Leibniz Centre for Agricultural Landscape Research (ZALF)

Crop growth and soil water fluxes at erosion-affected arable sites: a model inter-comparison based on weighing-lysimeter observations

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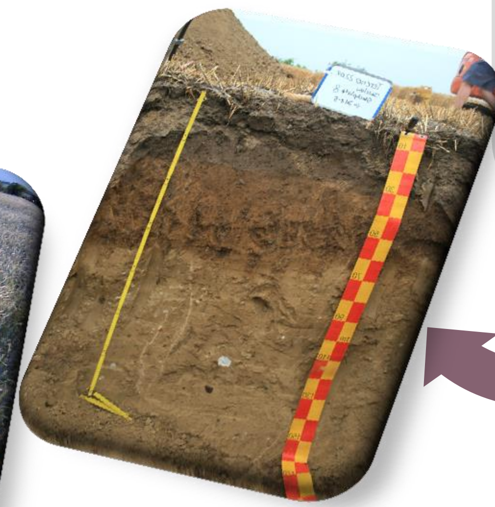
Date: April 06, 2020

Modeling Background

Model inter-comparison studies

Crop growth models mostly evaluated on yield



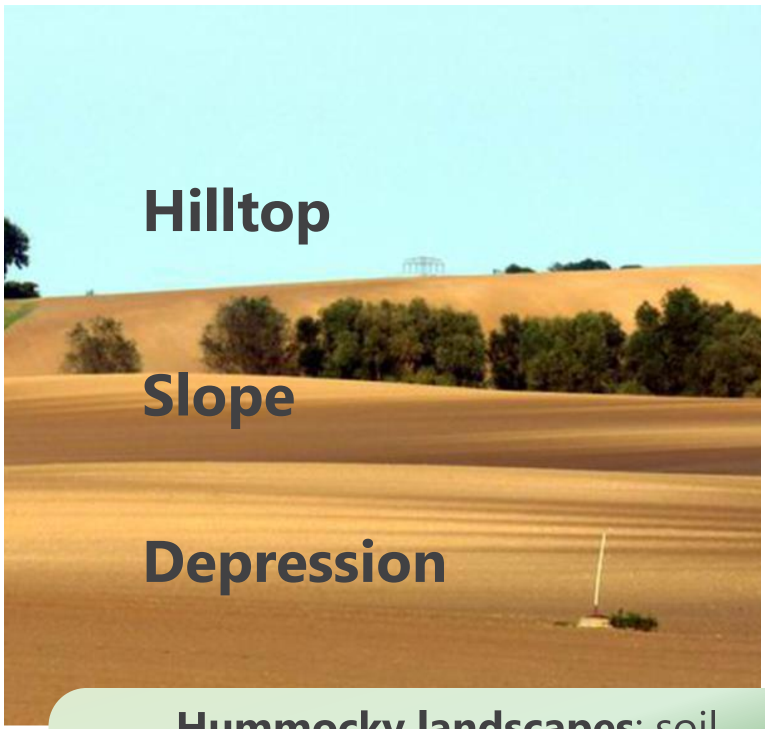
Soil hydraulic models evaluated on water fluxes and states

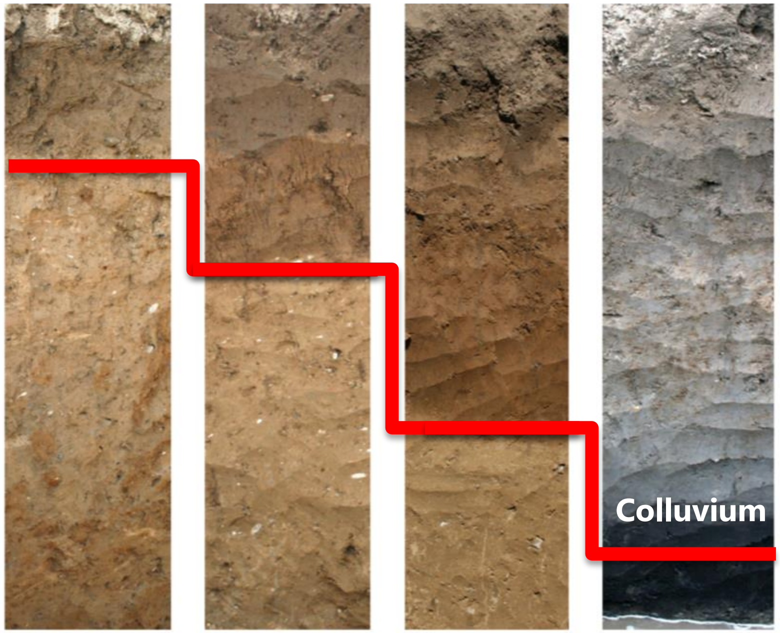
High precision weighing lysimeters (TERENO-SoilCan):

