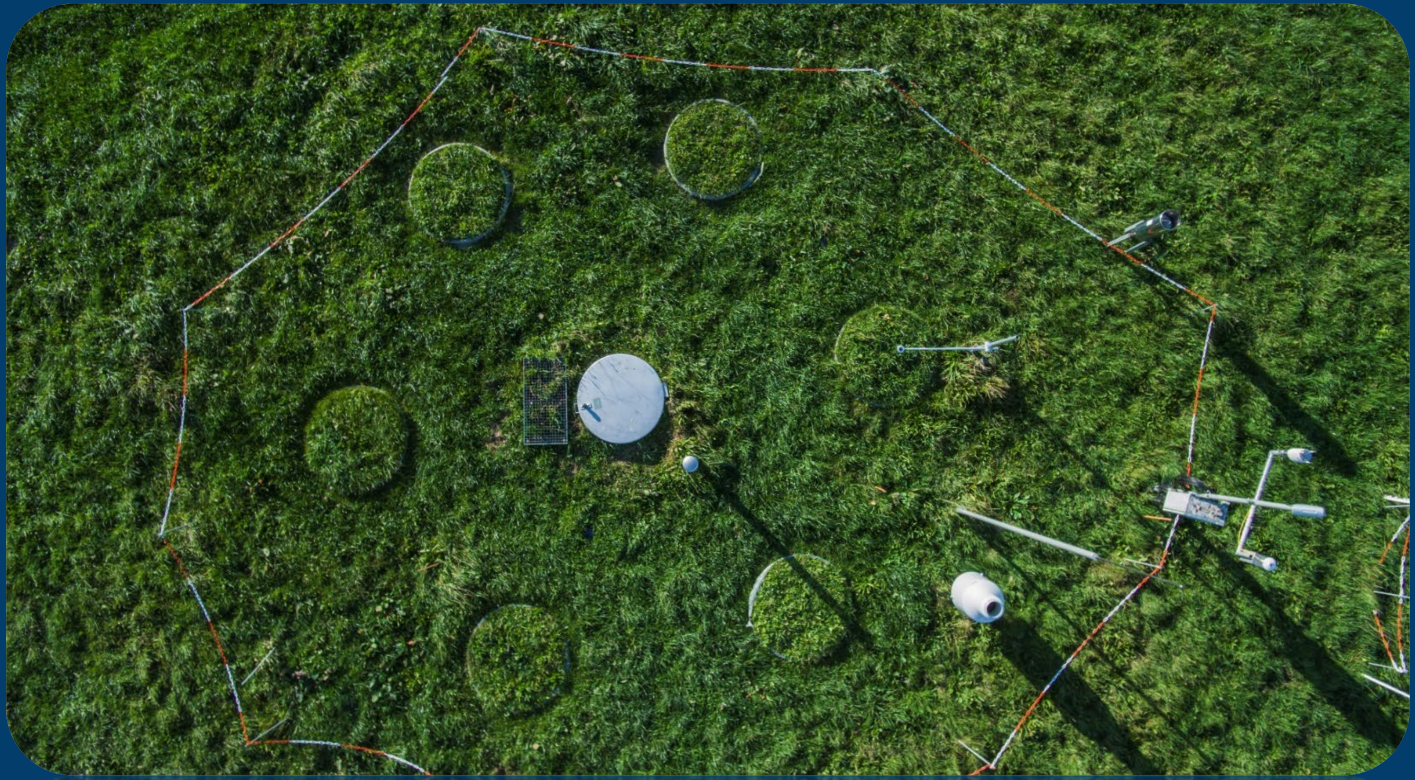
Do we know our soil´s water cycle well?



J. Groh[1,2,3], H.H. Gerke[3], J. Cuxart[4], D. Martínez Villagrasa[4], V. Filipovic[5,6], V. Krevh[6], R. Gründling[7], H. Rupp[7], H.J. Vogel[7], J. Vanderborght[2], H. Vereecken[2], T. Pütz[2]

[1]University of Bonn (INRES), [2]Forschungszentrum Jülich (Agrosphere - IBG-3), [3]Leibniz Centre for Agricultural Landscape Research (ZALF), [4]University of Balearic Islands, [5]Federation University Gippsland, [6]University of Zagreb, [7]Helmholtz-Centre for Environmental Research (UFZ)

TERENO OZCAR International Conference 25-28 Sept 2023, Bonn

Universitat de les Illes Balears

Federation University

zalf Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V.

University of Zagreb

BONN

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

JÜLICH Forschungszentrum

- It is really difficult to track directly changes of water fluxes in soil-plant ecosystems

- ..but we can use different methods to study water dynamics across the land surface and in the soil

Today I invite you to a walk through the soil water cycle

TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

Soil water cycle and it´s components

$$P + I - ET - Dr = \Delta S$$

Precipitation (P)

Irrigation (I)

Evapotranspiration (ET)

Change in soil water storage (ΔS)

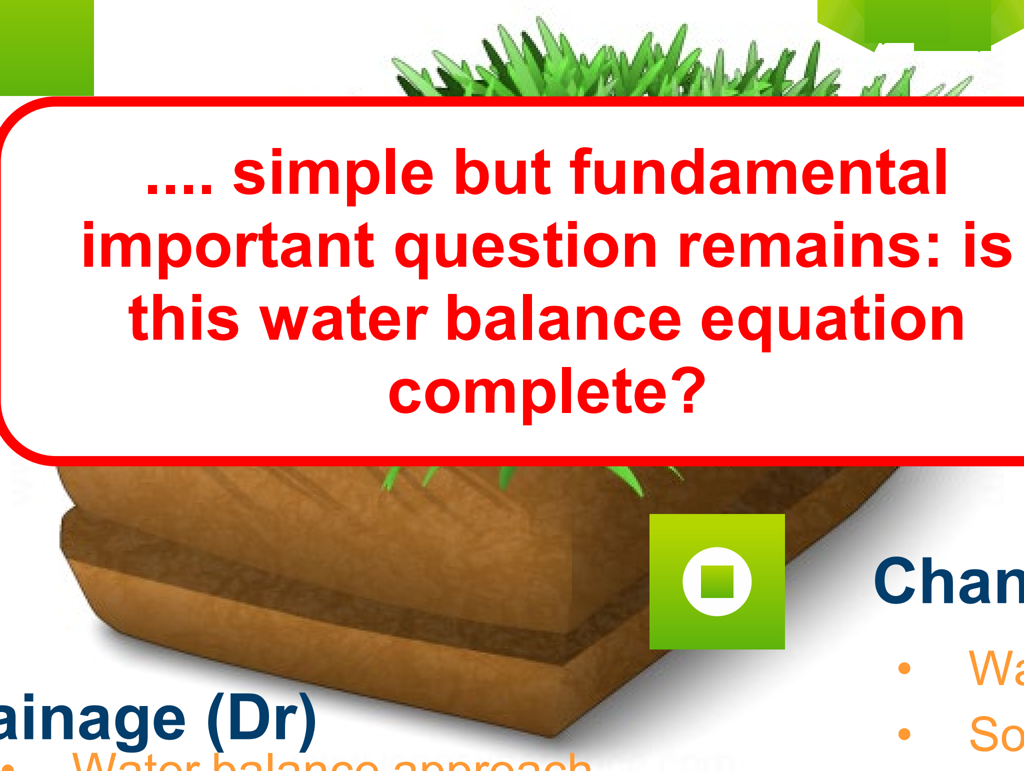
Drainage (Dr)

How can we measure the single soil water balance components?

$$P + I - ET - Dr = \Delta S$$

Precipitation (P)
Irrigation (I)

- Catching gauge types
  - Tipping bucket
  - Weighing gauge
- Non-catching gauge typ
  - Acoustic sensor
  - Laser based sens
- Weighable lysimeter



.... simple but fundamental important question remains: is this water balance equation complete?

