HelmholtzZentrum münchen
Deutsches Forschungszentrum für Gesundheit und Umwelt
GFZ Helmholtz-Zentrum Potsdam
Helmholtz Centre for Environmental Research – UFZ
TERENO Terrestrial Environmental Observatories
DLR
KIT Karlsruher Institut für Technologie
Jülich Forschungszentrum

Long-term, high precision lysimeter network an important tool to validate soil models

Th. Pütz, U. Wollschläger, J. Groh, H. Gerke, E. Priesack, R. Kiese, E. Borg & H. Vereecken - Agrosphere Institute, IBG-3, Forschungszentrum Jülich GmbH, Germany, t.puetz@fz-juelich.de

TERENO = TERrestrial ENvironmental Observatories

The main goal of TERENO was to create observation platforms on the basis of an interdisciplinary and long-term aimed research program. By the aid of SoilCan-lysimeters, an ideal network was built between the four different TERENO-observatories with their highly instrumented test sites. Within the four TERENO-observatories at 13 different experimental sites, in total 126 lysimeters were filled monolithically and the measurements were started in October 2010. The lysimeters have been cultivated as grassland or arable land with a standardized crop rotation: winter wheat - winter barley – winter rye – oat.

Motivation

- Observation of long-term effects of climate change on terrestrial systems with the "same soil" under different climate conditions and a special focus on:
  - terrestrial hydrology
  - N-/C-cycle
  - biodiversity
- Comprehensive data-sets for:
  - model development
  - model calibration – remote sensing
- Consistent experimental design
- Land use changes
- Bridging the up-/down scaling processes

Principle: "Space for Time"

SoilCan Lysimeter Concept

Definition lysimeter: a vessel filled with disturbed/undisturbed soil of an ecosystem that permits the sampling and the balance of water and chemicals.

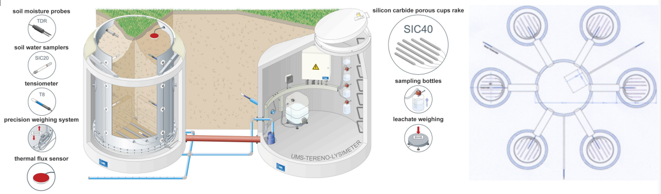

Fig. 1: Sectional drawing of a lysimeter and a service pit of a SoilCan hexagon including the different measuring and sampling devices (left) and the hexagonal design (right).

Technical specification of the lysimeters:
- Lysimeter-hexagon with six lysimeters and a central service pit
- Soil monoliths
- Balance resolution: 0.1 mm = 100 g
- Area: 1 m²
- Depth: 1.5 m
- Adjustment of the lower boundary condition via suction cups rake to direct the water flow up- or downwards
- Multiple sensors installation to elucidate the processes in the "black box" soil
- Open VPN access to each lysimeter station

Tab. 1: Instrumentation of the lysimeters:

sensors per lysimeter	number	depth (cm)
tensiometer	3	30 / 50 / 140
matrix potential sensor	4	10 / 30 / 50
TDR	3	10 / 30 / 50
temperature sensor	6	10 / 30 / 50 / 140
heat flux sensor	1	10
CO2 gas sensor	1	10
balances (leachate, lysimeter)	2	-
suction candles / leachate	4	10 / 30 / 50 /140

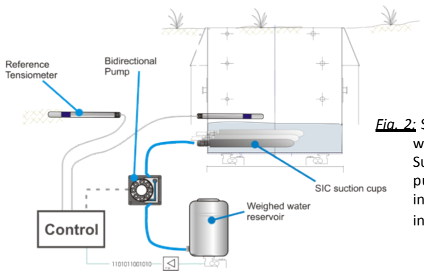

Fig. 2: Sectional drawing of a lysimeter with controlled lower boundary. Suction rake/cups, bidirectional pump, reference tensiometer inside the lysimeter and outside in the natural field site.

Climate Feedback Concept

Water balance equation with parameters measurable via instrumented lysimeters:

$$\Delta S = P + C - D - ETa - T$$

ΔS = change in soil water content, **P** = total precipitation, **C** = dew/hoar, **D** = drained/leached water, **ETa** = actual evaporation, **T** = transpiration (plants)

A change in present climate conditions was induced by relocation of the lysimeters mostly from humid to dryer conditions and from colder to warmer temperatures. This relocation was performed according to the expected climate changes. The lysimeters were transported from their place of origin to Selhausen (atlantic climate) and Bad Lauchstaedt (continental climate).