- Model evaluation for both, the crop and the soil water /element fluxes

Soil Background

Catena: landscape position





Profile 1: Gr_K
Position: Hilltop
Soil type: Calcaric Regosol

Profile 2: Dd_5
Position: Slope
Soil type: Nudiargic Luvisol

Profile 3: Dd_1
Position: Slope
Soil type: Calcic Luvisol

Profile 4: Hd_S
Position: Depression
Soil type: Gleyic Colluvic Regosol

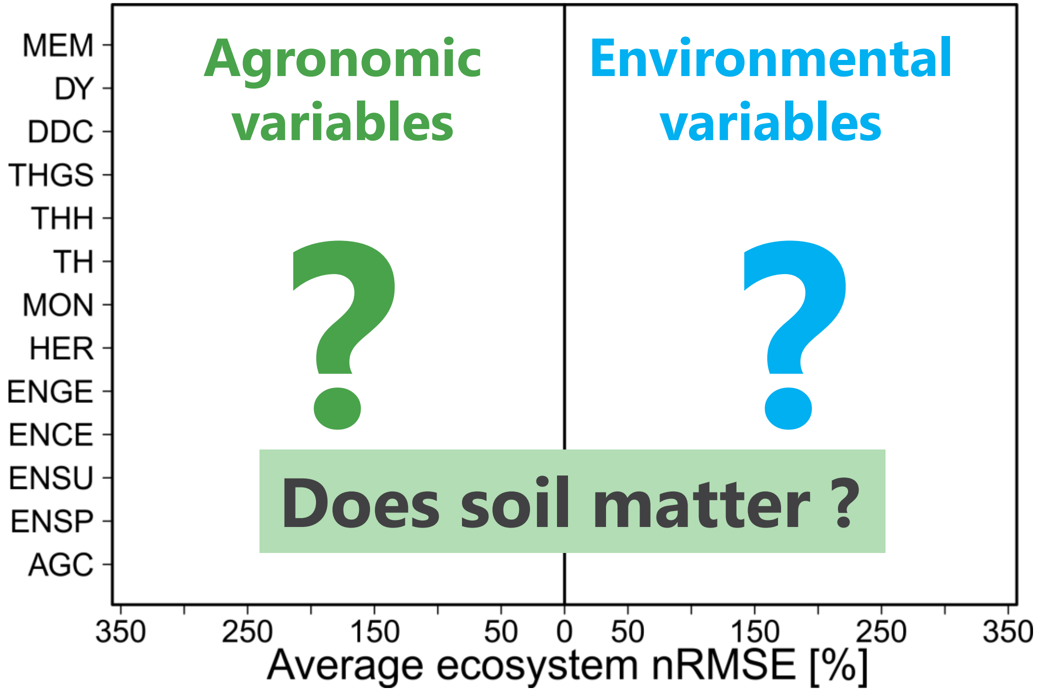
Hummocky landscapes: soil heterogeneity can result from long-term soil management in combination with erosion effects

Profile “truncation” by erosion

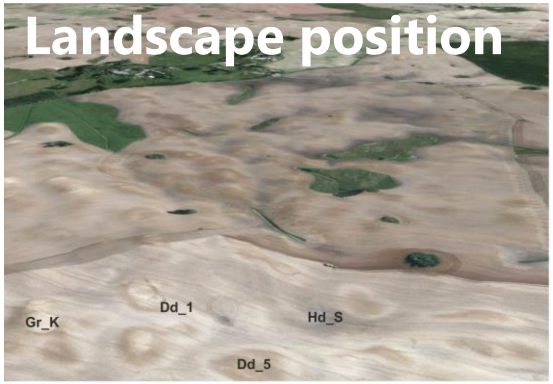
Motivation

Testing agro-ecosystem models to simulation agronomic and environmental variables based on lysimeter observations at a hummocky post-glacial soil landscape:

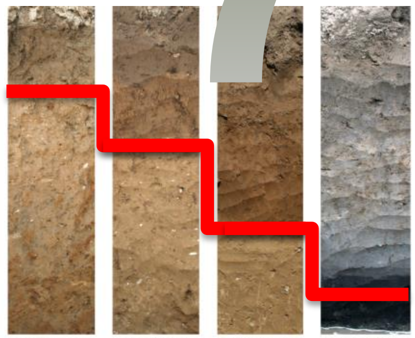
- forward simulations results after minimal calibration on phenology of crop growth and soil water flux related ecosystem variables
- Evaluate how well models reproduce agronomic and environmental variables of of erosion affected soil profiles



Methods



Soil transfer



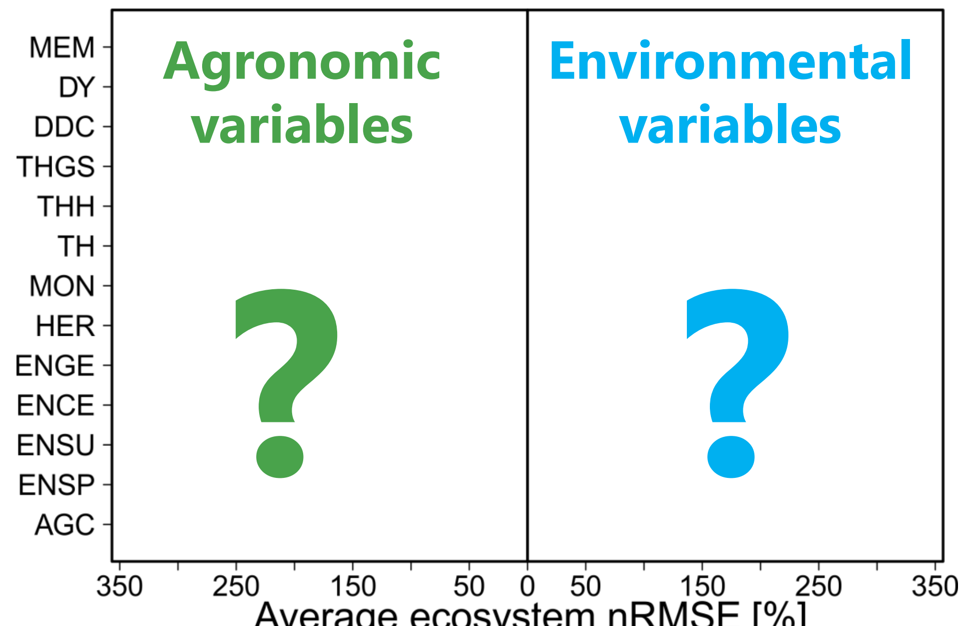
Background: transfer of soils from its landscape position to a central test site

Models:

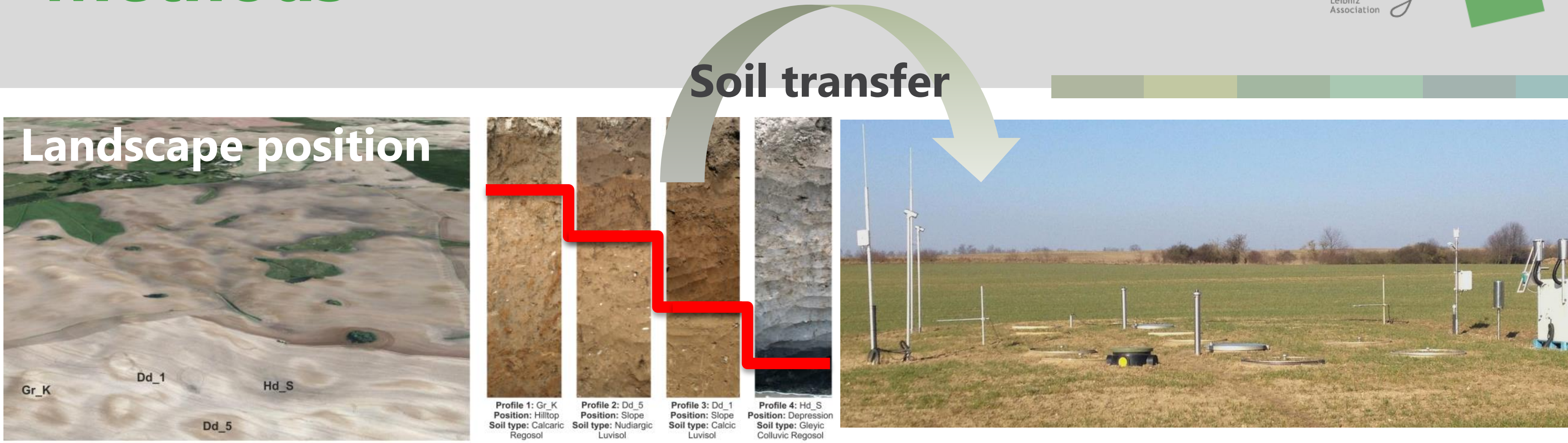
AgroC, DailyDayCent, Daisy,

Expert- N SPASS, Expert-N SUCROS, Expert-N CERES, Expert-N GECROS, HERMES, MONICA, THESEUS,

Hydrus-1D, HydroGeoSphere



Methods



Calibration info:

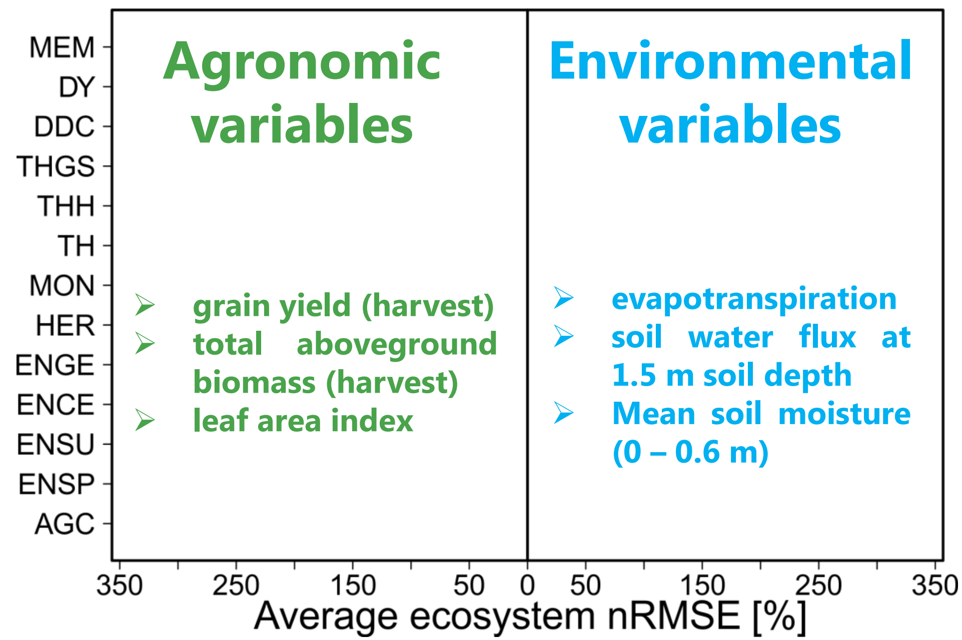
- phenological stages (BBCH)
- Weather data; reference ET_0
- Range of regional grain yield
- Root depth, site management

Evaluation strategy:

- Agronomic and environmental variables

$$nRMSE = 100 * \frac{RMSE}{sd(Obs)}$$

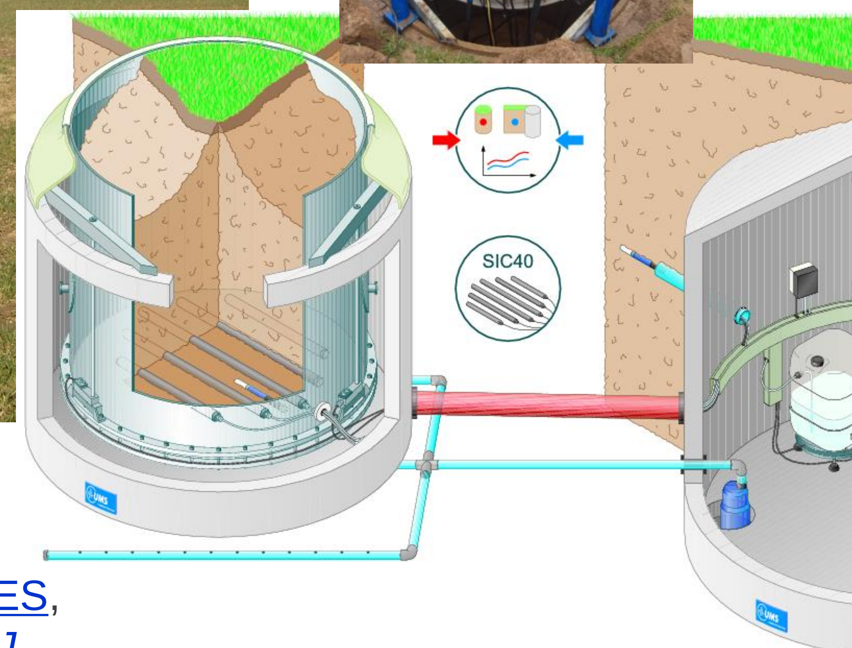
- Multi Model Mean (MMM)



Lysimeters

Lysimeter station Dedelow, part of the Northeast German Lowland Observatory of TERENO

More details see Herbrich et al. 2017 SOIL TILL RES, *Pütz et al. 2016 EES*, and *Heinrich et al. 2018 VZJ*