Evapotranspiration (ET)

- Sap-flow
- Evaporation pan
- Eddy-covariance
- Scintillometry
- Bown-ratio energy balance
- Weighable lysimeter

Change in soil water storage (ΔS)

- Water balance approach
- Soil moisture sensor
- Gravimeter
- Weighable lysimeter

Drainage (Dr)

- Water balance approach
- Groundwater level measurements
- Weighable lysimeter

Missing components of the soil water balance?

$$CR + NRW + P + I - ET - Dr = \Delta S$$

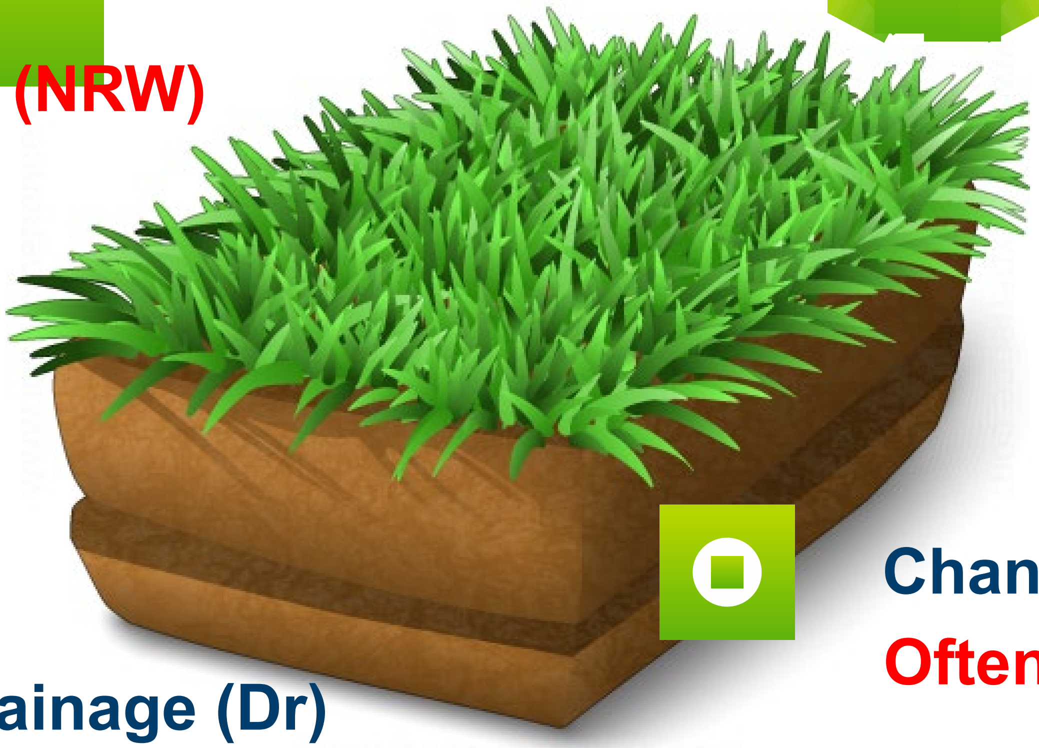
Precipitation (P)

Irrigation (I)

Non-rainfall water (NRW)

Evapotranspiration (ET)

Neglecting nighttime ET



Change in soil water storage (ΔS)

Often assumed to be ~0

Drainage (Dr)

Capillary rise (CR)

What can you use to measure this?

$$CR + NRW + P + I - ET \; - Dr = \Delta S$$

Precipitation (P)
Irrigation (I)
Non-rainfall water (NRW)

- ~~Catching gauge types~~
  - ~~Tipping bucket~~
  - ~~Weighing gauge~~
- ~~Non-catching gauge typ~~
  - ~~Acoustic sensor~~
  - ~~Laser based sensor~~
- Weighable lysimeter

.... weighable lysimeter

Evapotranspiration (ET)
Neglecting nighttime ET

- ~~Sap-flow~~
- ~~Evaporation pan~~
- Eddy-covariance?
- Scintillometry?
- ~~Bown-ratio energy balance~~
- Weighable lysimeter

Drainage (Dr)
Capillary rise (CR)

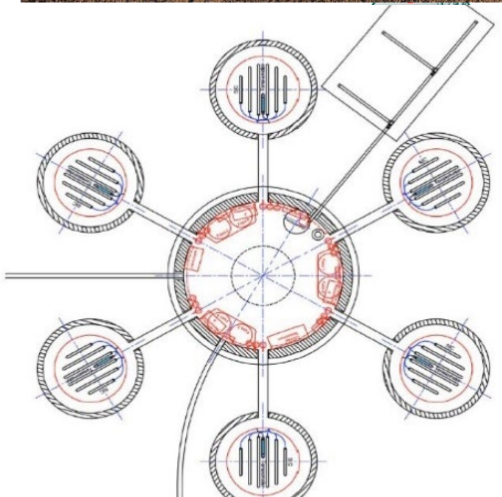
- ~~Water balance approach~~
- ~~Groundwater level measurements~~
- Weighable lysimeter

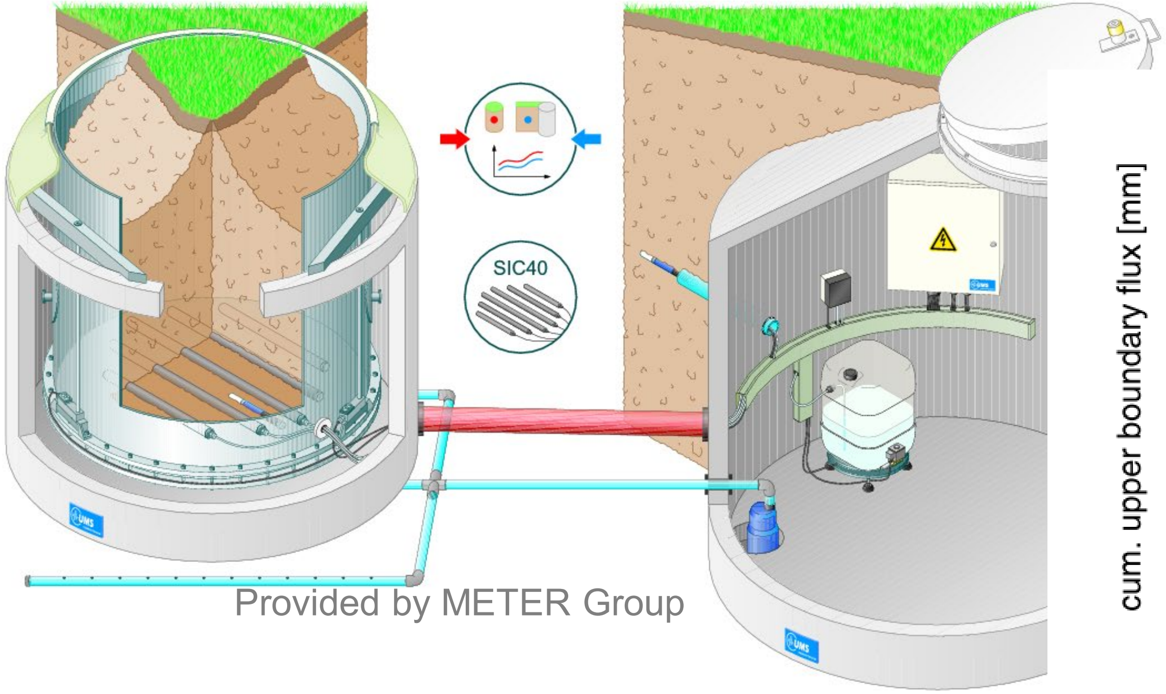
Change in soil water storage (ΔS)
Often assumed to be ~0

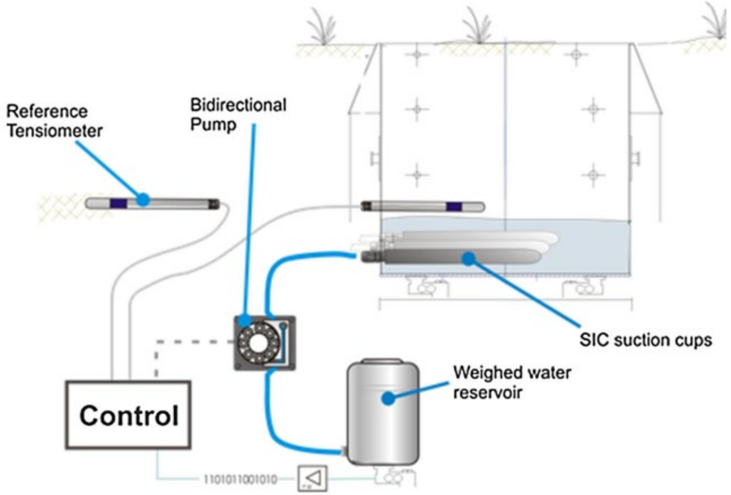
- ~~Water balance approach~~
- ~~Soil moisture sensor~~
- Gravimeter
- Weighable lysimeter

