Lysimeter Soil Retriever (LSR)-A tool for investigation on heterogeneity of the migration and structural changes

S. Reth[A, C], M. Gierig[B], J.B. Winkler[C], C.W. Mueller[D], C. Nitsche[E], and M. Seyfarth[A]

[A]Umwelt-Geräte-Technik GmbH, Müncheberg,(Branch South, Freising), Germany, Email sascha.reth@ugt-online.de
[B]Bavarian Environmental Agency, Wielenbach, Germany
[C]Helmholtz Zentrum München, German Research Center for Environmental Health, Institute of Soil Ecology, Department of Environmental Engineering, Neuherberg, Germany
[D]Lehrstuhl für Bodenkunde, TU München, Freising-Weihenstephan, Germany
[E]BGD Boden- und Grundwasserlabor GmbH, Dresden, Germany

Abstract
Generally research fields of lysimeter studies scheduled as long term experiments. In the course of the studies, the lysimeters act more or less as a “black box”. Usually the soil material is identified and analyzed at the beginning of the experiments, but there is also a strong need to analyze the soil without disturbance of the soil structure after the experiments in order to obtain information about spatial and structural changes within the soil profile. The new technique of the Lysimeter Soil Retriever (Reth *et al.* 2006; 2007; Seyfarth and Reth 2008) for the first time enables studies on the heterogeneous migration of percolating water, and changes of soil structure as well as soil organic matter (SOM) and biomass distribution, as well as the distribution of mycorrhiza and microbes in different depths on intact soil profiles. The main target by using the LSR is the preparation of an intact soil monolith from the field lysimeter and the immediate dissection into slices to enable a direct sampling of its soil environment at several depths. Distribution and composition of SOM, pF-values, soil porosity, as well as degradation of PAH were only a few parameters, which are determined at the different soil depths. In this presentation we give some examples for the different application of the LSR and the advantage for the experiments:

Introduction
Objectives of the retrieving the lysimeter soil:

- Compare chemical and biological soil functions, which are affected in long term experiments
- Clarify the lysimeter vessel’s effect on the soil (e.g. side effects)
- Measure changes in the top soil, e.g. packing, root distribution, aeration, water conductance, biological activities
- Quantify changes in soil physical parameters within long term experiments that used lysimeters as well the reference site

Measurements
Example 1: In a lysimeter study, the impact of elevated ozone concentration and root pathogen infection on the plant-soil-system of young beech (*Fagus sylvatica*) trees was assessed down to 2 m depth with a high vertical resolution. Due to the accurate sectioning of the soil monoliths a very dense and intensive soil sampling was possible. Fine root biomass below 1 m depth was significantly reduced under elevated ozone while fine root biomass increased in soil deeper than 20 cm when trees were infected with the pathogen (Figure 1). As the whole soil space of 8 lysimeters could be sampled, precise spatial information were obtained about the rapid formation of SOM depth gradients within the duration of the experiment (Figure 2).

Example 2: After the investigation on the mobilization of polycyclic aromatic hydrocarbons (PAH) by the seepage water, the lysimeter soil was retrieved. Investigations on the microbiological degradation of the PAH were possible in the whole soil monolith. From spring 2004 to October 2006 a lysimeter (1 m² x 1.40 m depth) installed on the test area Wielenbach was investigated on the mobilization of polycyclic aromatic hydrocarbons (PAH) by the seepage water. The soil originated from a sleeper factory of the Deutsche Bahn at Kirchsee on (Oberbayern, Germany) was contaminated by PAH with a concentration of 16 mg/kg soil. The slices were analyzed to get information about the heterogeneity of the migration of the percolating water.

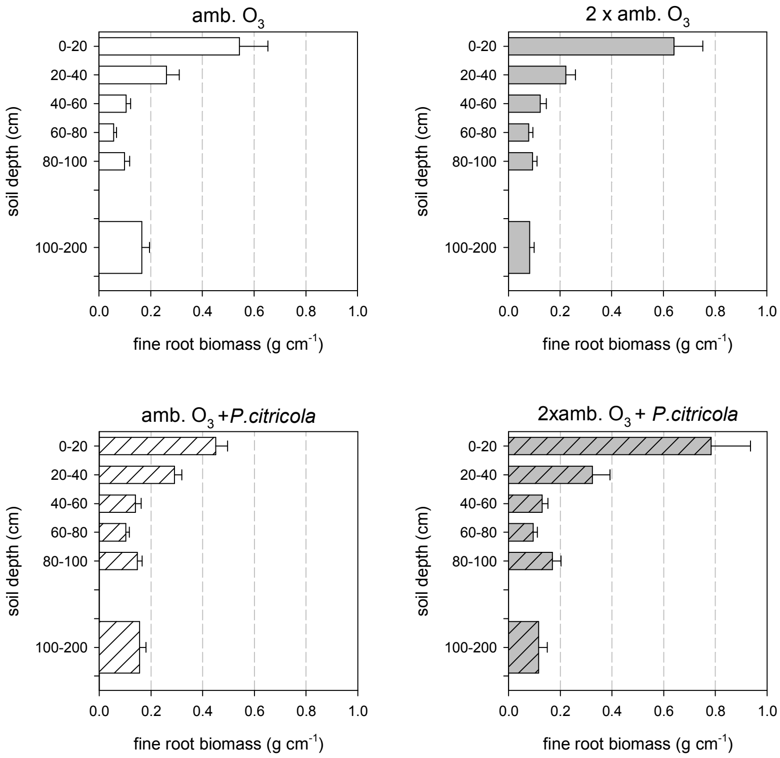

Figure 1. Vertical distribution of fine roots per tree and depth in the four treatments. Root biomass that was estimated for each depth was equally distributed to 1 cm. Given are means ± 1SE, *n*=8. (Winkler *et al.* 2009).