Provided by METER Group, Munich, Germany

Observation data

Lysimeter, weather and soil moisture data from 01.08.2014 to 31-10.2018

Crop rotation: winter wheat, winter wheat, winter rye, and oat

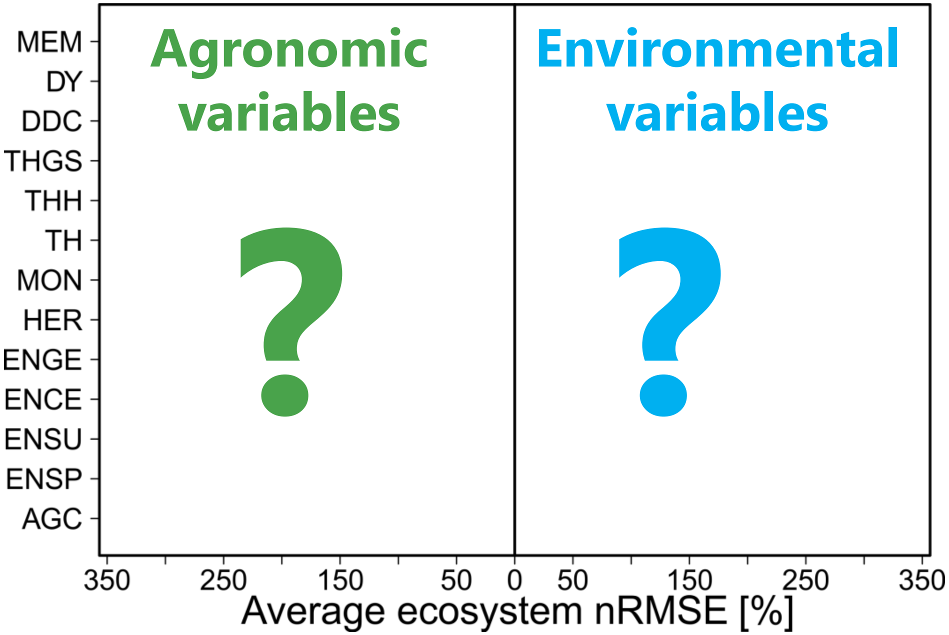
Lysimeter data processing using the AWAT filter and implemented snap-routine (*Peters et al. 2017, JOH*)

Agronomic variables:

- phenological stages (BBCH)
- grain yield (Y) and total aboveground biomass at harvest (AgBio)
- leaf area index (LAI)

Environmental variables:

- Evapotranspiration (ET)
- soil water flux at 1.5m soil depth (NetQ)
- Mean soil moisture (0 to 0.6 m; SWC)



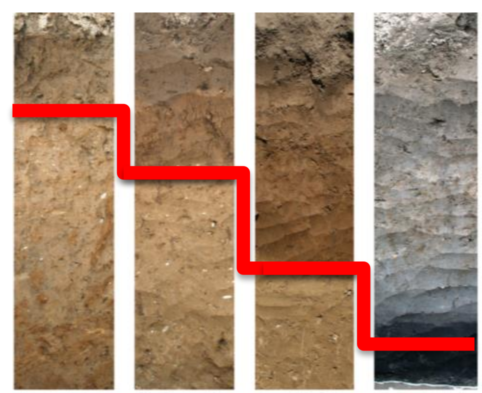
Lysimeter data: water balance & yield

	Precipitation [mm]				Evapotranspiration [mm]				Soil water flux [mm]				Storage [mm]			
	Dd2-3	Dd1-5	Dd1-1	Dd2-6	Dd2-3	Dd1-5	Dd1-1	Dd2-6	Dd2-3	Dd1-5	Dd1-1	Dd2-6	Dd2-3	Dd1-5	Dd1-1	Dd2-6
2014-2015	541	553	520	556	497	552	598	663	81	90	29	-24	-37	-89	-108	-83
2015-2016	565	536	523	548	503	545	577	571	47	-23	-54	-22	16	14	0	-1
2016-2017	818	851	854	822	562	708	675	722	173	26	63	-9	83	117	116	108
2017-2018	454	443	434	429	370	434	490	461	163	163	90	136	-78	-155	-147	-168
Mean	595	596	582	589	483	560	585	604	116	64	32	20	-4	-28	-35	-36

Increase ET & yield **Decrease NetQ**

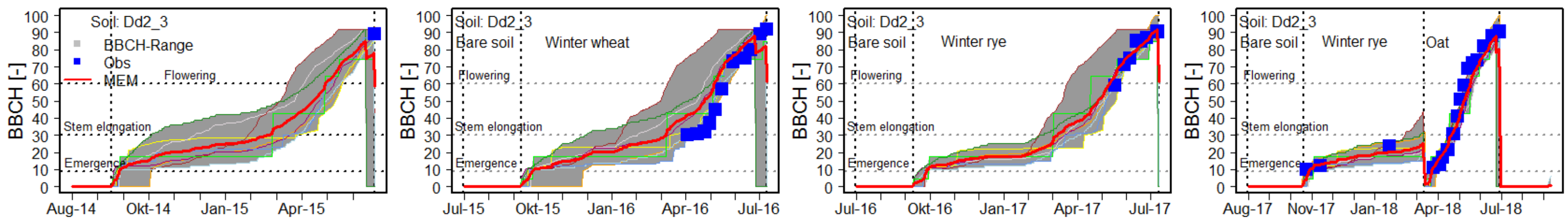
Soil profile effect

Year	Crop	Grain yield			
		Dd2-3	Dd1-5	Dd1-1	Dd2-6
		[t/ha]	[t/ha]	[t/ha]	[t/ha]
2014-2015	Winter wheat	6.7	9.0	9.4	12.1
2015-2016	Winter wheat	5.8	7.8	8.2	7.9
2016-2017	Winter rye	5.2	8.8	9.0	10.8
2018	Oat	2.0	2.9	3.9	3.3



Calibration

BBCH Crop development stages for model calibration



	Calcaric Regosol (Gr_K)	Nudiargic Luvisol (Dd_5)	Calcic Luvisol (Dd_1)	Colluvic Regosol (Hd_S)
Model	nRSME (%)			
AgroC	16.6	17.3	17.2	16.6
DailyDayCent	noData	noData	noData	noData
Daisy	19.3	19.1	18.8	19.4
Expert-N CERES	33.3	33.2	34.5	33.2
Expert-N GECROS	82.7	82.3	82.8	82.6
Expert-N SPASS	21.0	21.5	20.8	20.8
Expert-N SUCROS	47.0	46.8	45.8	47.0
HERMES	19.8	19.7	19.4	18.9
HydroGeoSphere	noData	noData	noData	noData
Hydrus-1D	noData	noData	noData	noData
MONICA	32.2	31.3	31.0	32.5
Theseus	37.2	37.1	36.1	37.9