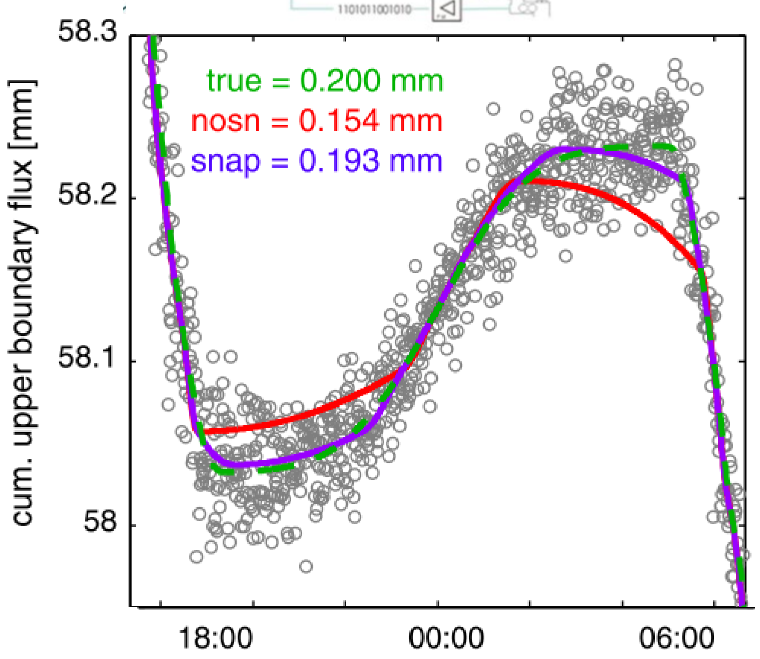
High precision lysimeter

- ✓ High precision and temporal resolution
- ✓ Development of new filter routine
- ✓ Dynamic control bottom boundary









More details on the project TERENO-SoilCan and data see Pütz et al. 2016 ESS, and www.tereno.net

AWAT-filter see Peters et al. 2017 Journal of Hydrology

PRECIPITATION

Some previous comparison studies

Hydrol. Earth Syst. Sci., 19, 2145–2161, 2015
www.hydrol-earth-syst-sci.net/19/2145/2015/

Hydrology and Earth System

Atmospheric Research 174–175 (2016) 120–123

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmosres

ELSEVIER

Technical note

Comparison of simple rain gauge measurements with precision

Journal of Hydrology 575 (2019) 537–543

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

ELSEVIER

Research papers

Evaluation of precipitation measurements methods under field conditions during a summer season: A comparison of the standard rain gauge with a weighable lysimeter and a piezoelectric precipitation sensor

Lisa Haselow[a,*], Ralph Meissner[b], Holger Rupp[b], Konrad Miegel[c]

[a] Department of Soil System Science, Helmholtz Centre for Environmental Research – UFZ, Theodor-Lieser-Straße 4, 06120 Halle, Germany
[b] Department of Soil System Science, Helmholtz Centre for Environmental Research – UFZ, Falkenberg 55, 39615 Altmärkische Wische, Germany

Tipping bucket until 35% less precipitation

ARTICLE INFO

This manuscript was handled by Emmanouil Anagnostou, Editor-in-Chief

ABSTRACT

Current precipitation measurements are conducted largely by simple automatic rain gauges. Despite being error-prone and sometimes of questionable accuracy, the procedure is still widely used. In recent years new possi-

Missing multi-comparison?

Hydrol. Earth Syst. Sci., 27, 3265–3292, 2023
https://doi.org/10.5194/hess-27-3265-2023
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Hydrology and Earth System Sciences

Open Access

EGU

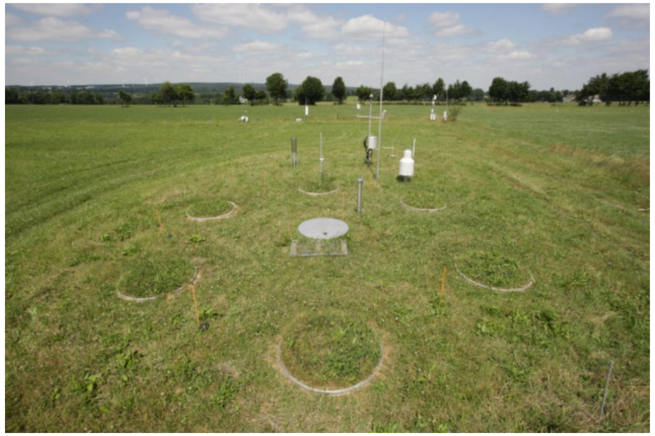
Evaluation of precipitation measurement methods using data from a precision lysimeter network

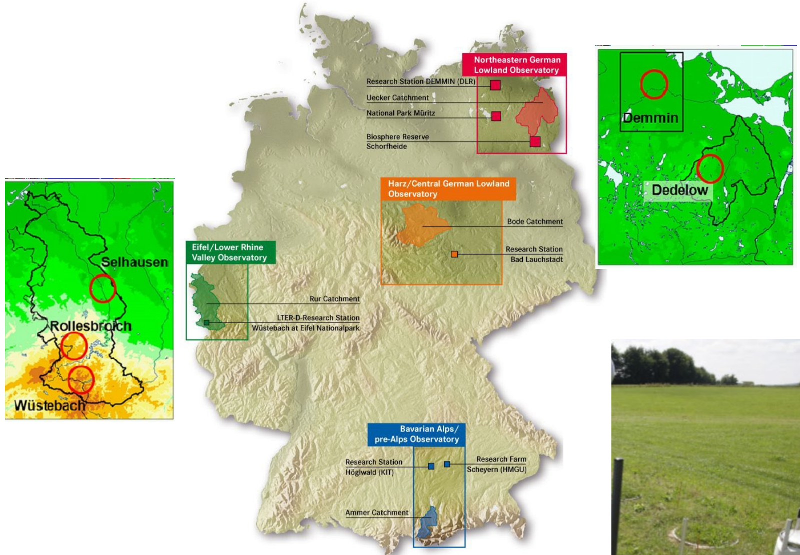
Tobias Schnepper[1,2,3], Jannis Groh[1,4,5], Horst H. Gerke[4], Barbara Reichert[2], and Thomas Pütz[1]

[1]Institute of Bio- and Geoscience IBG-3: Agrosphere, Forschungszentrum Jülich GmbH, 52428 Jülich, Germany
[2]Institute for Geosciences, University of Bonn, Nussallee 8, 53113 Bonn, Germany
[3]GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany
[4]Research Area 1 "Landscape Functioning", Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany
[5]Institute of Crop Science and Resource Conservation – Soil Science and Soil Ecology, University of Bonn, Nussallee 13, 53113 Bonn, Germany

PRECIPITATION

TERENO-SOILCan





Schnepper et al. 2023, Hydrol. Earth Syst. Sci. ,doi: 10.5194/hess-27-3265-2023

PRECIPITATION


Tipping bucket

Weighable

Acoustic

Disdrometer

Site	Year [-]	n [h]	P_{ref} [mm]	P_{lys_crop}	CR_{lys_crop}	P_{TB1} [mm]	CR_{TB1} [%]	P_{TB2} [mm]	CR_{TB2} [%]	P_{WG} [mm]	CR_{WG} [%]	P_{AS} [mm]	CR_{AS} [%]	P_{LD} [mm]	CR_{LD} [%]
Rollesbroich	2015	793	709			334	47.1	594	83.8	606	85.5	499	70.4	676	95.3
	2016	989	801			184	22.9	634	79.2	659	82.2	526	65.6	687	85.7
	2017	1007	881			273	30.9	732	83.1	744	84.5	553	62.8	795	90.2
	2018	694	583			189	32.4	471	80.8	519	89.0	456	78.2	522	89.6
Selhausen	2015	736	599	600	100.1	244	40.7			549	91.7	423	70.6	589	98.4
	2016	697	554	556	100.3	221	39.9			495	89.4	388	70.0	455	82.1
	2017	581	431	430	99.8	169	39.2			398	92.3	303	70.2	317	73.6
	2018	548	388	394	101.4	79	20.4			367	94.5	319	82.1	373	96.1
Dedelow	2015	571	414			344	83.1					373	90.1		
	2016	641	423			322	76.1					351	83.1		
	2017	719	693			504	72.8					572	82.6		
	2018	407	279			235	84.0					255	91.3		

Partially large underestimation of precipitation!