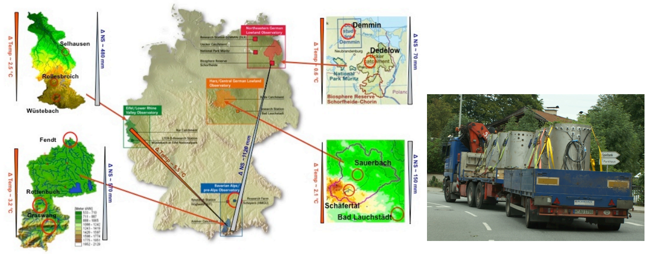

Fig. 3: The different lysimeter locations with the temperature- and rainfall gradients within and between the four TERENO observatories completing the climate-feedback-concept (left) and the lysimeter transport (right).

High Data Quality

Various factors may affect the different measuring devices and create incorrect results, e.g. wind, temperature, mass changes induced by animals, sampling of the seepage reservoir, malfunctions, etc.. For that reason, it is necessary to establish a filtering procedure for the measured data to assess the water and matter fluxes with high accuracy.

Manual filter (filtering of unreliable periods) → Theshold filter (filtering of unrealistic data points) → Median filter (filtering of single outliers) → Smoothing filter (filtering of short-time noise) → Oscillation threshold filter (filtering of unreliable periods)

Fig. 4: Flowchart of the basic data processing scheme (from Hannes, M. et al. (2014): High resolution estimation of the water balance components from high-precision lysimeters. Hydrology and Earth System Sciences submitted).

Fig. 5: Lysimeters at their place of origin (Wüstebach, Eifel) and translocated to Selhausen.

To determine the water balance in the lysimeters and to validate their functionality, a tracer experiment was started in January 2014. To 90 lysimeters of the network, about 25 g of potassium bromide were applied simultaneously. During the initial period (first three months), water samples were taken once a week and and thereafter at two-week intervals.
The tracer experiment is on-going (Groh, J., et al. : Numerical study of different bottom boundary conditions on the water flow in lysimeters, Vadose Zone Journal. in prep.).

Exemplary Results

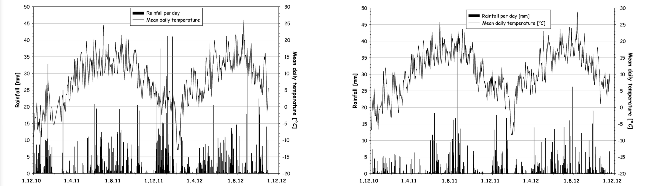

Fig. 6: Rainfall per day and mean daily temperature at Wüstebach lysimeter station (left) and at Selhausen lysimeter station (right)

Long-term mean value of air temperature (calculated for 1979-1999):
Wüstebach 7.5 °C
Selhausen 10.0 °C

For the observation period (2010-2013):
Wüstebach 8.0 °C (range -12.9 to 25.9 °C)
Selhausen 10.9 °C (range -8.3 to 28.8 °C)

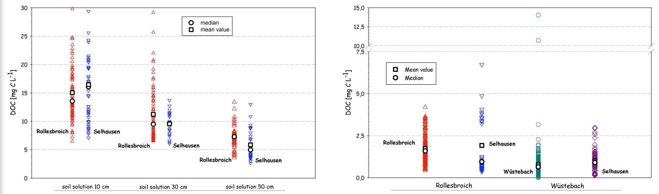

Fig. 7: Comparison of DOC-concentrations in soil solutions (left) and leachates (right) at Rollesbroich lysimeter station, Wüstebach lysimeter station and at Selhausen lysimeter station.

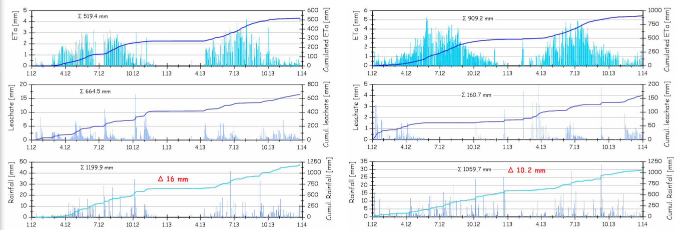

Fig. 8: ETa, leachate and rainfall of Wüstebach lysimeters at Wüstebach lysimeter station (left) and at Selhausen lysimeter station (right) (from Gebler, S., et al. (2014): Actual evapotranspiration and precipitation measured by lysimeters: A comparison with eddy covariance and tipping bucket. Hydrology and Earth System Sciences (submitted).

Conclusion

- The measurement of a precise water balance is enabled taking into account the most important terms of the water balance equation.
- Trends for a more rapid carbon turnover of the soil organic matter were observed in the warmer and drier locations.
- Problems arose in controlling the lower boundary conditions of the lysimeters due to widely varying groundwater levels between origin and new location.

Acknowledgment

We would like to thank the BMBF for financing the lysimeter network.