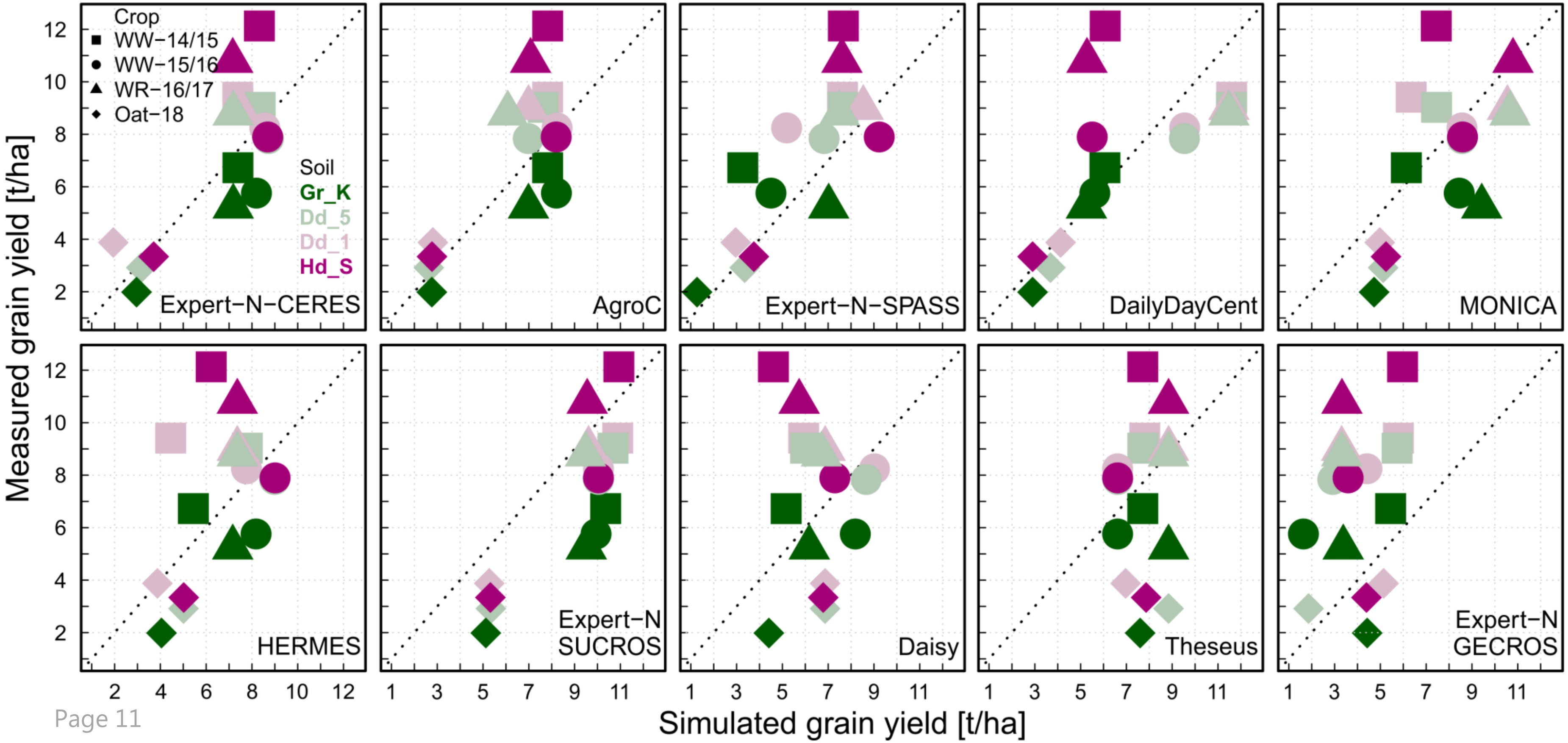
Model performance:

- ✓ range nRMSE 17% and 83%
- ✓ Models achieved relatively low nRMSE (~30%)
- ✓ Model are able to describe the observed phenology stages well

Model evaluation: Grain yield

Simulations:

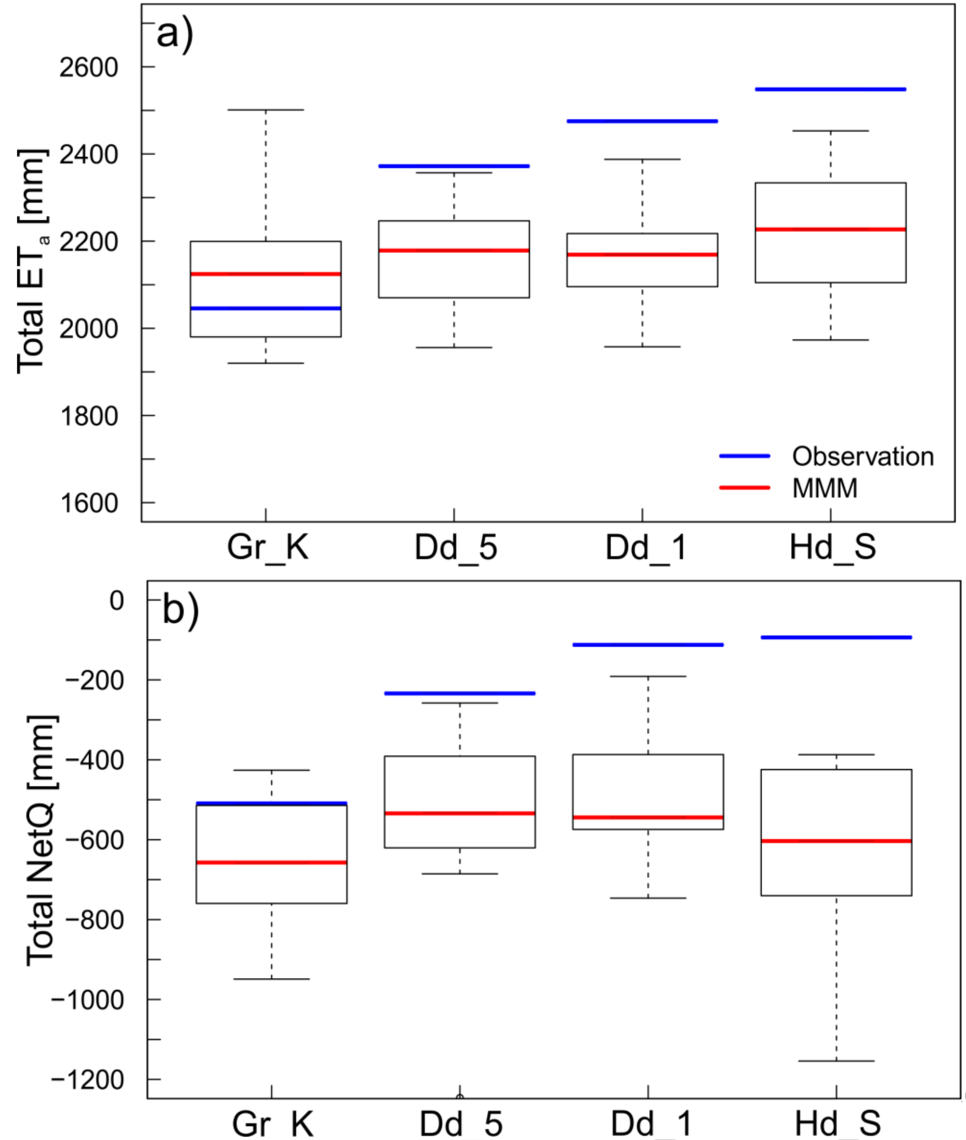
- Hardly any soil profile effects visible in both Richards and capacity models