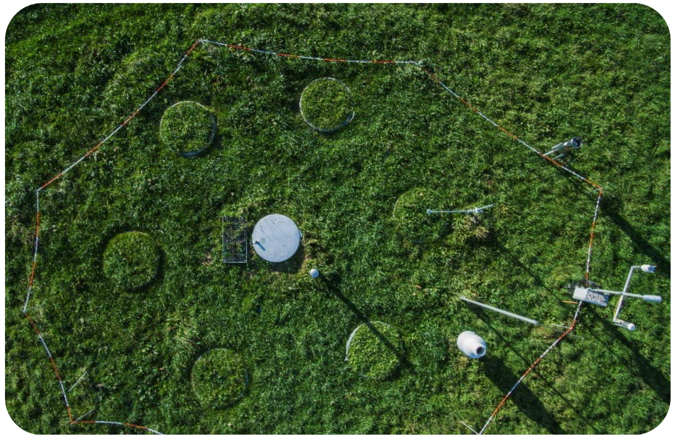
NON-RAINFALL WATER

How much water does NRW inputs contribute at the annual scale to ecosystem and are those of ecological relevance?

Location: Gumpenstein, Austria

Year	P			NRW			NRW% of P		
	RO	Se	GS	RO	Se	GS	RO	Se	GS
	mm y^{-1}			mm y^{-1}			mm y^{-1}		
2015	1092	700	1019	?			?		
2016	1039	669	1161						
2017	1076	602	1306						
2018	990	485	1013						
Mean	1020	614	1125						

Forstner et al. 2021, Hydrol. Earth Syst. Sci. ,doi: 10.5194/hess-2021-100



Location: Rollesbroich, Germany

Hydrological year	Water stress	
	RO	GS
	d y^{-1}	d y^{-1}
2013-2014	?	?
2014-2015		

Groh et al. 2018, Journal of Hydrology, doi: 10.1016/j.jhydrol.2018.06.009

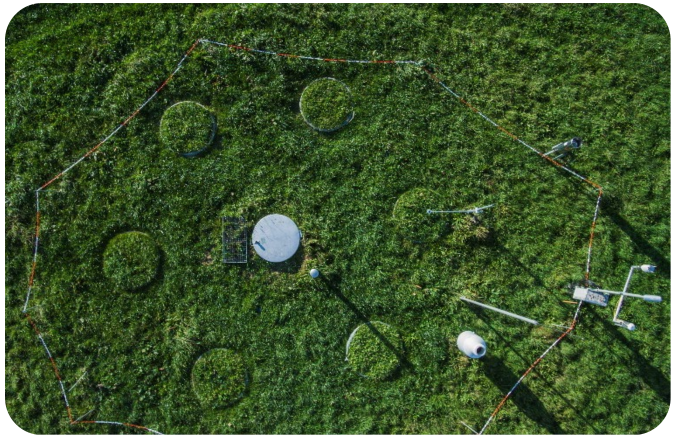
NON-RAINFALL WATER

How much does NRW contribute to the water and are those of ecological relevance?

Location: Gumpenstein, Austria

Year	P			NRW			NRW% of P		
	RO	Se	GS	RO	Se	GS	RO	Se	GS
	mm y^{-1}			mm y^{-1}			mm y^{-1}		
2015	1092	700	1019	57	49	51	5.2	6.9	5.0
2016	1039	669	1161	64	44	74	6.1	6.6	6.4
2017	1076	602	1306	57	47	73	5.3	7.8	5.6
2018	990	485	1013	45	38	60	5.2	7.9	5.9
Mean	1020	614	1125	56	44	65	5.5	7.2	5.7

Forstner et al. 2021, Hydrol. Earth Syst. Sci.,doi: 10.5194/hess-2021-100



Location: Rollesbroich, Germany

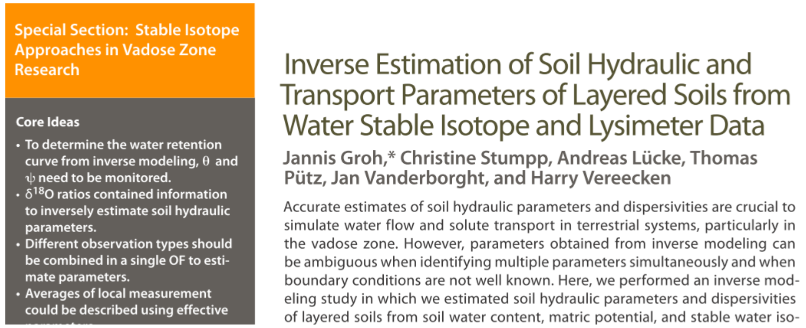
Hydrological year	Water stress	
	RO	GS
	d y^{-1}	d y^{-1}
2013-2014	1	0
2014-2015	27	0

Importance of NRW in dry years and during dry periods

Groh et al. 2018, Journal of Hydrology, doi: 10.1016/j.jhydrol.2018.06.009

PRECIPITATION ACCURACY

Does it matter?



Special Section: Stable Isotope Approaches in Vadose Zone Research

Core Ideas

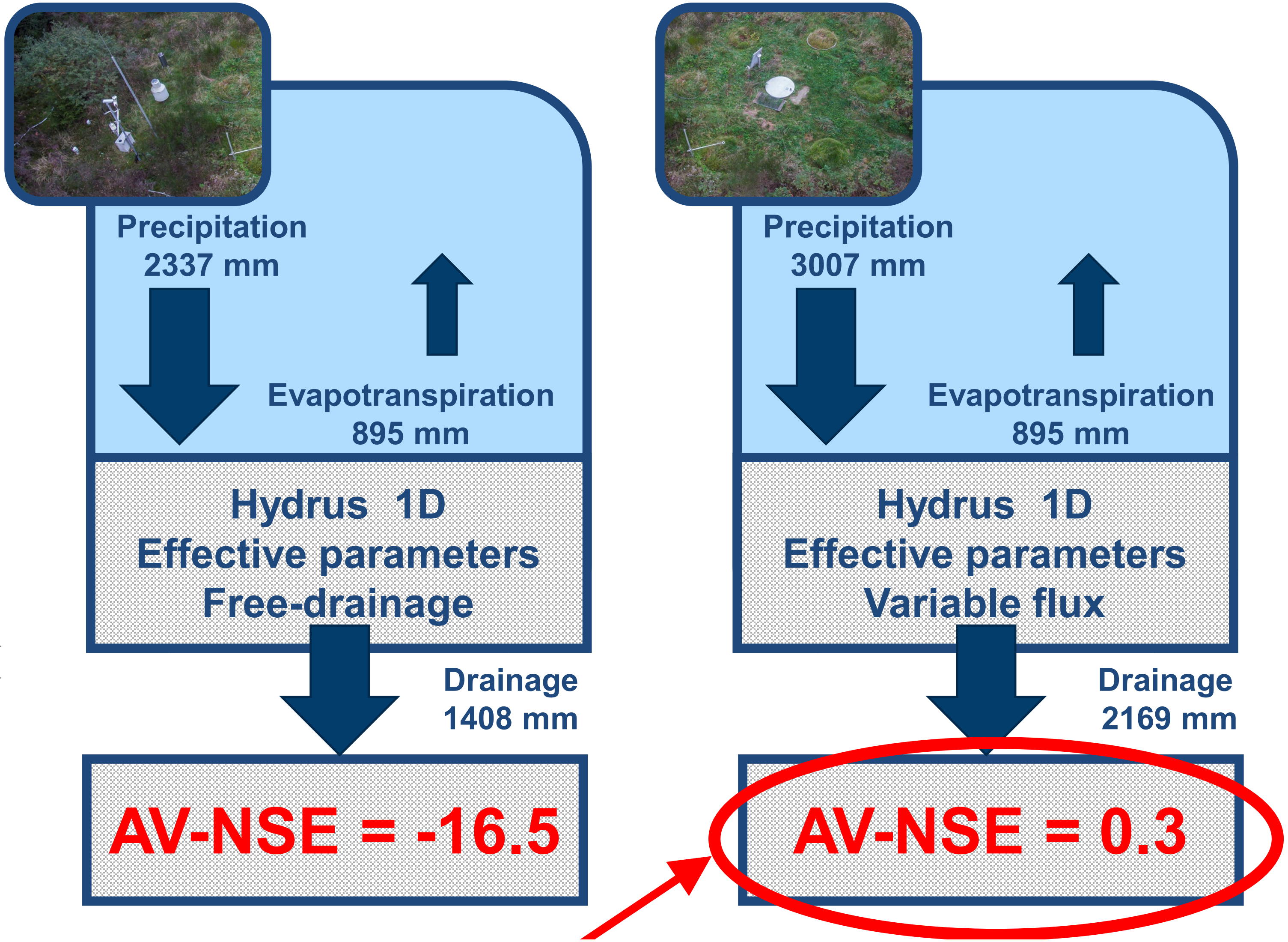
- To determine the water retention curve from inverse modeling, θ and ψ need to be monitored.
- $\delta^{18}O$ ratios contained information to inversely estimate soil hydraulic parameters.
- Different observation types should be combined in a single OF to estimate parameters.
- Averages of local measurement could be described using effective

