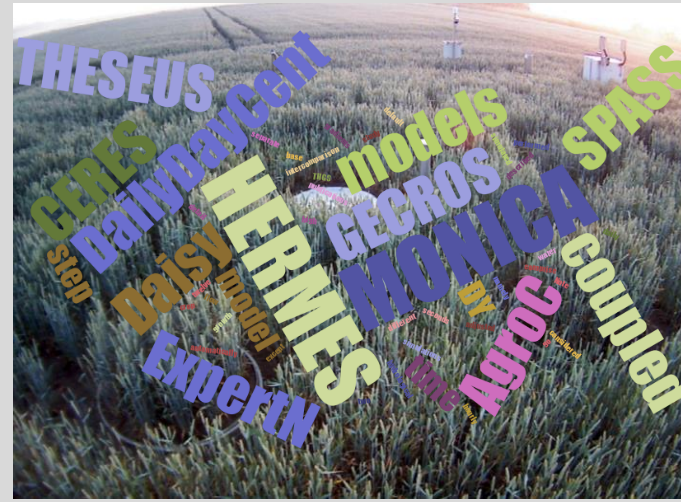
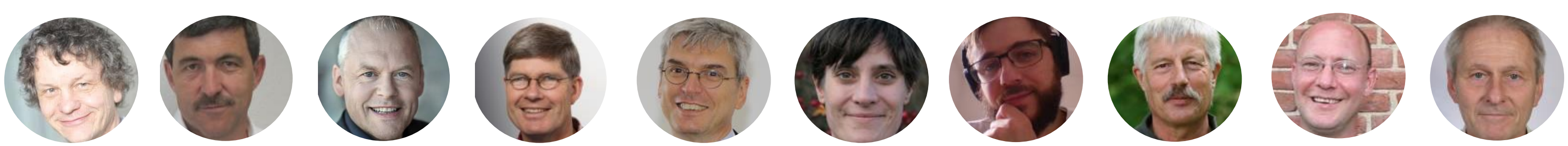
Leibniz Centre for Agricultural Landscape Research (ZALF)

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




J. Groh, E. Diamantopoulos, X. Duan, F. Ewert, M. Herbst, M. Holbak, B. Kamali, K.-C. Kersebaum, M. Kuhnert, G. Lischeid, C. Nendel



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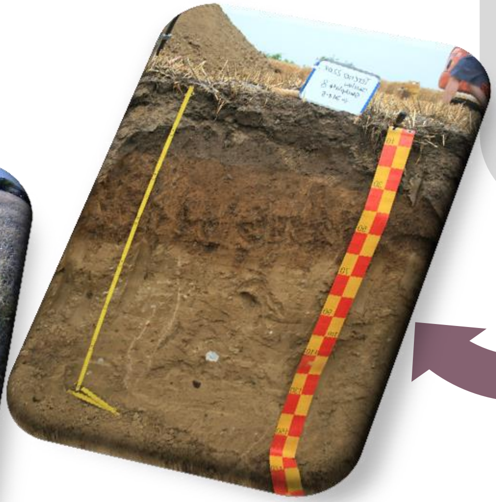
# Modeling Background

**Model inter-comparison studies**

Crop growth models mostly evaluated on yield

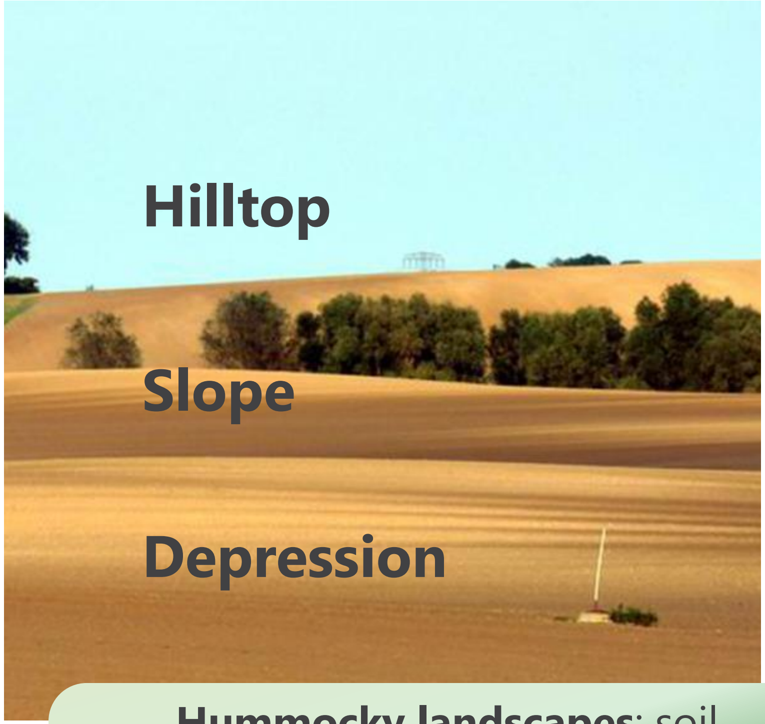
Soil hydraulic models evaluated on water fluxes and states