Evaluation: example ET and NetQ

Observation:
Clear dependency of water flux rates on the erosion-affected differences in the soil profiles can be related to the soil water storage capacities, which differ due to erosion/ or deposition processes

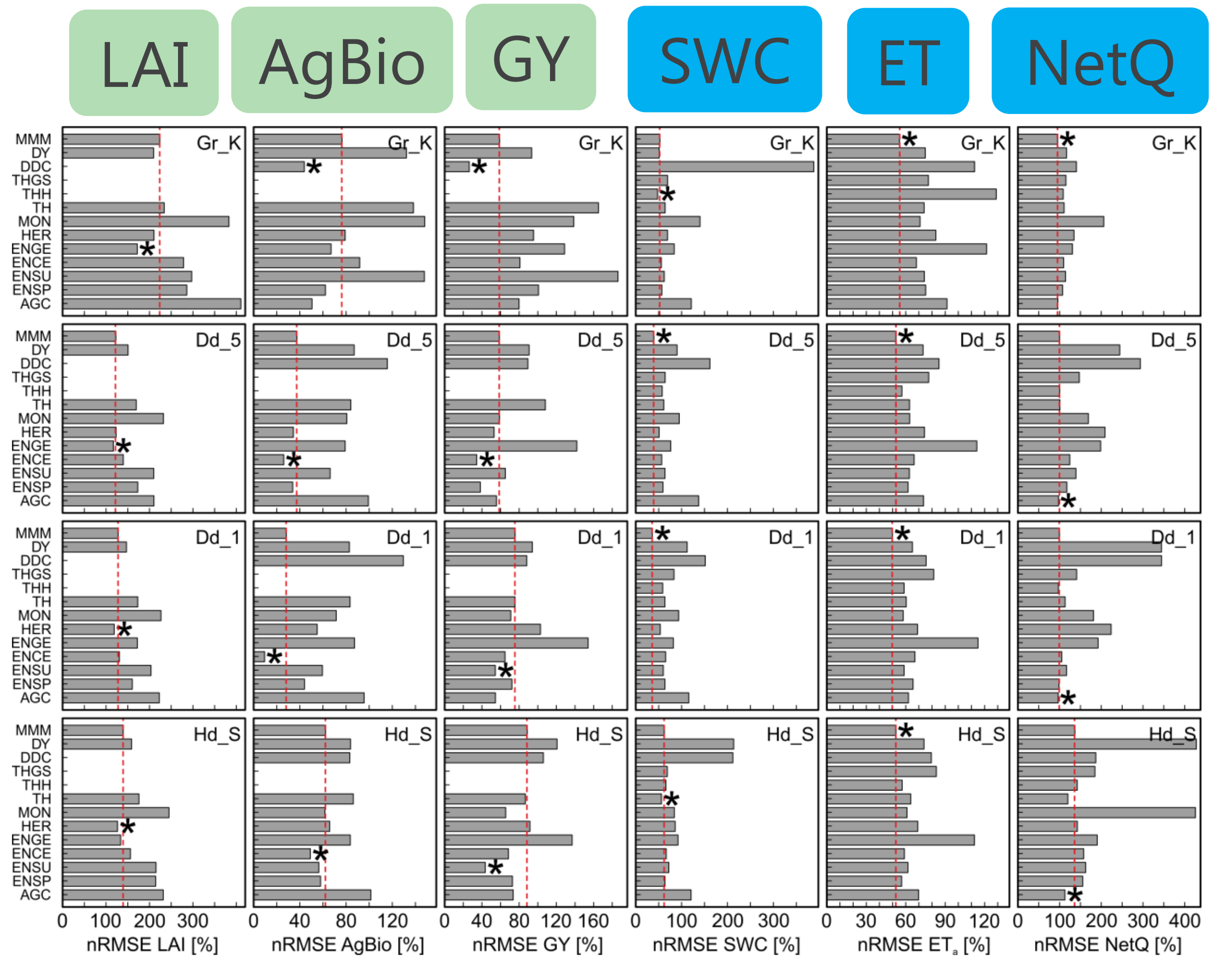
Simulations:
No effect of soil profile truncation on simulated evapotranspiration and net drainage



Evaluation single categories

Simulations results:

- nRMSE for in-season are larger than for end-season variables
- Large variability between crop model outputs reflects differences in model structure and model parameterization
- MMM best agreement
- Non-Richards based models achieved higher nRMSE values for SWC and NetQ