Inverse Estimation of Soil Hydraulic and Transport Parameters of Layered Soils from Water Stable Isotope and Lysimeter Data

Jannis Groh,* Christine Stumpp, Andreas Lücke, Thomas Pütz, Jan Vanderborght, and Harry Vereecken

Accurate estimates of soil hydraulic parameters and dispersivities are crucial to simulate water flow and solute transport in terrestrial systems, particularly in the vadose zone. However, parameters obtained from inverse modeling can be ambiguous when identifying multiple parameters simultaneously and when boundary conditions are not well known. Here, we performed an inverse modeling study in which we estimated soil hydraulic parameters and dispersivities of layered soils from soil water content, matric potential, and stable water iso-

More details see Groh et al. 2018 Vadose Zone J., doi:10.2136/vzj2017.09.0168



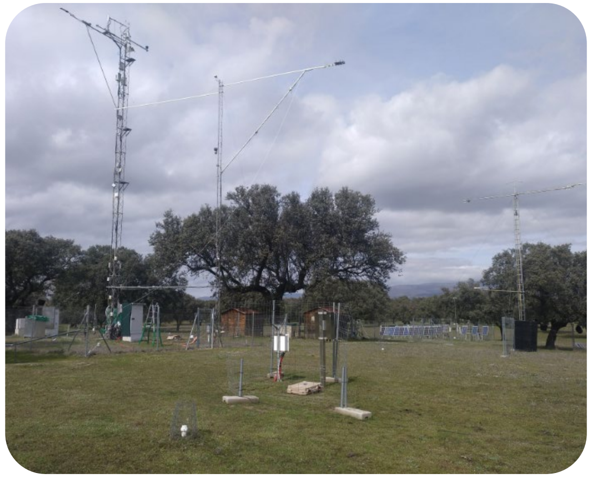
Importance of precipitation accuracy and NRW for inverse estimation of soil hydraulic and transport parameters

EVAPOTRANSPIRATION (DAYTIME)

Location: Selhausen, Germany

Elora, Canada

Els Plans, Spain



Majadas, Spain

$\Delta ET_{ly\text{-}EC}$

Sites	Rollesbroich (mm/d)		Elora (mm/d)		Majadas (mm/d)		Els Plans (mm/d)	
	clear	cloudy	clear	cloudy	clear	cloudy	clear	cloudy
2017	1.27	0.29	-	-	-	-	-	-
2018	0.69	0.24	1.75	1.34	0.41	1.58	-	-
2019	1.44	0.54	0.68	0.37	0.55	0.65	-	-
2020	1.12	0.50	-0.26	0.23	0.65	1.20	-	-
2021	1.81	0.77	-0.16	-0.18	-	-	0.50#	0.27#
mean	1.26	0.47	0.50	0.44	0.54	1.15	0.50	0.27

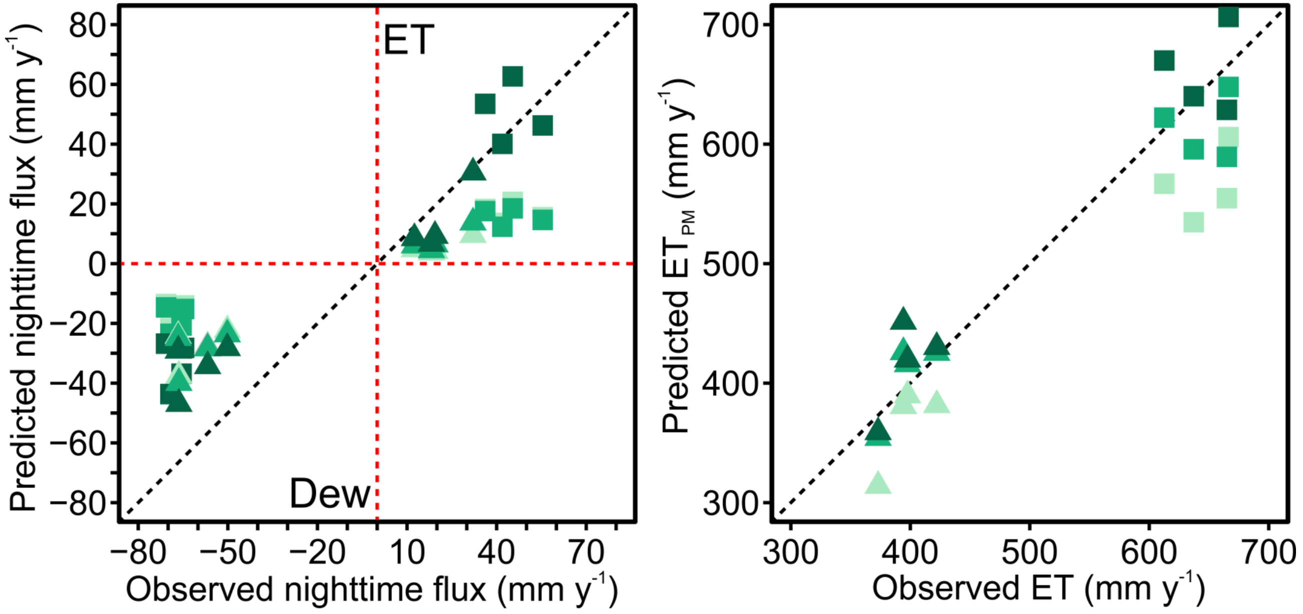
(Els Plans: 14/06/2021-18/07/2022)

Han et al. , in preparation

EVAPOTRANSPIRATION (NIGHTTIME)

Location: Wüstebach, Germany

Location: Rollesbroich, Germany

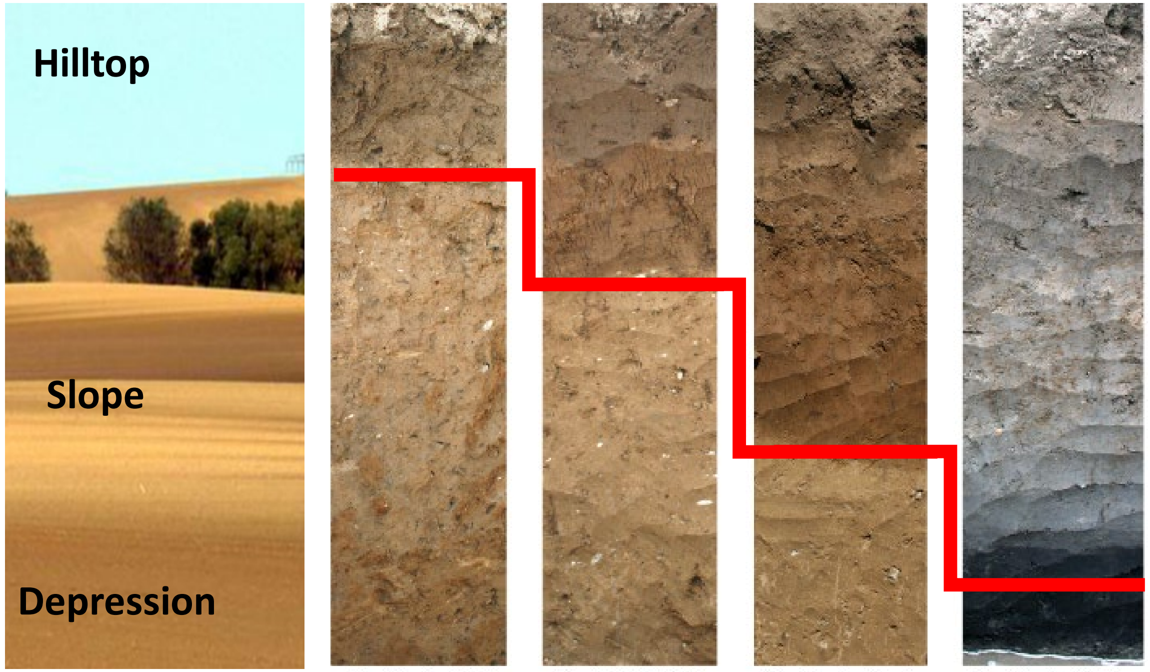


Mostly evaporation as ET_N occurred mainly during wet surface conditions

	Wüstebach	Rollesbroich	Wüstebach	Rollesbroich	Wüstebach	Rollesbroich	Wüstebach	Rollesbroich
	Average ET_N (mm/year)		Average [illegible] (mm/year)		Average ET_{Ndry} (mm/year)		Average dew formation (mm/year)	
Observation	20.51 (±2.40)	44.71 (±4.50)	16.95 (±1.85)	42.03 (±4.21)	3.56 (±0.67)	2.68 (±1.11)	60.00 (±2.81)	67.53 (±4.06)
PM_{FAO}	5.59	17.05	[illegible]	16.07	1.13	0.98	27.90	17.04
PM_{r288}	7.69	15.77	6.22	14.83	1.47	0.94	29.22	18.50
PM_{r0}	13.75	50.64	10.32	47.65	3.43	2.99	34.66	33.86

