Development of a Forest Floor Grid Lysimeter

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Motivation

The Forest Floor (FF) is hydrologically highly relevant but remains only partly explored.

In temperate forests the mineral soil is usually covered by organic layers with various thickness. Due to it's high porosity it can store large amounts of water, which can evaporate (FF interception) or percolate. Especially in the O-Layer water repellency can be strong and seasonal highly variable. This variability influences infiltration patterns and may enhance bypass flow.

Since direct observations of water fluxes are missing, the goal of this study was to **develop a weighing Forest Floor Grid-Lysimeter (FFGL)**. With this we want to explore the differences in throughfall patterns, storage capacity and infiltration patterns.

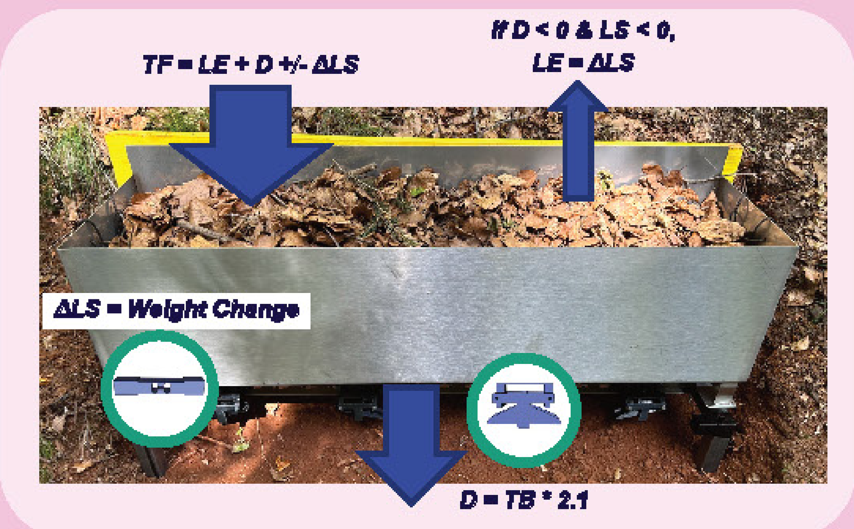
Background

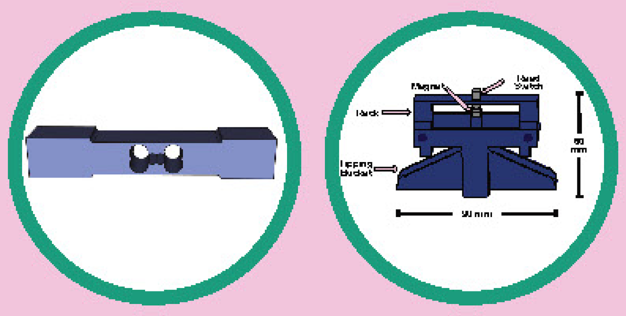
- The canopy structure of forests influences throughfall patterns. The tree morphology leads to a redistribution of precipitation [3].
- Litter interception has a large influence on the water balance: it alters quantities of water available for soil infiltration and runoff [2].
- Litter interception is often disregarded, combined with transpiration or taken as a fixed percentage, but it can account for 20-50% of precipitation [1].
- Typical canopy ecosystem services like carbon sequestration, water infiltration, filtration, soil erosion control and biodiversity should also be attributed to the FF [2]

Water Flux Quantification

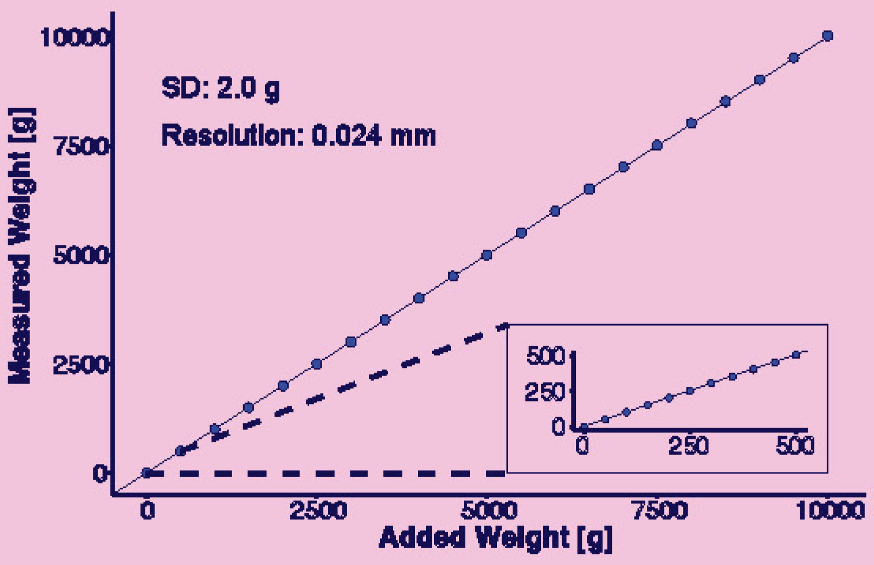
The Lysimeter consists of a stainless steel box (25x100cm) and is seperated into 4 grids with 4 outlets. It is filled to a height of 20 cm with forest floor material (organic layers + some mineral soil).