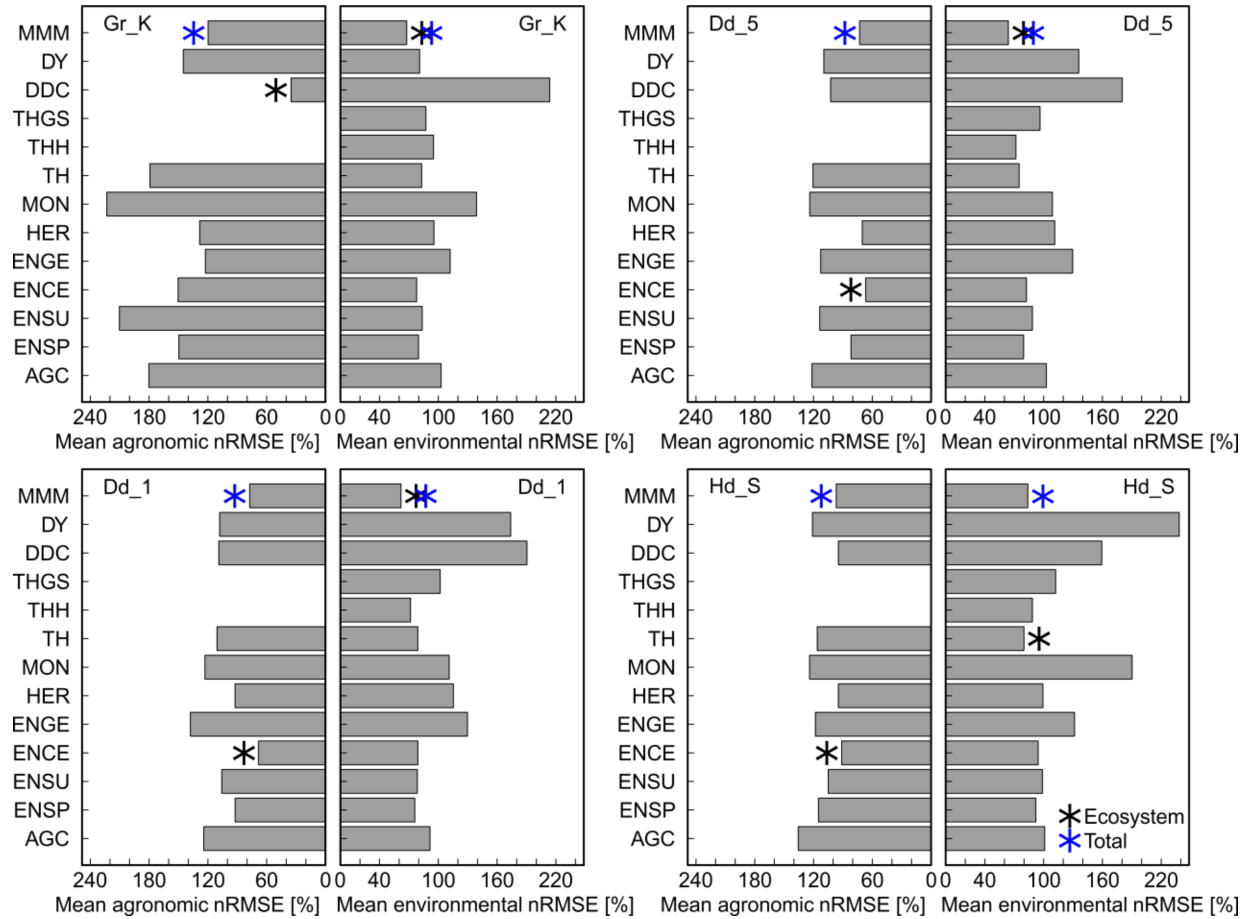
might emphasize the importance, how soil hydraulic properties are represented in crop models