Groh et al. 2019, Quantification and Prediction of Nighttime Evapotranspiration for Two Distinct Grassland Ecosystems, Water Resource Research

DRAINAGE & CAPILLARY RISE



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

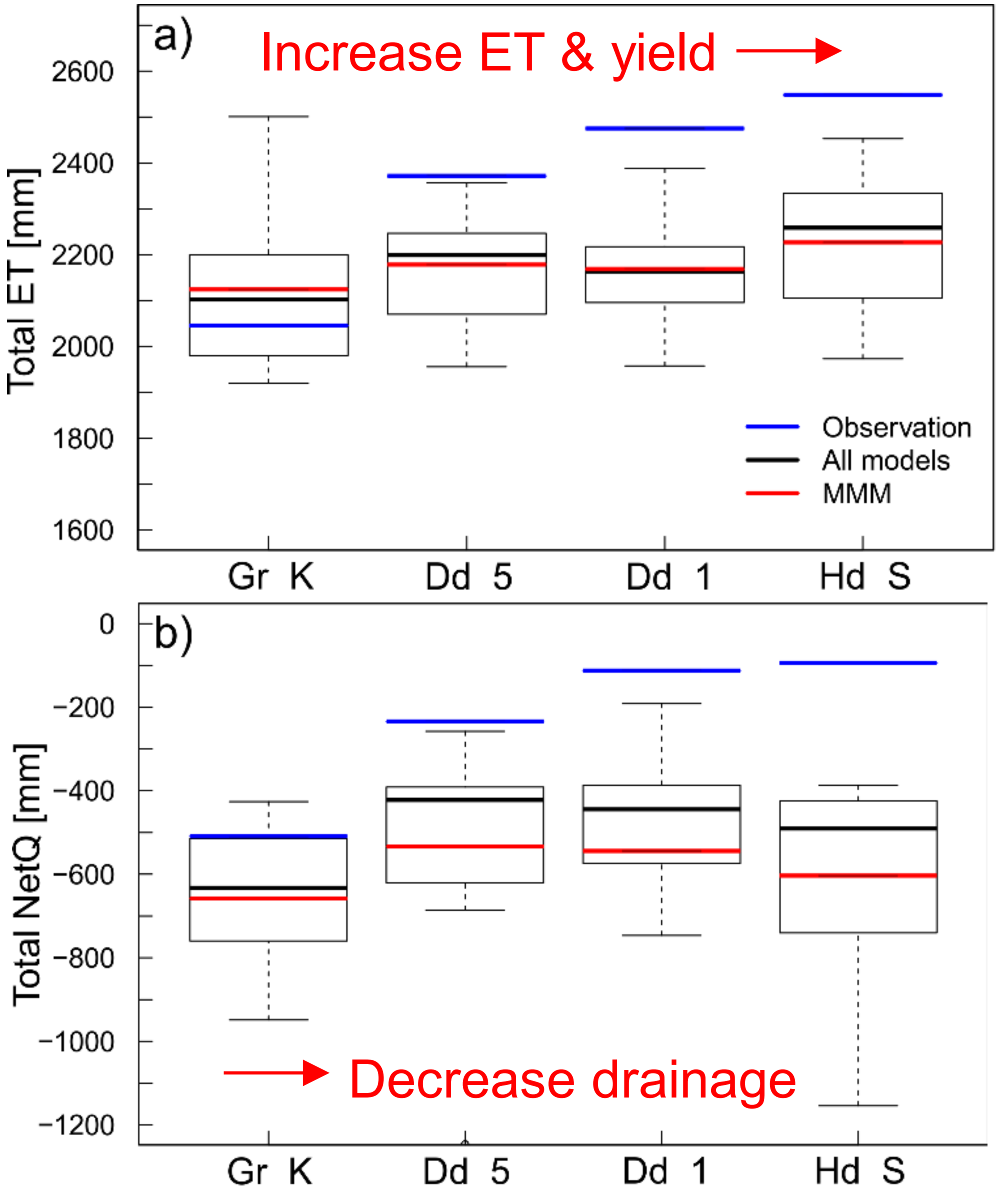
Profile 2: Dd_5 **Position:** Slope **Soil type:** Nudiargic Luvisol

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

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

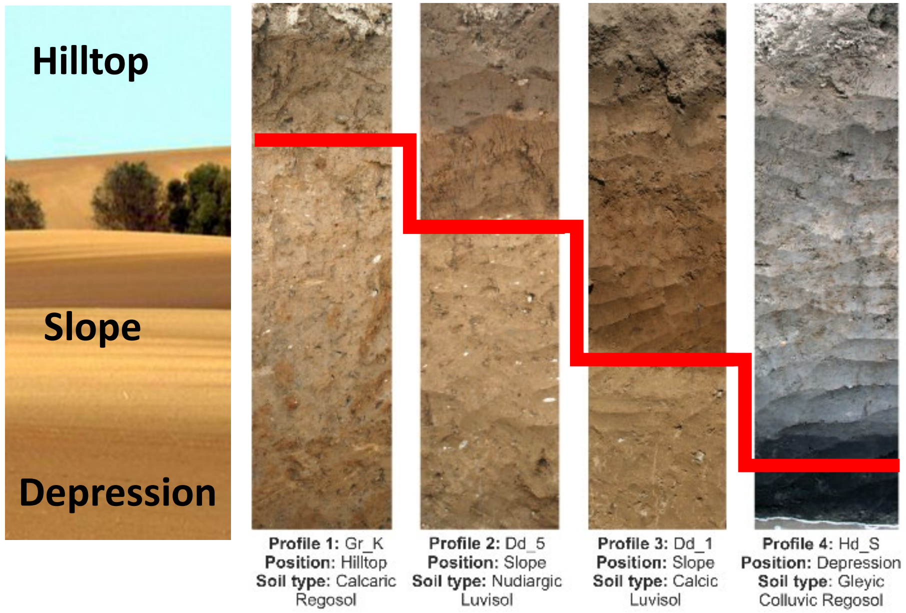
Location: Dedelow, Germany

Groh et al. 2020, Crop growth and soil water fluxes at erosion-affected arable sites: Using weighing lysimeter data for model intercomparison, Vadose Zone J.