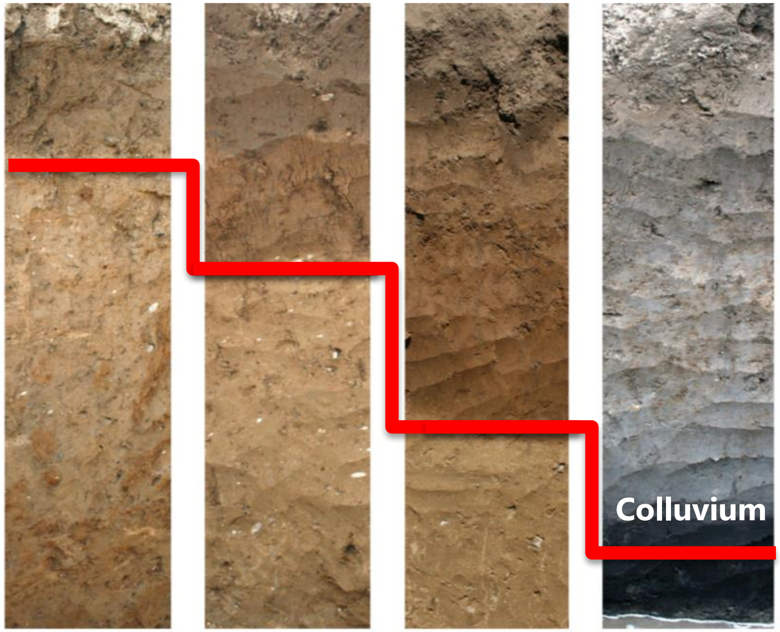


High precision weighing lysimeters (TERENO-SoilCan):
- Model evaluation for both, the crop and the soil water /element fluxes

# 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

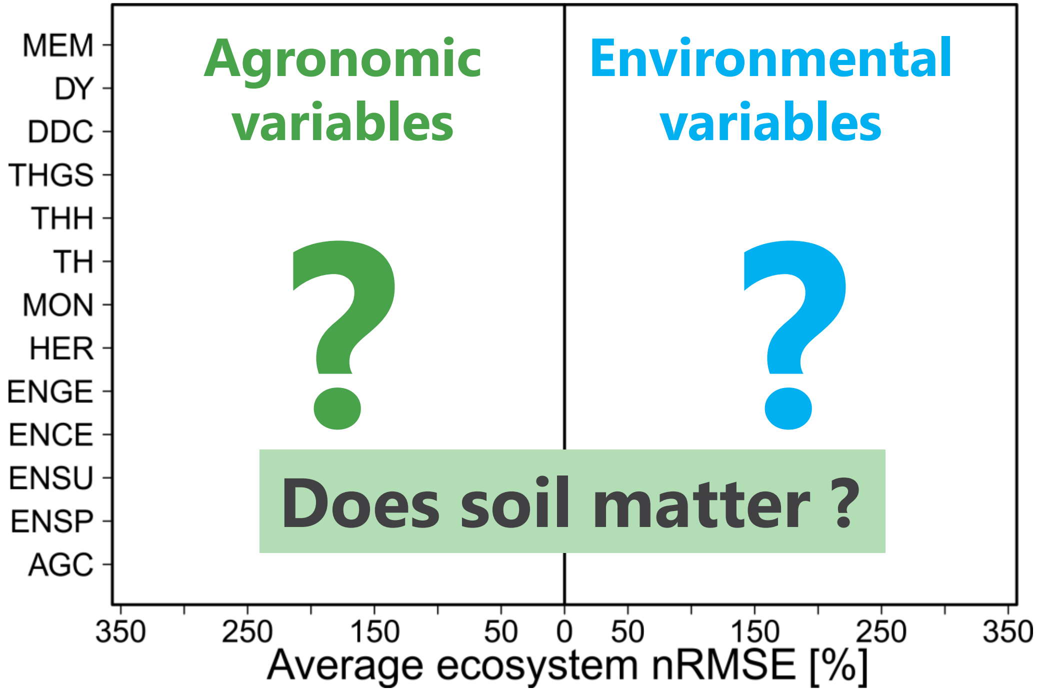
**Hummocky landscapes**: soil heterogeneity can result from long-term soil management in combination with erosion effects

Profile "truncation" by erosion

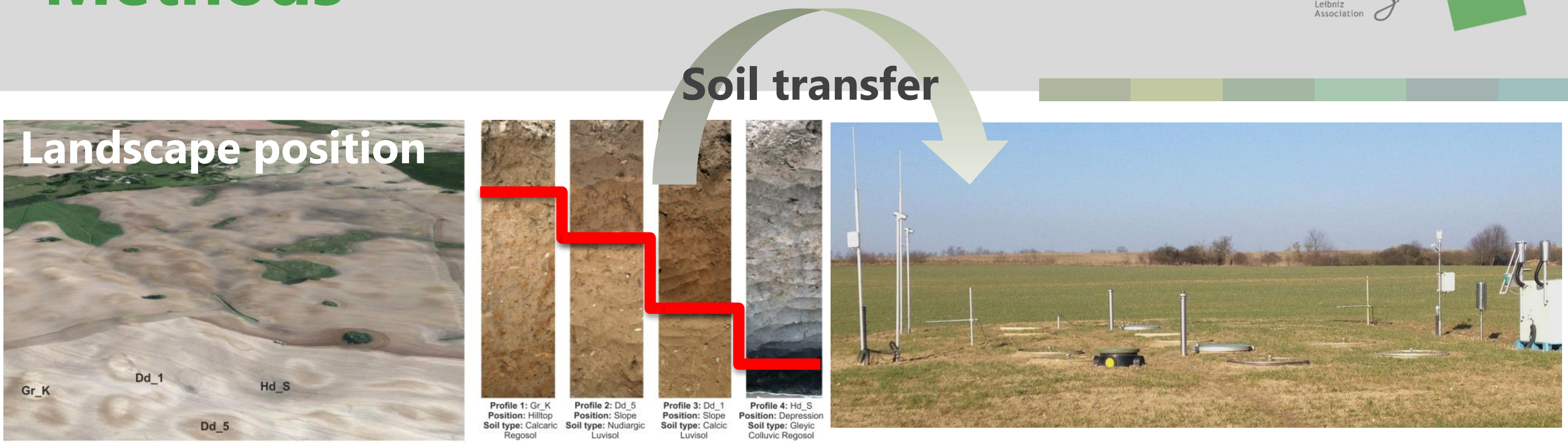
# Motivation

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 erosion affected soil profiles