The box is standing on a frame holding the measurement equipment. With the continous measurement of the total mass and the amount of draining water, we can calculate the FFGL water balance.



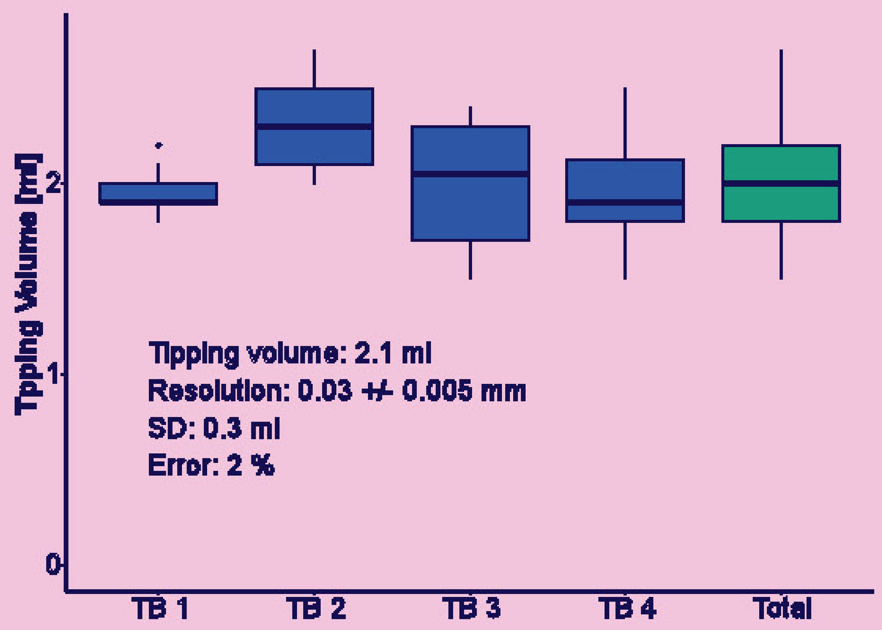


The load cells (LC) have a resolution of 6 g. After calibration, they show good accuracy. The temperature dependency, of the LC will be corrected using temperature sensors in and on the FFGL.



Comparison of measured and added weight (n=20).

The tipping bucket (TB) consists of a 3D printed bucket and frame. These parts are connected with a thin pin. Further parts are a magnet and a reed switch.

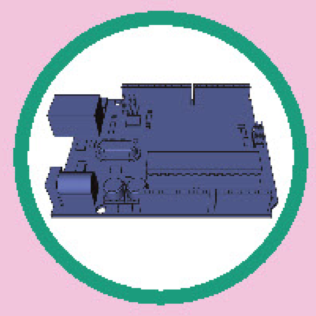


Tipping volume (n=40) of four different TBs of one lysimeter.

The accuracy test of the TB shows small differences among the different TBs due to unevenness caused by the 3D printer. Compared to other TBs installed in rain gauges the accuracy is comparable and acceptable.