Landscape position/Soil profile effect

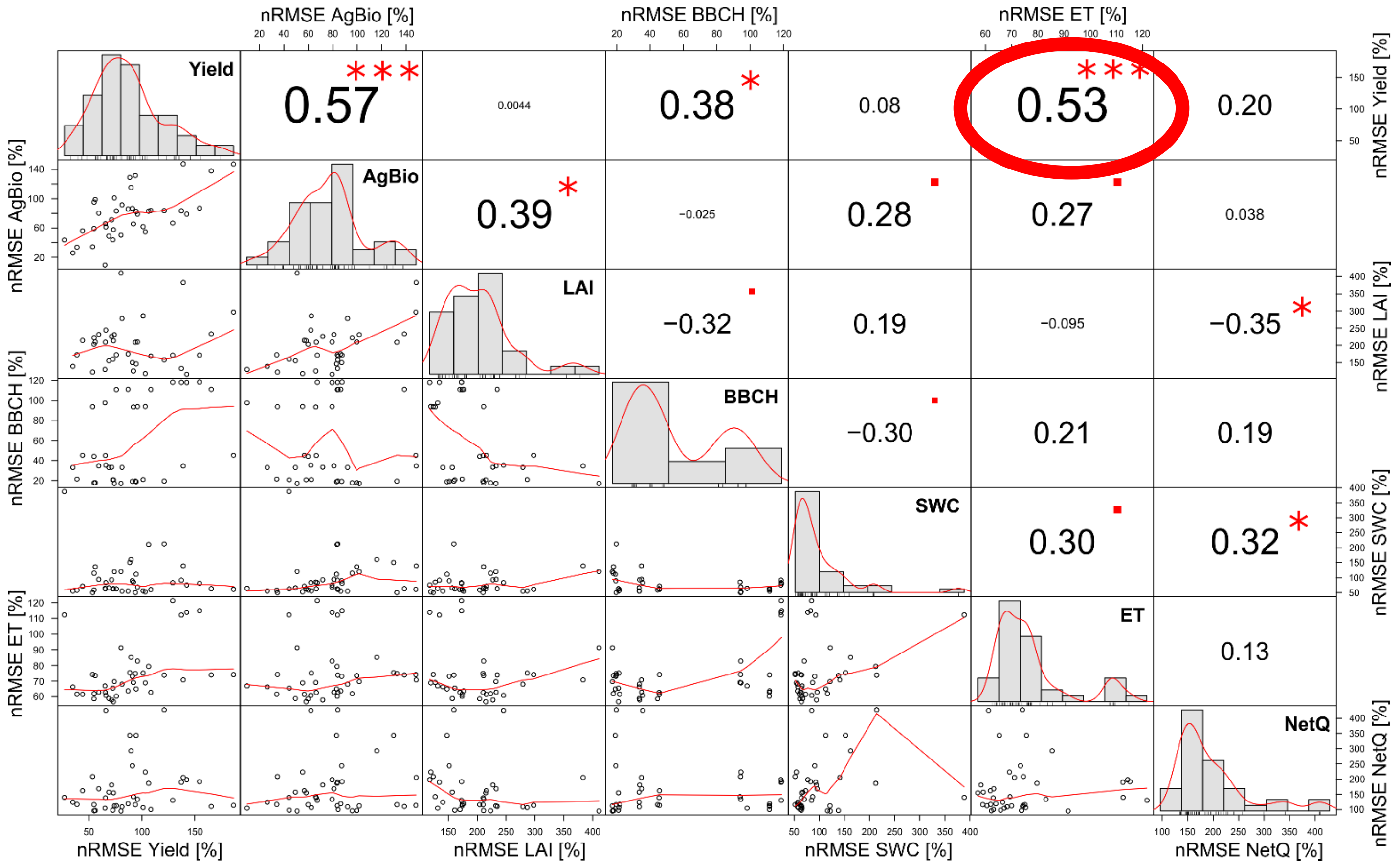
DATA-SET



Location: Dedelow, Germany

Groh et al. 2020, Crop growth and soil water fluxes at erosion-affected arable sites: Using weighing lysimeter data for model intercomparison, Vadose Zone J.

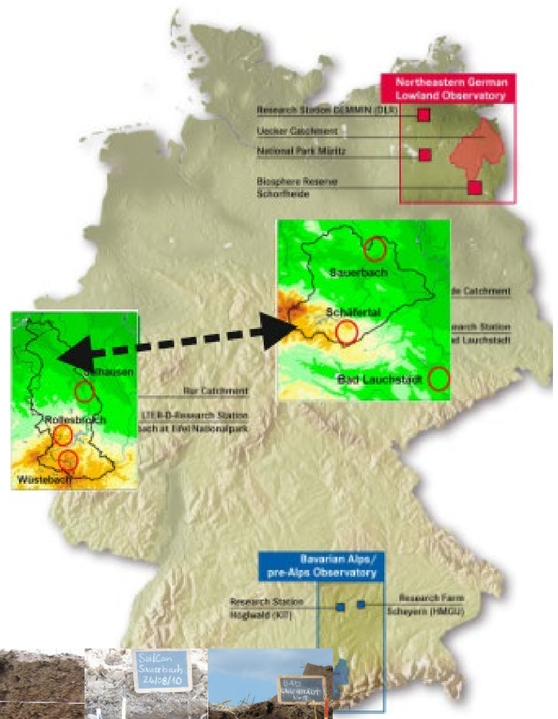
Why is this important?

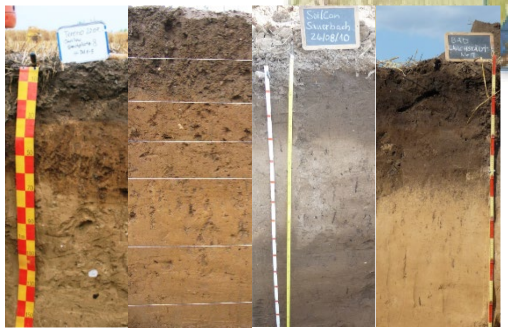


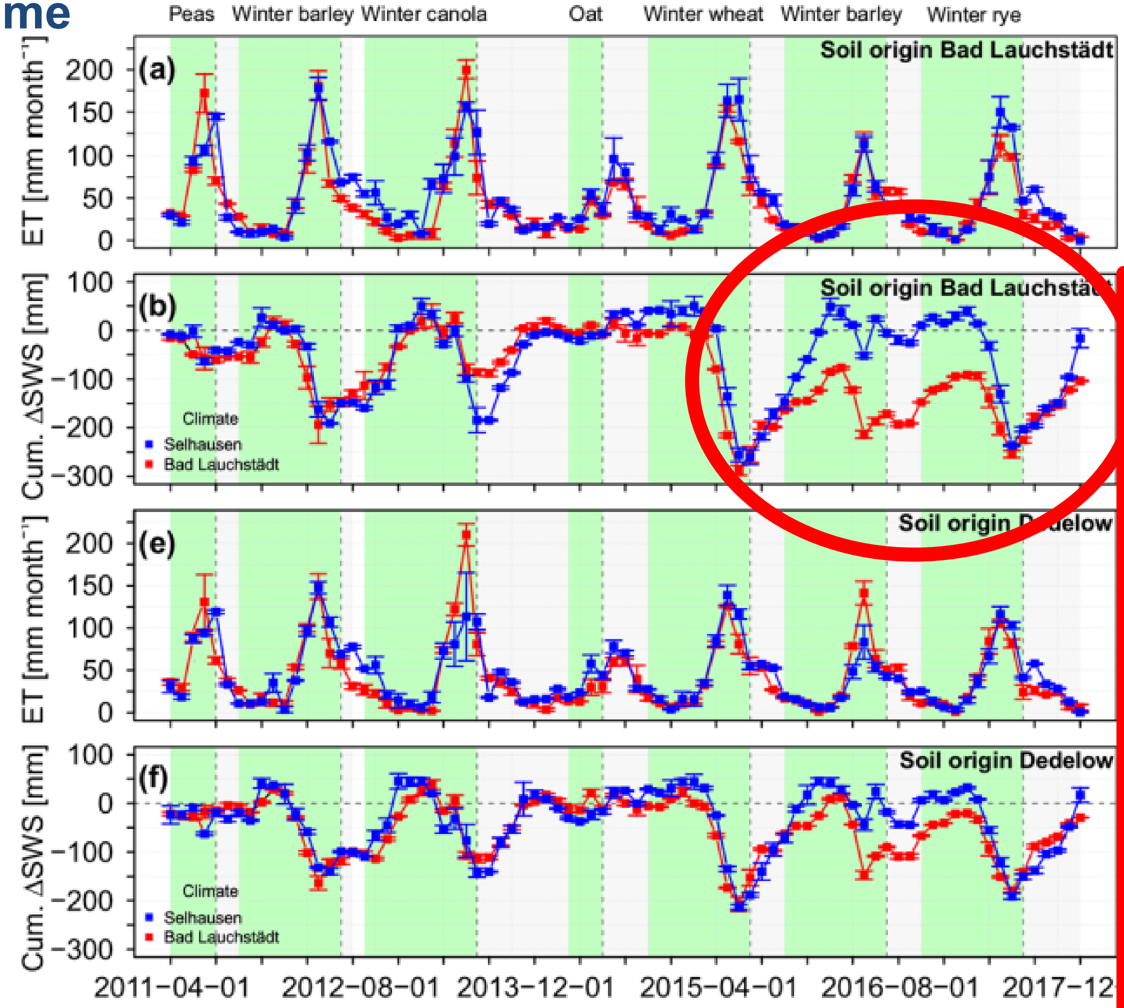
SOIL WATER DYNAMICS

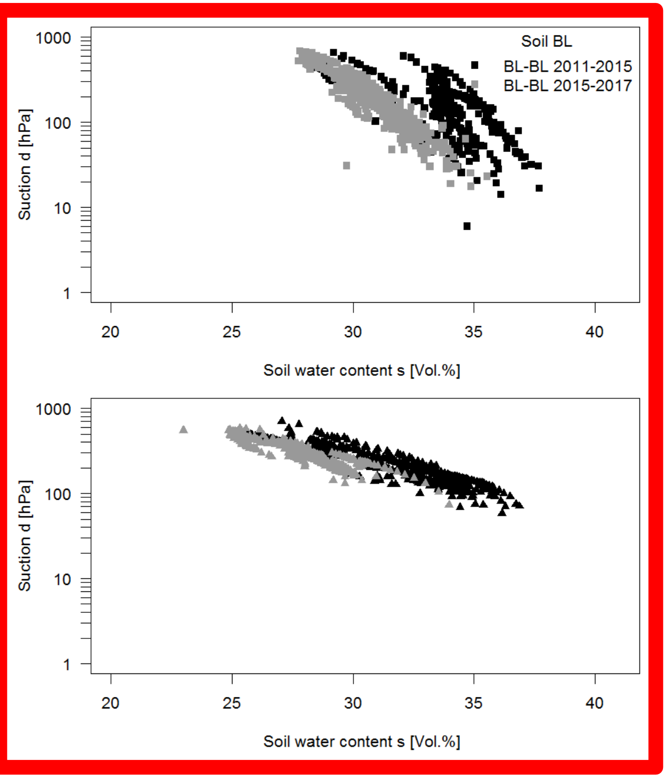
Climate change experiment
Space for time

Temporary or long-term change?