# Methods



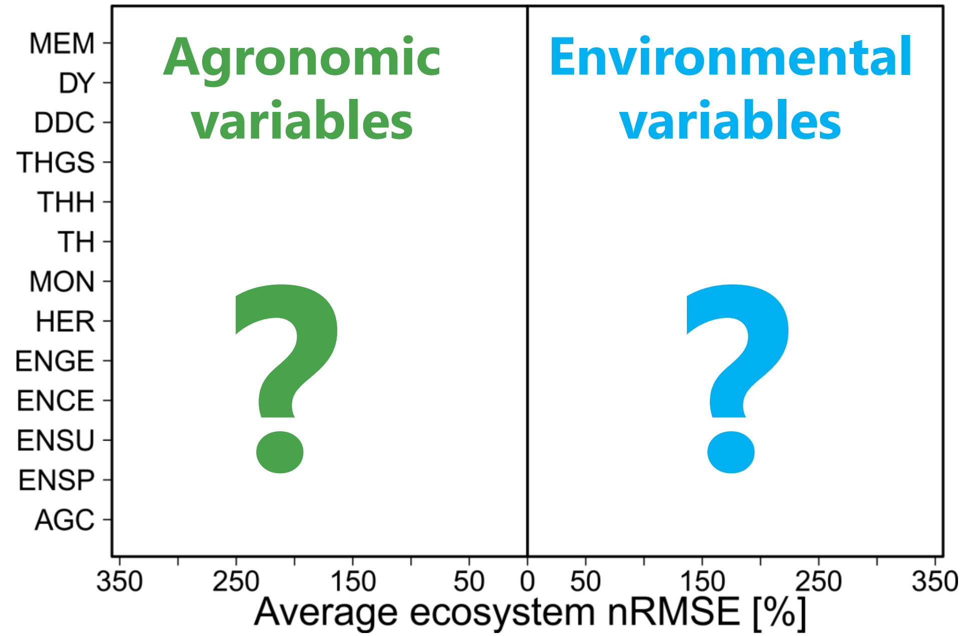

**<u>Background:</u>** transfer of soils from its landscape position to a central test site

**<u>Models:</u>**

AgroC, DailyDayCent, Daisy,

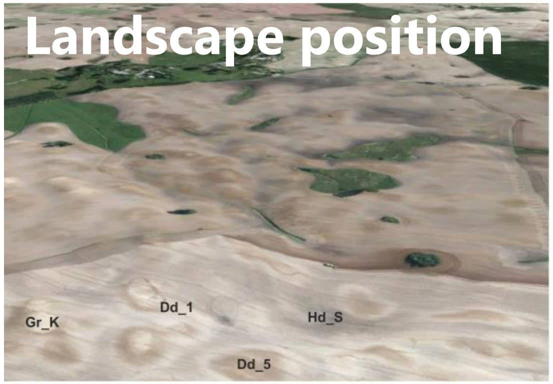
Expert- N SPASS, Expert-N SUCROS, Expert-N CERES, Expert-N GECROS, HERMES, MONICA, THESEUS,

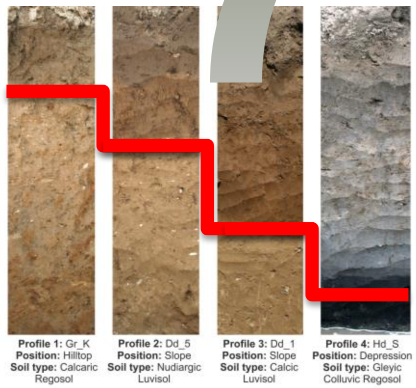
Hydrus-1D, HydroGeoSphere



# Methods

Soil transfer




**Calibration info:**

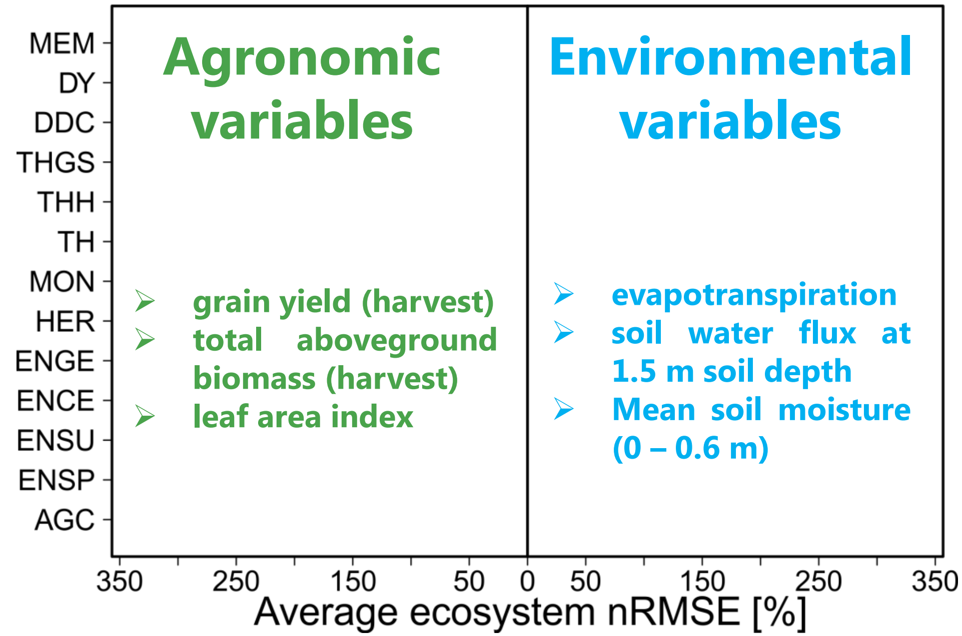
- phenological stages (BBCH)
- Weather data; reference $ET_0$
- Range of regional grain yield
- Root depth, site management