Microcontroller

The FFGL is run by a customized MKR Zero microcontroller board.
It allows to connect:



- 4x load cells
- 4x tipping buckets
- 4x electrical conductivity sensors
- 4x temperature sensors

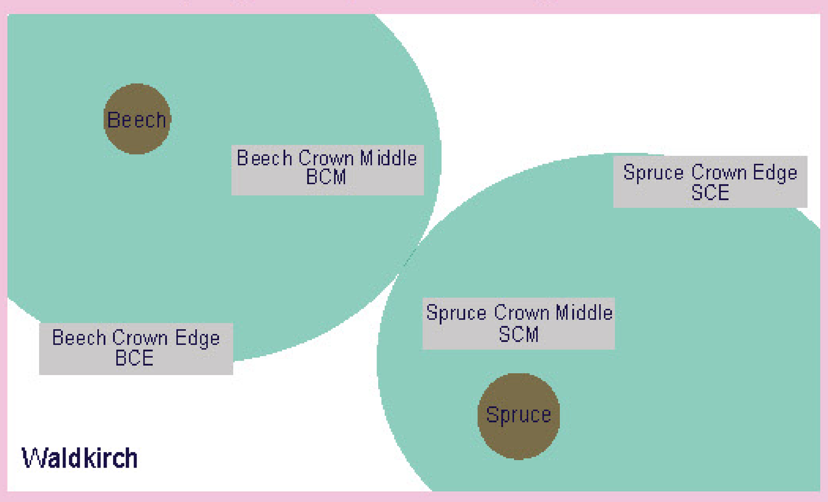
The sensors can be read in different timesteps. In combination with event-based programming and depending on the electrical power supply, data can be collected more often (i.e. every minute) during rain events and less often (i.e. every 10 minutes) in drier time periods.

The collected data is saved to a SD-card.

The lysimeter is designed to generate data in a high spatial and temporal resolution. Therefore we needed a low-cost setup to install several lysimeters at one study site.

Setting

We installed four lysimeters in a mixed spruce-beech forest. We placed two under a beech tree and two under a spruce tree. One was located under the crown edge and one in the middle between the trunk and the crown edge (see figure below).



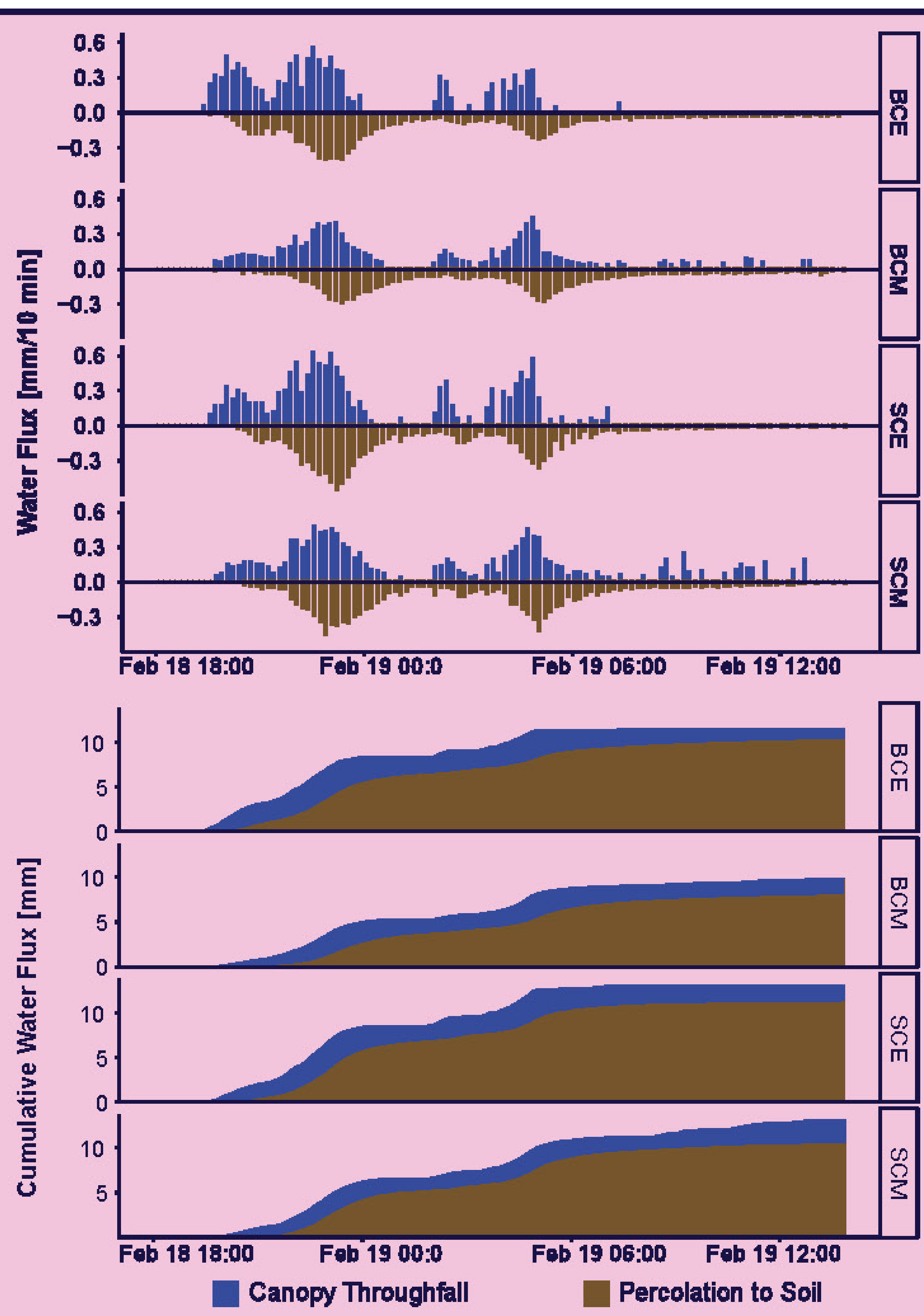
Due to the funneling morphology of beech trees we expect more throughfall under spruce than under beech and more throughfall under the beech crown edge compared to the crown middle.