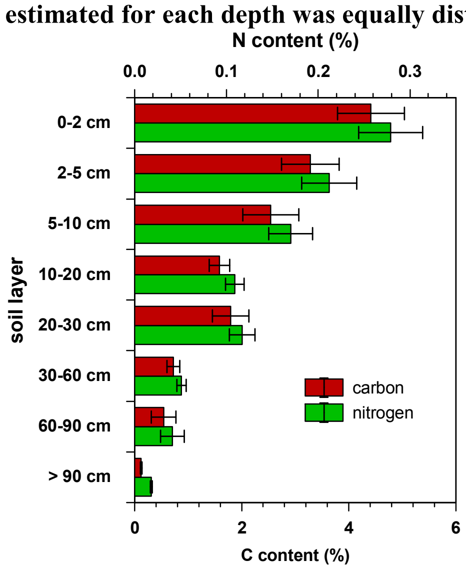

Figure 2. The dense sampling of the lysimeters ensured a detailed study of the reforming depth distribution of SOM properties (Mueller *et al.* 2009).

Example 3: After the investigation on the migration behavior of BTEX (Benzol, Toluol, Ethylbenzol and Xylol), MKW (oil hydrocarbons), PAK (polycyclic aromatic hydrocarbons) and Phenol, the soil in a lysimeter was retrieved to get information about the soil properties. To predict the seepage water in the region of selected contaminated areas of the ecological project “SOW BÖHLEN”, the lysimeter soil was retrieved to get the balance of the migration. The course of the BTEX concentration in the percolating water is given in figure 5.

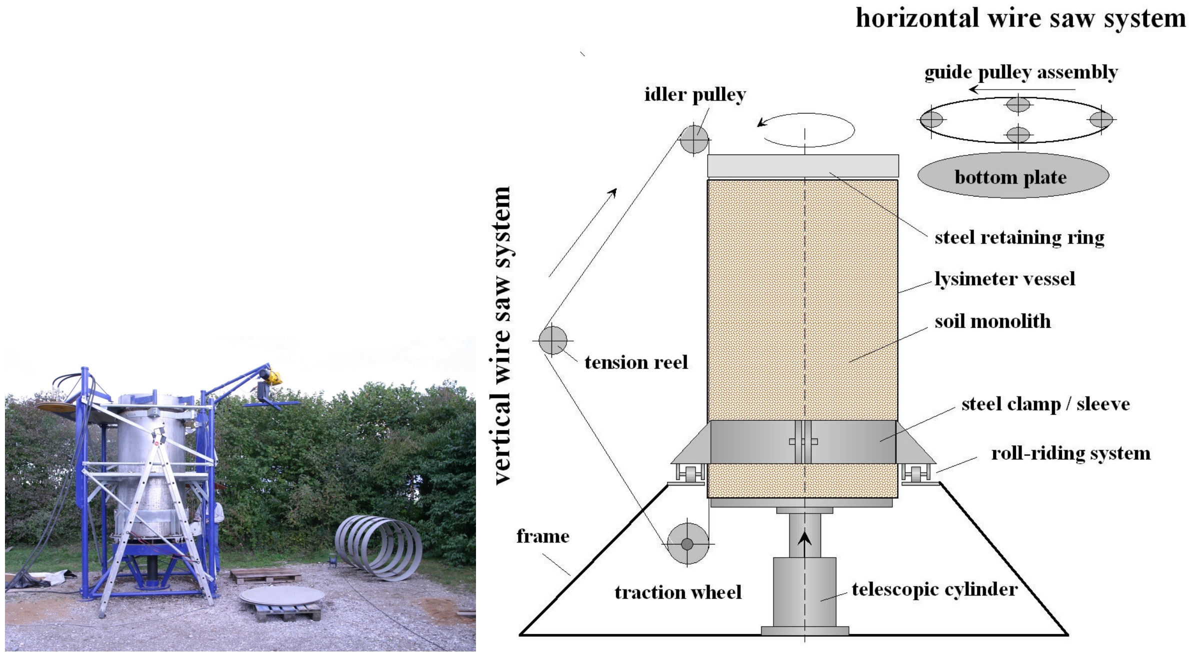

Figure 3. a) LSR in preparation for slicing a monolith, b) and the scheme of the apparatus.