**Evaluation strategy:**

- Agronomic and environmental variables

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

- Multi Model Mean (MMM)




**Agronomic variables**

- grain yield (harvest)
- total aboveground biomass (harvest)
- leaf area index

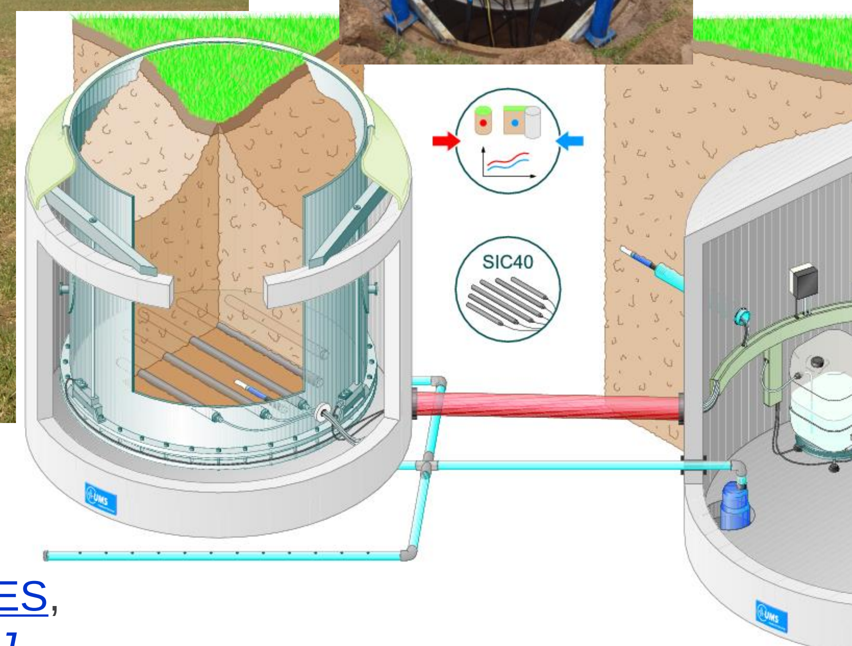
**Environmental variables**

- evapotranspiration
- soil water flux at 1.5 m soil depth
- Mean soil moisture (0 – 0.6 m)

# 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

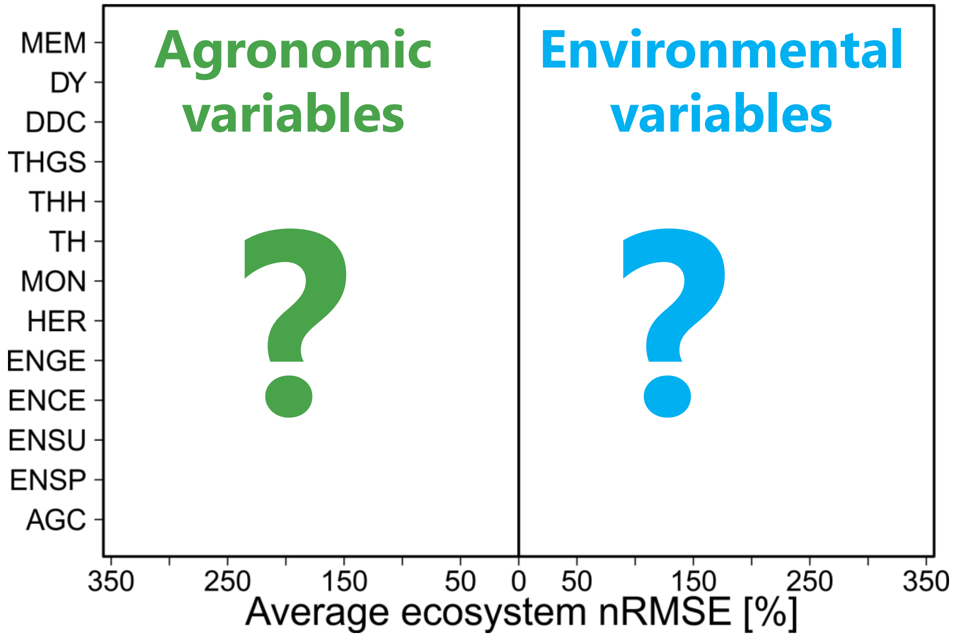
Lysimeter data processing using the AWAT filter and implemented snap-routine (*Peters et al. 2017, JOH*)

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 |

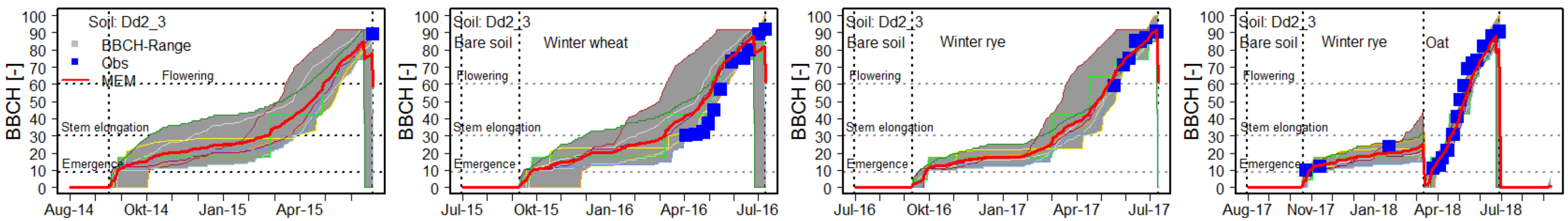
**Increase ET & yield** **Decrease NetQ**