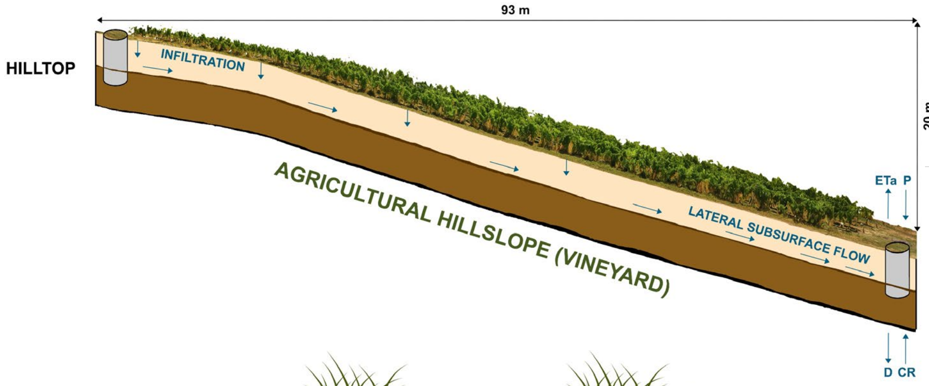


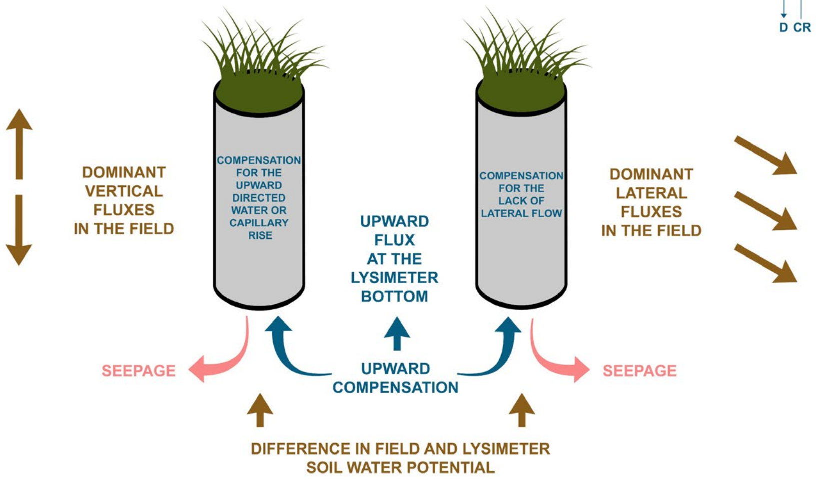


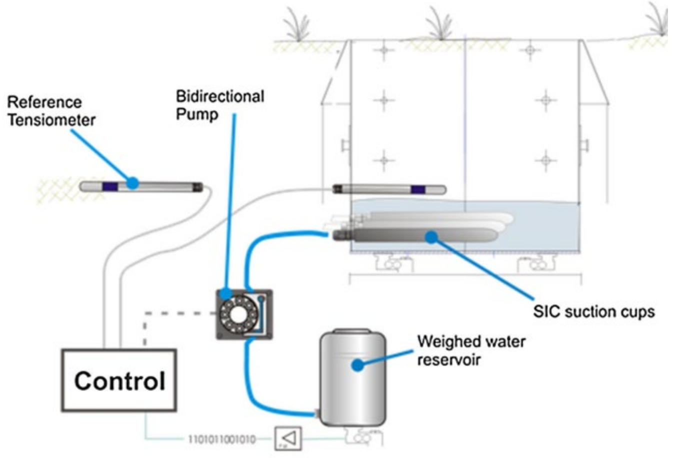
Groh et al. 2020, Responses of soil water storage and crop water use efficiency to changing climatic conditions: a lysimeter-based space-for-time approach, Hydrol. Earth Syst. Sci.

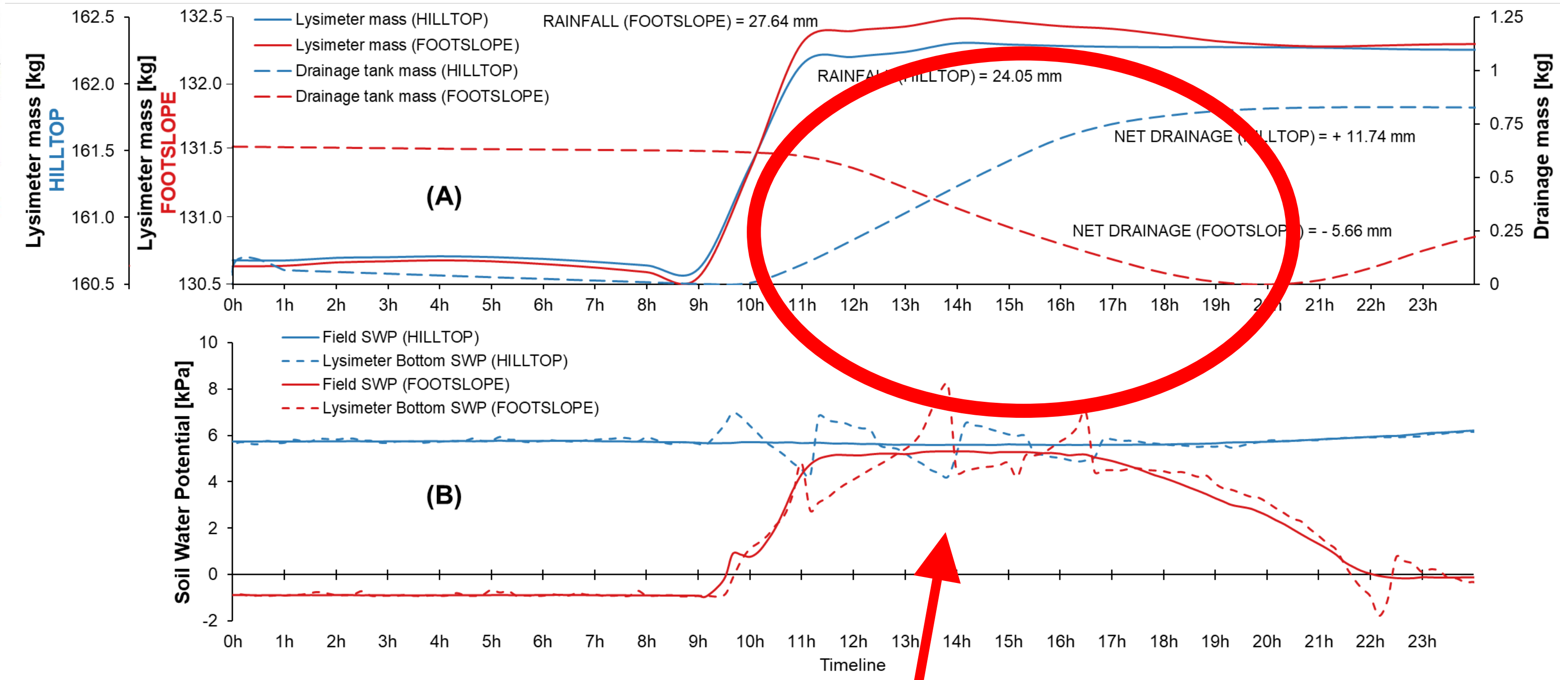
NEW WAYS TO USE LYSIMETERS…

Looking at hillslope processes









Change in flux direction due to lateral processes

Krevh et al. 2023, Water, doi: 10.3390/w15132398

TAKE HOME MESSAGE

- Data for all water balance components
- Tool to track water and solutes trough the soil
- Helps to identify hidden process across the soil-plant-atmosphere continuum

Lysimeter are a holistic tool for quantifying and tracking water fluxes at the land surface and in the soil

- Data are helpful to improve process understanding
- High potential for climate change studies (e.g., Ecotrons)

Thank you for your attention