Red Line = Multi Model Mean
* Best nRMSE value

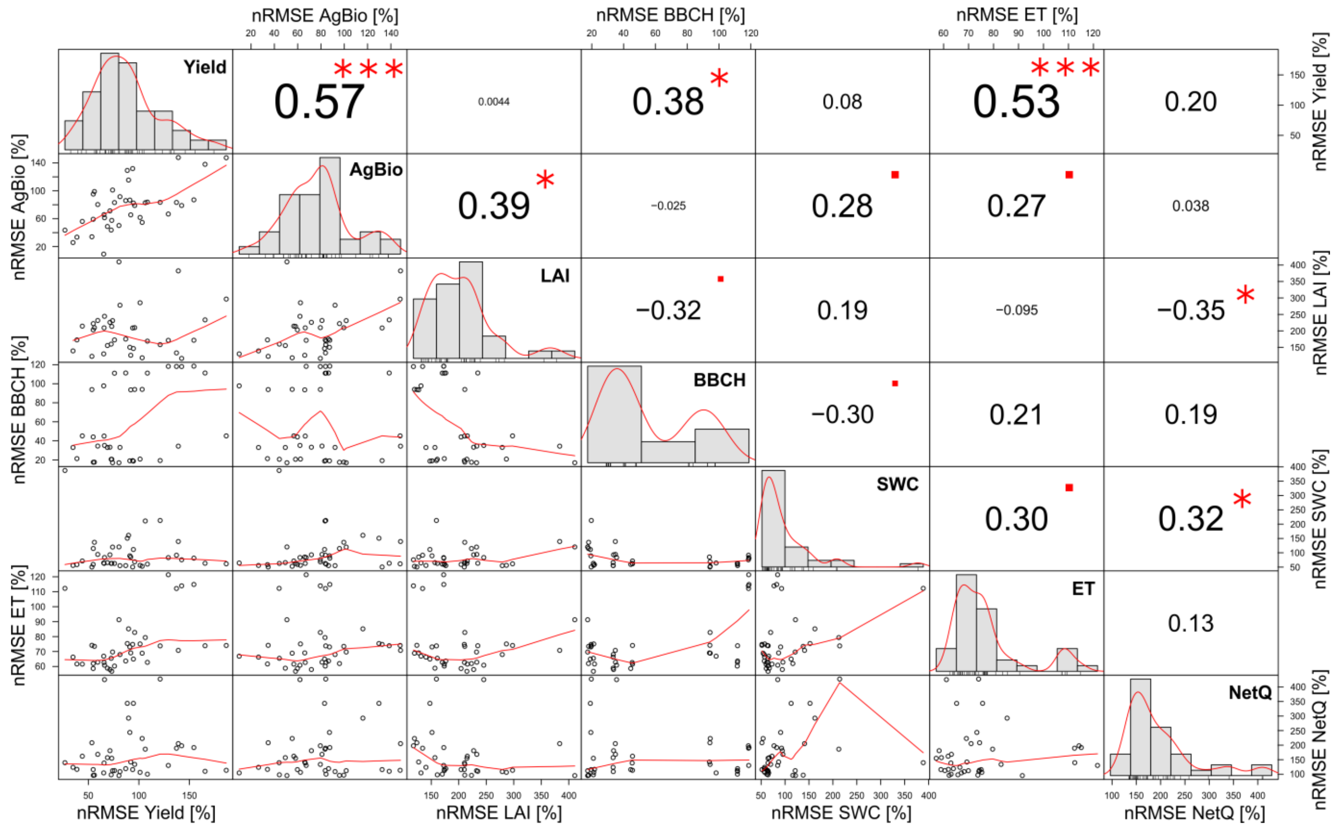
Evaluation: agro-ecosystem

<u>Equal weighted mean nRMSE for all variables:</u>

- Large variability between models to predict agronomic and environmental-ecosystem related fluxes and states
- nRMSE of MMM were lower than any individual crop model
- The better predictions for ET and NetQ by the MMM as compared to a particular crop model was already reported for other agronomic variables



Relationship between nRMSE of agronomic and environmental fluxes and states



Errors in simulating the most important end-of-season values (GY, AgBio) are related to errors in simulating in-season growth processes (LAI, ET)

Including in-season observations in the calibration helps simulating and describing more realistically in-season processes, which finally lead to end-of season values of AgBio and GY

Conclusions

- The predictive capability of the models was highly diverse for simulating both crop development and environmental fluxes
- Soil does matter in agro-ecosystem models and lysimeters provide such soil related data for testing modelling of soil-vegetation-atmosphere processes
- Erosion/deposition induced changes in depth functions of soil properties are relevant in understanding biomass production, water fluxes and soil states in hummocky arable landscapes
- Differences between erosion-affected soils in crop yield, water fluxes, and states could not satisfactorily be described by individual models and MMM when calibrated for crop phenological stages only

.....soon more: VZJ article (in review)

Vadose Zone Journal

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Crop growth and soil water fluxes at erosion-affected arable sites: Using weighing lysimeter data for model inter-comparison

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Outlook

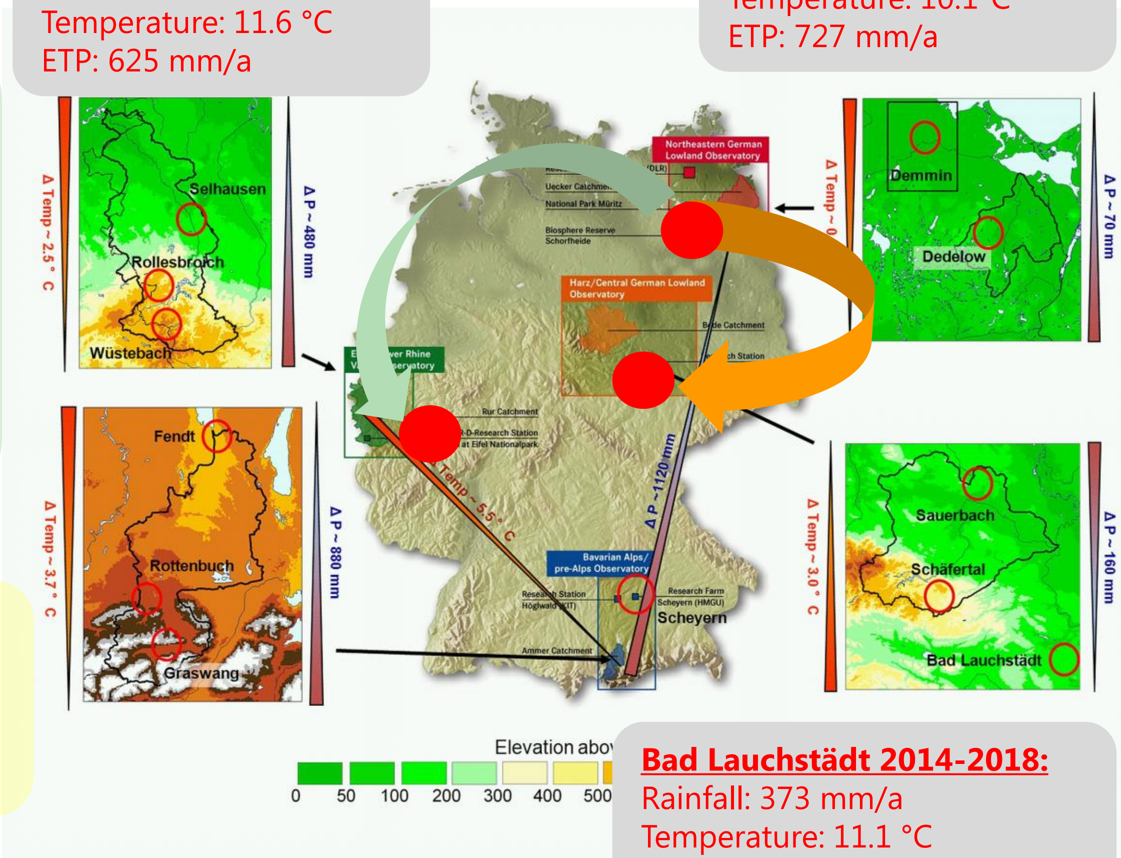
Evaluation of crop / soil models under changed climatic boundary conditions (TERENO-SoilCan)

- "Space-for-time" approach (i.e., transfer of lysimeters)

More info's on SoilCan and first results see *Pützt et al. 2016 EES* and *Groh et al. 2020 HESS*

Selhausen 2014-2018:
Rainfall: 649 mm/a
Temperature: 11.6 °C
ETP: 625 mm/a

Dedelow 2014-2018:
Rainfall: 591 mm/a
Temperature: 10.1°C
ETP: 727 mm/a



Bad Lauchstädt 2014-2018:
Rainfall: 373 mm/a
Temperature: 11.1 °C
ETP: 755 mm/a

Thank you for your attention!

Acknowledgements:

We acknowledge the support of TERENO and SOILCan, which were funded by the Helmholtz Association (HGF) and the Federal Ministry of Education and Research (BMBF).

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