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




**Model performance:**

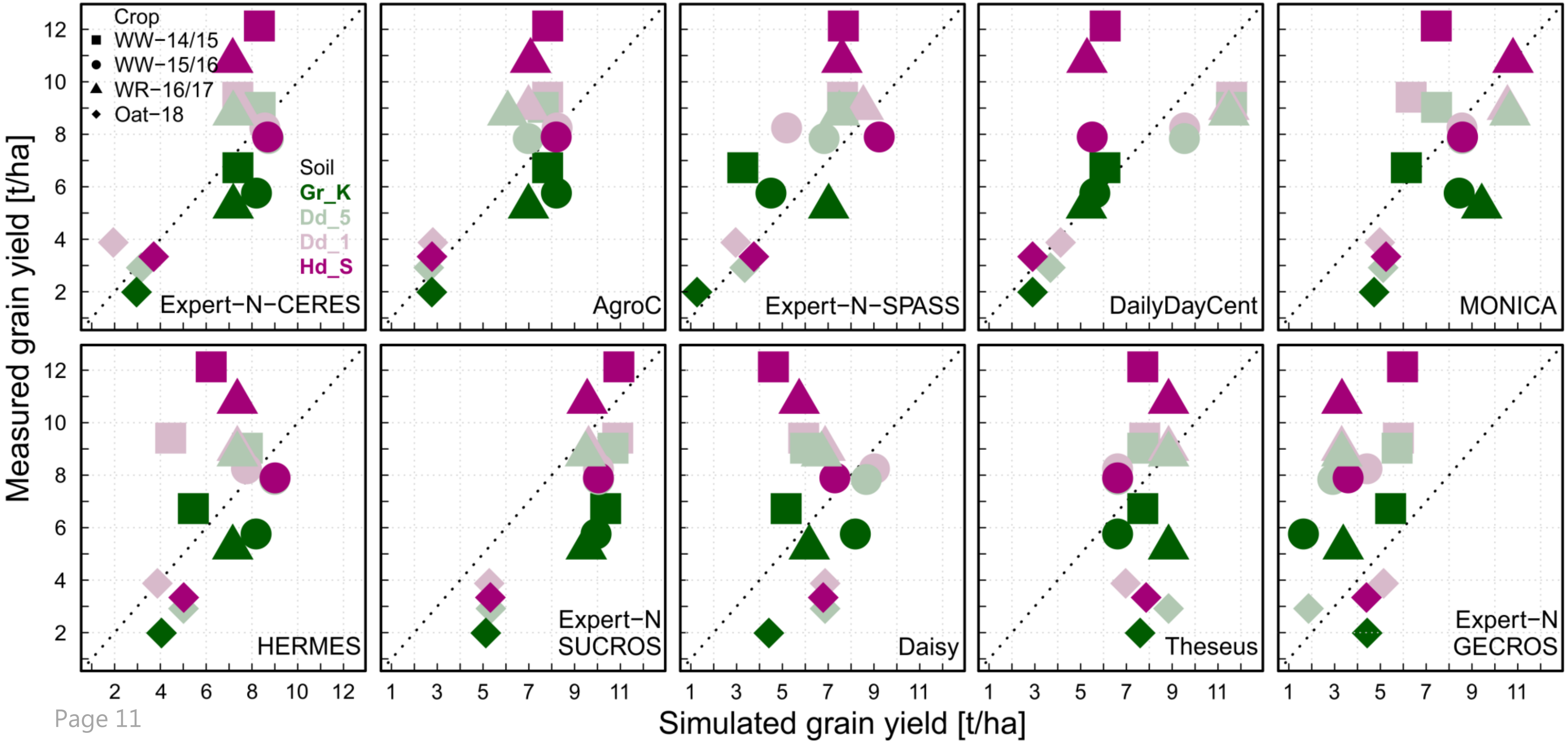
- ✓ range nRMSE 17% and 83%
- ✓ Models achieved relatively low nRMSE (~30%)
- ✓ Model are able to describe the observed phenology stages well

| | 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 evaluation: Grain yield