Regarding storage capacities we expected higher storage in beech litter due to a higher surface area compared to needle litter and higher storage in thicker FFs.

Additionally we want to observe small scale heterogeneity of infiltration patterns due to hydrophobicity.

Results

- Our results show that the FF buffers water fluxes into the deeper mineral soil. Percolation to the soil starts with a 30-60 minutes delay after precipitation occurs.
- The four lysimeters show similar dynamics of canopy throughfall and percolation, but there are differences in the dynamic and amount of throughfall for different positioning under the tree. The throughfall signal for the crown middle lysimeters seems damped with longer dripping of branches, after the throughfall ceases.
- In total we measured higher canopy throughfall under spruce (13mm) than under beech (9/11mm) for this event. As well as higher throughfall under beech crown edges (11mm) compared to the crown middle (9mm).
- Six hours after the event 10-20 % of throughfall water is still stored in the FF.



Total and cumulative water fluxes during one rainfall event in February 2024.

The dye pattern with Brilliant Blue after irrigation of 20 mm of the FF shows the small scale heterogeneity of infiltration.

This could also be shown with our FFGL data. The total amounts of TB tips during one event below the seperate lysimeter grids varied from 0 to 620 tips.

	Tipping Bucket Variation in Waldkirch Event: 18. - 19.2.2024 in mm				
	TB 1	TB 2	TB 3	TB 4	Mean
BCE	14.4	7.6	0	19.2	10.3
BCM	20.0	0	12.4	0	8.0
SCE	15.2	4.4	12.8	12.4	11.2
SCM	14.0	4.0	8.4	15.6	10.4

Conclusion

The newly developed Forest Floor Grid-Lysimeter (FFGL) allows for detailed quantification of water fluxes of the Forest Floor in a relative low-cost setup. The minimum resolution for rainfall/throughfall detection lies at 0.024 mm, whilst the quantification of seepage water is 0.03 mm.

Our first results show that there is a huge heterogeneity in water fluxes percolating to the mineral soil of forests caused by differences in throughfall patterns as well as differences in FF composition.

Outlook

- Further testing of the FFGL in the field is still necessary.
- In addition to the water fluxes we also plan to include in-situ water quality measurements of electrical conductivity (EC) and dissolved organic carbon (DOC).

Literature

[1] Gerrits, A. M. J., H. H. G. Savenije, L. Hoffmann, and L. Pfister. 2007. "New Technique to Measure Forest Floor Interception – an Application in a Beech Forest in Luxembourg." Hydrology and Earth System Sciences 11 (2): 695– 701. https://doi.org/10.5194/hess-11-695- 2007.

[2] Guevara-Escobar, A, E Gonzalez-Sosa, M Ramos-Salinas, and G D Hernandez- Delgado. 2007. "Experimental Analysis of Drainage and Water Storage of Litter Layers." Hydrol. Earth Syst. Sci.

[3] Levia, Delphis F., Darryl Carlyle-Moses, and Tadashi Tanaka, eds. 2011. Forest Hydrology and Biogeochemistry: Synthesis of Past Research and Future Directions. Vol. 216. Ecological Studies. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-1363-5.

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