Figure 4. Freshly cut soil slices (diameter 1.13 m, thickness 20 cm), 1) topsoil 0-20cm; 2) 20-40 cm; 3) 40-60cm; 4) 60-80 cm

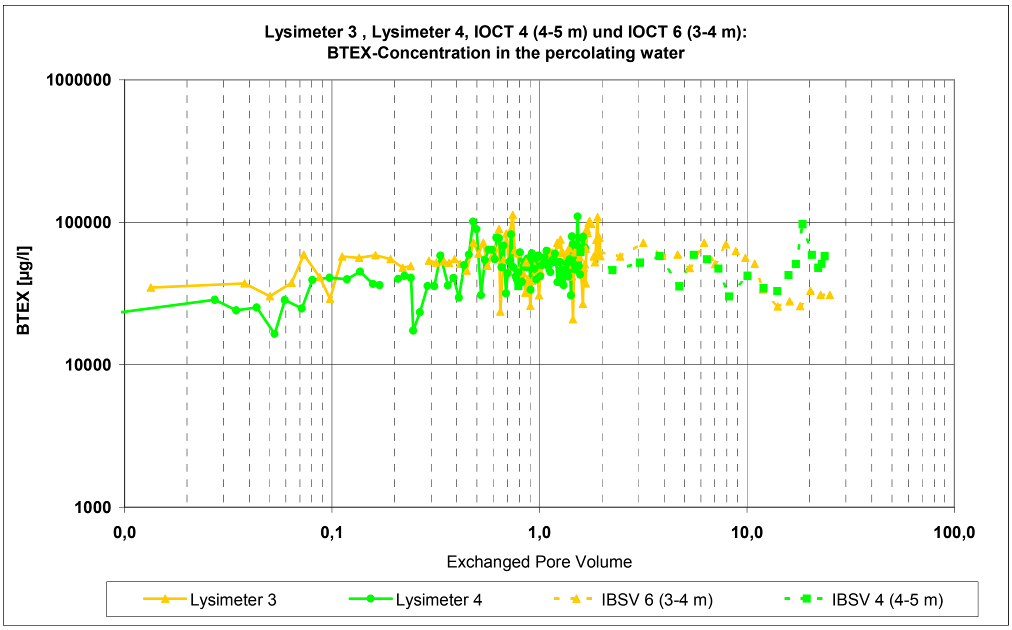

Figure 5. Lysimeter Tests in comparison with the results of IOCT in the laboratory scale EPV = cumulative soil water outflow/ pore volume.

Conclusions

This technique allows, for the first time, the analysis of the soil without disturbing a long-term experiment. Retrieving intact soil slices allows for a much broader range of applications of lysimeters. The main goal, was the retrieval of intact soil monoliths from the lysimeters, and the immediate dissection into slices, such that the rhizosphere and its soil environment can be directly probed at several depths. The complete harvest at the end of the experiment by using the LSR technology enabled for the first time the assessment of fine and coarse root biomass of individual beech trees with a high vertical resolution down to two meter depth. The development of depth gradients of SOM composition and distribution within 4 years after soil disturbance and homogenization was studied in a lysimeter experiment with juvenile beech trees (*Fagus sylvatica* L.). By this approach it was possible to imitate the ploughing and concomitant planting of trees as it is common for newly established forests. The use of lysimeters with homogenised soil in eight replicates enabled an experiment unbiased by field scale heterogeneities. The sampling scheme applied to the given dense soil layers (0–2 cm, 2–5 cm, 5–10 cm and 10–20 cm) was crucial to study the subtle reformation of SOM properties with depth in the artificially filled lysimeters. Due to the combination of physical SOM fractionation with the application of ^{15}N-labelled beech litter and ^{13}C-CPMAS NMR spectroscopy a detailed view was obtained on vertical differentiation of SOM properties.

References

Mueller C, Bruegemann N, Pritsch K, Stoelken G, Gayler S, Winkler JB, Kögel-Knabner I (2009) Initial differentiation of vertical soil organic matter distribution and composition under juvenile beech (*Fagus sylvatica* L.) trees. *Plant and Soil* DOI 10.1007/s11104-009-9932-1.

Reth S, Seyfarth M, Gefke O, Friedrich H (2007) Lysimeter Soil Retriever (LSR) - a new technique for retrieving soil from lysimeters for analysis. *Journal of Plant Nutrition and Soil Science* **170**, 1-2.

Reth S, Seyfarth M, Gefke O and Friedrich H (2006) Deutsche Patentanmeldung „Vorrichtung zur Entnahme eines Bodenmonolithen aus einem Lysimetergefäß". Anmeldedatum 27.02.2006, Patentnr. 10 2006 010 158.

Seyfarth M, Reth S (2008) Lysimeter Soil Retriever (LSR) – An application of a new technique for retrieving soils from lysimeters. (2008) *Water, Air, & Soil Pollution: Focus* **8**(2), 227-231.

Winkler JB, Fleischmann F, Gayler S, Scherb H, Matyssek R, Grams TEE (2009) Do chronic aboveground O_3 exposure and belowground pathogen stress affect growth and belowground biomass partitioning of juvenile beech trees (*Fagus sylvatica L.*)? *Plant and Soil*, DOI 10.1007/s11104-009-9968-2.