**Simulations:**

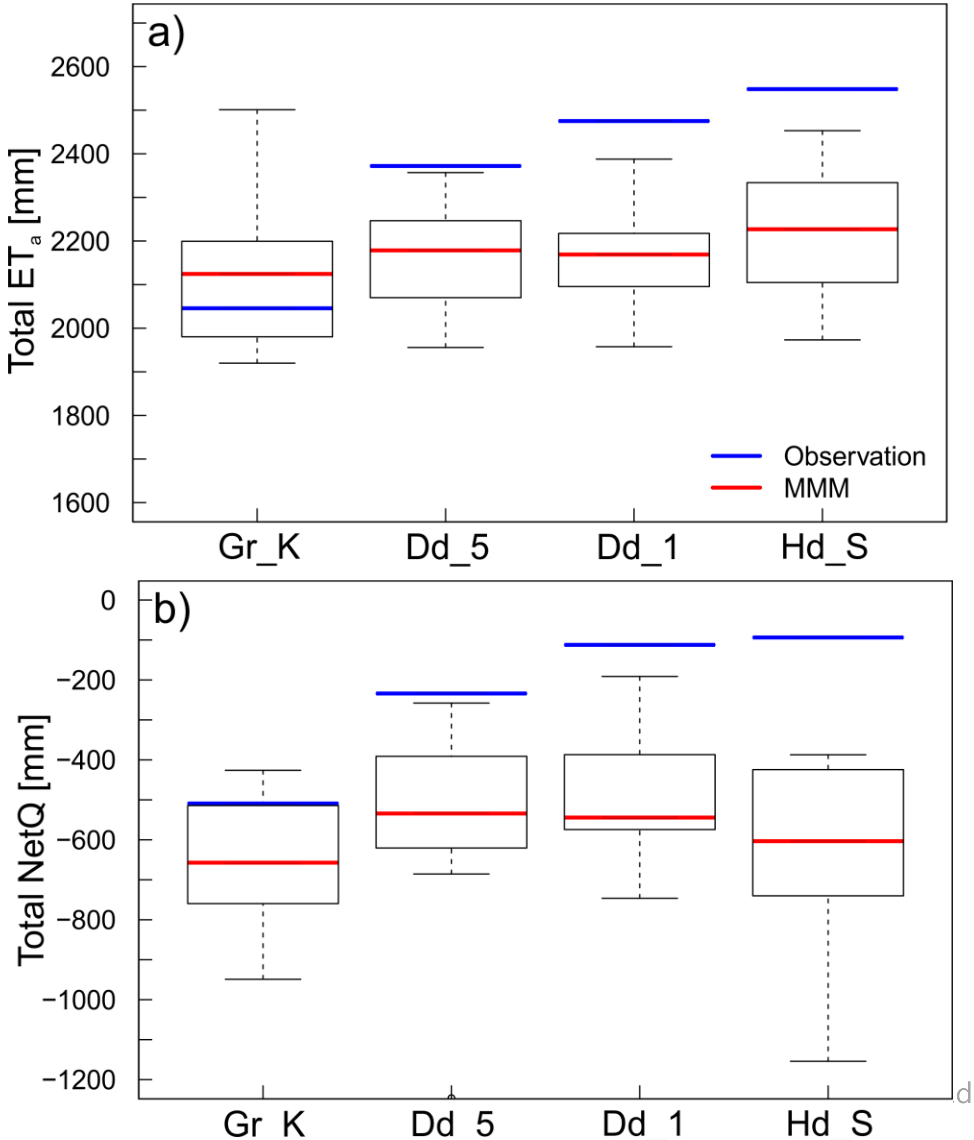
- Hardly any soil profile effects visible in both Richards and capacity models



# 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

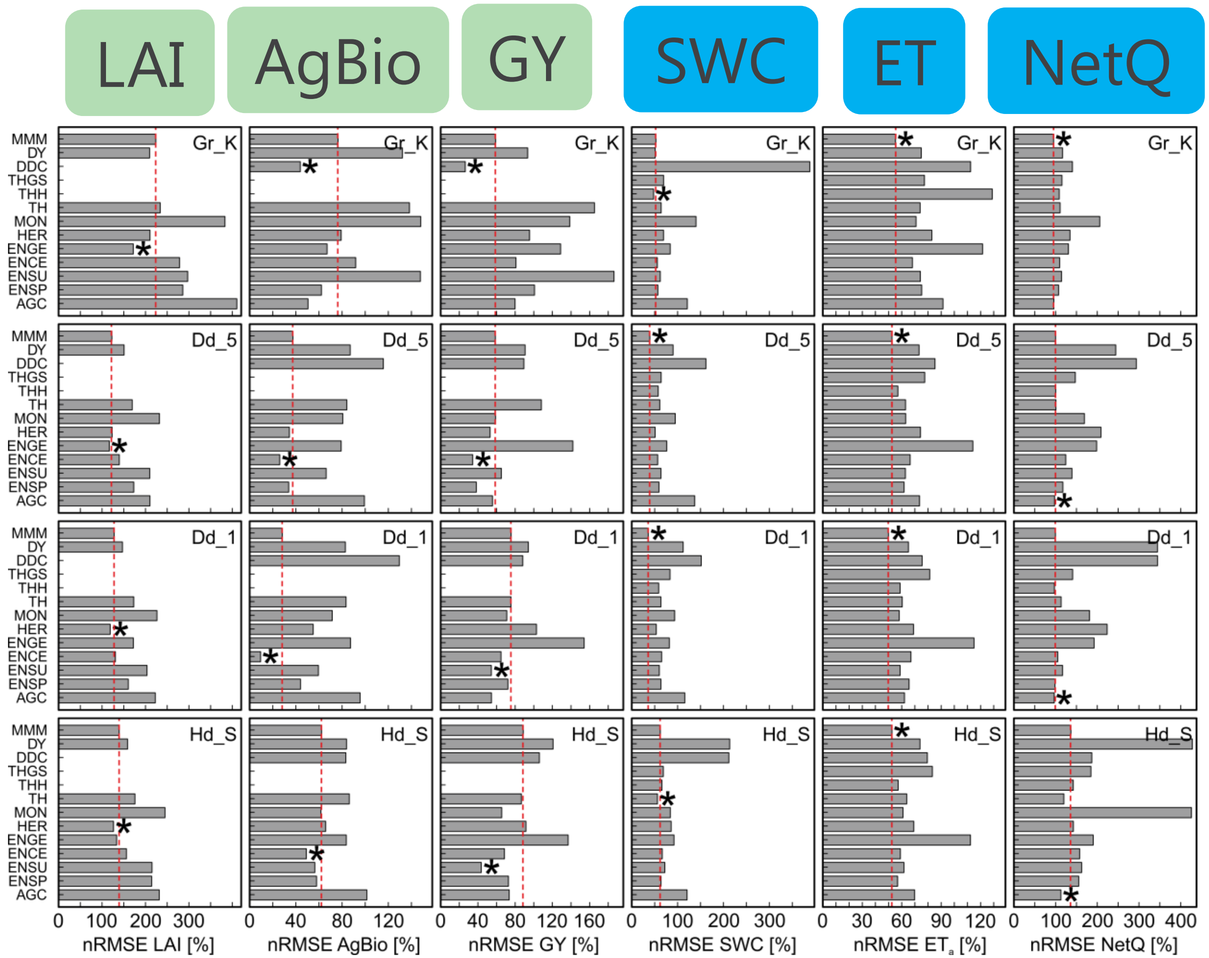
**Simulations:**
No effect of soil profile truncation on simulated evapotranspiration and net drainage



# Evaluation single categories

**<u>Simulations results:</u>**

- 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



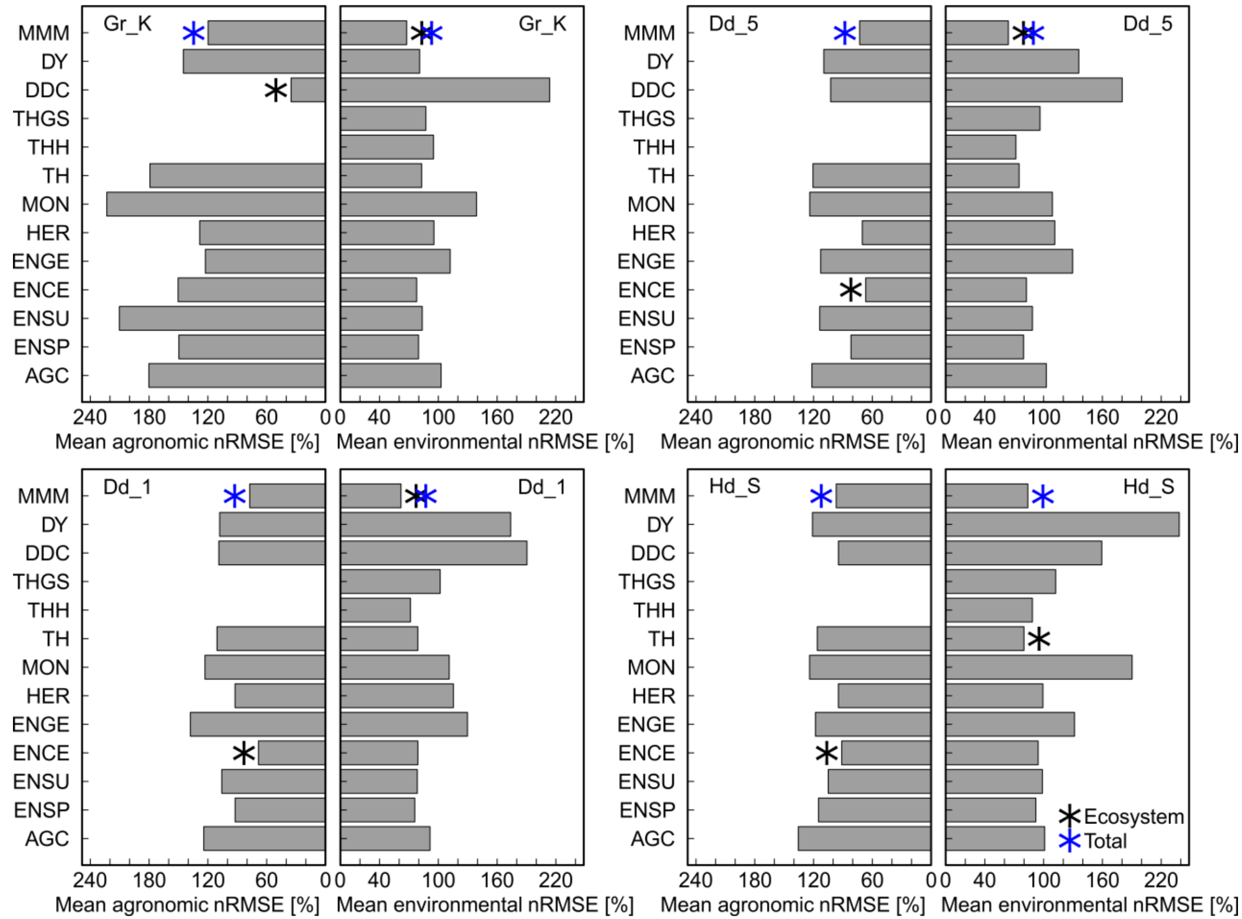

**might emphasize the importance, how soil hydraulic properties are represented in crop models**

Red Line = Multi Model Mean
* Best nRMSE value

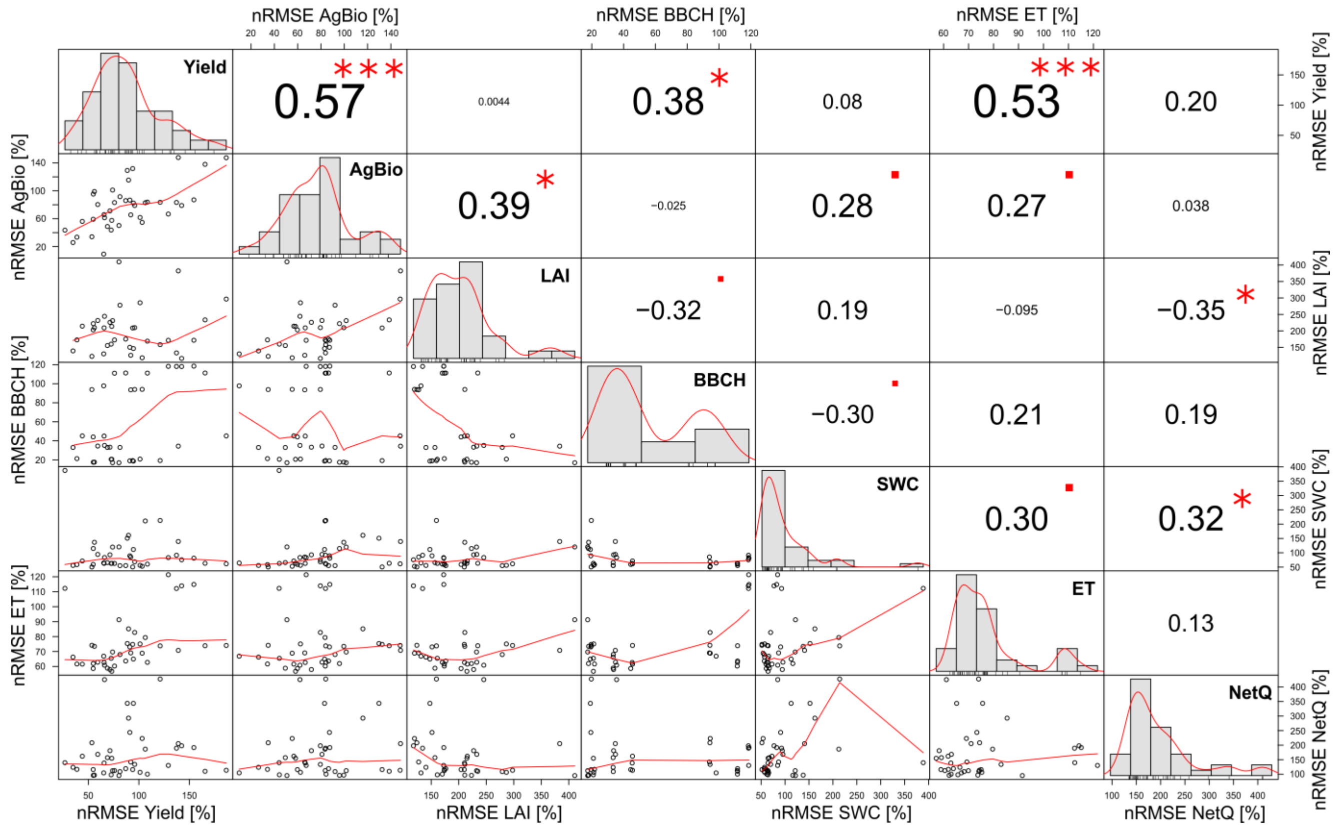
# Evaluation: agro-ecosystem

**Equal weighted mean nRMSE for all variables:**

- 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

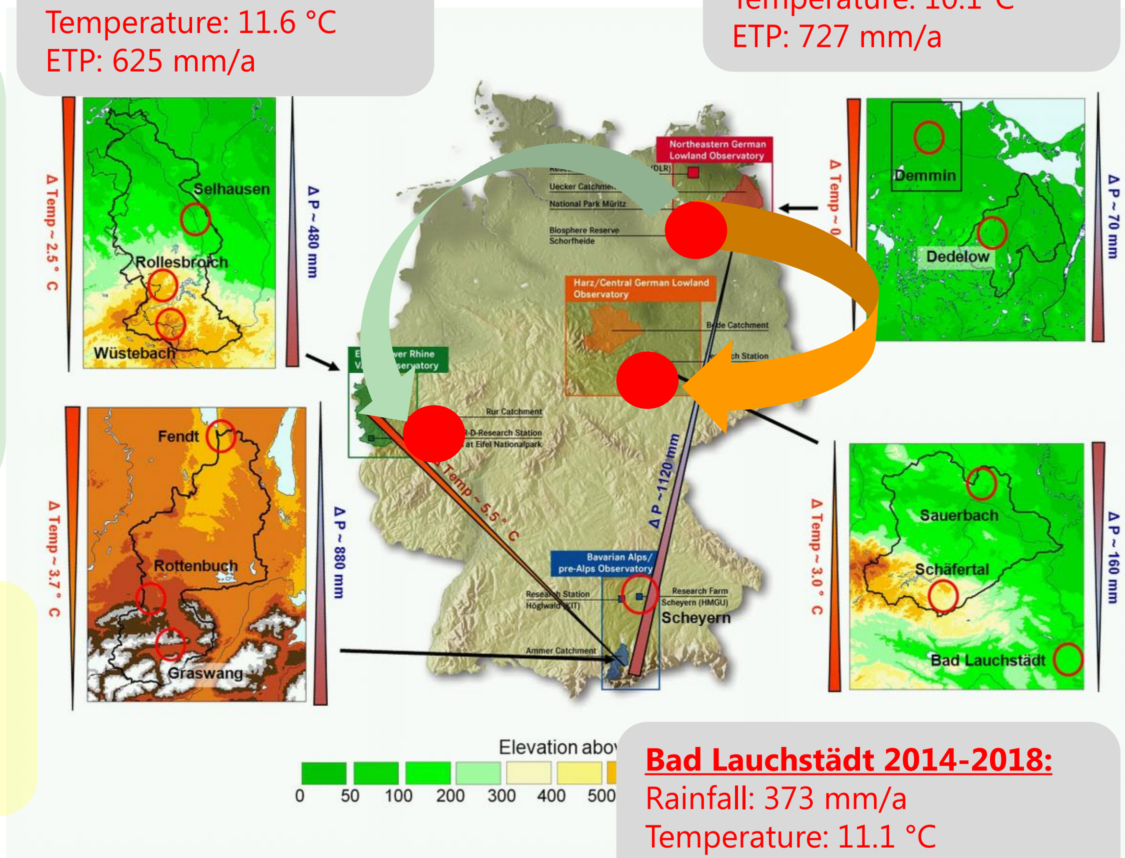
Evaluation of crop / soil models under changed climatic boundary conditions (TERENO-SoilCan)

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

More info's on SoilCan and first results see *Pütz 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:

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