Lysimeter Stations and Soil Hydrology Measuring Sites in Europe - Results of a 2004 Survey

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Abstract

The main goal of a diploma thesis was to provide an overview of **lysimeter types** used in Europe and to show their employment in **research centres**. Purpose, details on equipment, research results and future perspectives of lysimeter facilities were arranged logically and presented clearly. To gain data of lysimeter operators and their stations a **questionnaire** was sent out. According to that survey, 117 institutions in Europe operate ca. **2930 lysimeters/seepage water samplers** in 18 countries. 2440 of the total number are lysimeter vessels. **More than half of all vessels (54 %)** are used for studies of **arable land**. The main challenges for research in the future are calibrating numeric soil water and nutrient transport models with data collected by lysimeter studies as well as improving precise measuring methods.

Lysimeter- und bodenhydrologische Forschungsstationen in Europa - Ziele, Ausstattung, Ergebnisse, Perspektiven

Im Rahmen einer Diplomarbeit wurden die europäischen Lysimeter- und bodenhydrologischen Messstationen hinsichtlich ihrer Zielsetzung, den Ausstattungsmerkmalen (z. B. Lysimetertypen, installierte Sonden), ihren Forschungsergebnissen und zukünftigen Entwicklungen erfasst. Um diese Informationen einzuholen, wurden an die Betreiber von Lysimeterstationen eigens entwickelte **Fragebögen** ausgesandt. Der Auswertung der Umfrage zufolge betreiben in 18 Ländern ca. 117 Institutionen etwa **2930 Lysimeter/Sickerwassersammler (SWS)**, davon sind 2440 Lysimetergefäße, die zu ca. 84 % nicht wägbar und zu etwa 30 % monolithisch befüllt sind. Lysimeter werden zu fast **zwei Drittel** für **ackerbauliche** Fragestellungen, SWS vermehrt im Grünland (41 %) eingesetzt. Der Gesamtanteil aller Gefäße im **Ackerland** beläuft sich auf etwa **54 %**.

Die Herausforderungen für zukünftige Forschungen liegen vor allem in der Übertragung von gemessenen punktbezogenen Daten mittels numerischer Bodenwasserhaushalts- und Stofftransportmodelle sowie in der Verbesserung der präzisen Messtechnik. Als Schnittstelle für einen erweiterten Informationsaustausch sind die Stationsbeschreibungen im Sinne einer **Lysimeterplattform** unter http://www.lysimeter.at → Stationen abrufbar. Die kartographische Darstellung und Navigation unterstützt den Besucher bei der Lokalisierung der einzelnen Messstellen.

Introduction

The purpose of this paper is to present the main results of the diploma thesis - which was finished in December 2004 - concerning lysimeter stations and soil hydrology measuring (SHMS) sites of Europe. As lysimeter studies are important for many research fields such as **(soil) hydrology, agricultural** and **forest economy** or ecology, it is important to get to know about lysimeter types built in at measuring sites and to describe future developments of lysimeter research.

In the thesis, lysimeter types used in Europe were described and then summarized according to the following four important criteria to provide as much information as possible in the name of the type: **weighing possibility, soil filling technique, if seepage water is collected gravimetrically**, and **groundwater connection**. I decided not to take the size or shape (square, cylindrical) of the vessels first because the four parameters tell us **more about the use of lysimeters at a glance**. The size (and shape if known) of each lysimeter is provided in the description of the stations, see homepage (described in section 5/lysimeter platform). For example, combined types are called *non-weighable backfilled gravitation lysimeter, weighable monolithic gravitation lysimeter, etc.* To distinguish between lysimeter vessels mentioned before and larger test areas, a separate category for **"large lysimeters/test areas"** was created, meaning big trays or geomembrane being backfilled with soil or substrate - only at one station is the soil undisturbed. According to information reported in the questionnaires their surface is between 30 m² and 670 m² (LANTHALER, 2004).

Several seepage water samplers/SWS were also divided into two main categories: SWS with or without applied vacuum. The main difference between an SWS and a lysimeter is that an SWS does not have a side border to the soil surface and is in general smaller than a lysimeter (STENITZER in v. UNOLD 2003, pp 9-10).

Developing a Questionnaire and Searching for Operators

To gain data about lysimetric stations around Europe, I developed a questionnaire (in MS Excel) that I sent to operators by e-mail with a request to complete it. I extracted general information about lysimeter types and soil hydrology measuring equipment/methods and their use from proceedings of the BAL Gumpenstein (1991-2004) and arranged questions about

- research purpose of the stations, general data about lysimeter types, number of lysimeters/vessels and seepage water determination,
- the surrounding area (topographic features), mean annual temperature and

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precipitation, etc. to describe the lysimeter sites geographically, and also about the meteorological parameters that are determined,

- soil (fractions, types, horizons) and vegetation types of the locations,
- data storing and managing and formulas used to determine evapotranspiration and water balances or models used and their goals to facilitate the exchange of information among lysimeter operators,
- future development of the stations (see section 6) which is an important part of the survey,
- contact information (address, Web site, etc.).

I completed the questionnaire according to detailed information about lysimeter types provided in DVWK 1980 and according to a questionnaire by KRETZSCHMAR which was sent to German lysimeter operators in 1996/1997.

I looked up operator contact information in proceedings, other articles and on the internet using a Web search engine to search for universities, research centres, or other institutions related to lysimeters and soil hydrology. More than 250 e-mails were sent either with a general request or the attached questionnaire. After I had got back several questionnaires, I created an MS Access database to easily arrange all the data and to build queries for several evaluations. Data was collected from June to November 2004.

53 operators of lysimeter sites sent back a completed questionnaire, 22 sent information by e-mail (and attached files with general information about their sites or research articles); four operators provided site information by post; some operators sent additional research articles by post. I also collected papers and information during the lysimeter excursion in October 2004 (Croatia and Slovenia) and extracted information from proceedings and excursion reports (BAL Gumpenstein, GSF Neuherberg - e.g. KLOTZ, 2002, 2004), a survey by KRETZSCHMAR, 1999 and his compilation of German lysimeters, a DVWK publication with descriptions of weighable lysimeters in Germany (current as of 1990) and a number of Web sites and pdf articles. Except for three lysimeter stations in France, information about sites in that country was extracted from MULLER, 1996, who lists lysimetric research centres in France up to 1990.

Lysimeter Sites in Europe

268 data records are stored in the database providing information about approximately 220 locations and the different lysimeter types used at these sites (including all inactivated lysimeter sites and SHMS). The exact number of sites cannot be quoted as some operators use lysimeters at different locations which are summarized in the database and the map. The area of investigation is shown in *figure 1*: I sent inquiries to **37 countries**; Luxembourg and Liechtenstein are definitely not operating SHMS/lysimeters. In 17 countries it was not possible to find any lysimetric stations, or I did not get a response. Map 2 provides information about lysimeter sites in Germany, the Czech Republic, Austria and Slovenia. **Lysimeter facilities** are classified as sites with at least three lysimeters or two lysimeters and SWS (most of the facilities have a lysimeter cellar); **stations** are operating less than three lysimeters and (several) SWS; lysimeter sites at several locations are sometimes summarized to one "station". SHMS and SWS sites are indicated with other symbols (see maps).

According to the survey, **2930 vessels** including SWS and large lysimeters/test areas **(2440 lysimeters)** are installed at **178 sites** around Europe (by 117 institutions), but as information on some stations, on numbers of vessels implemented at several stations or on whether some vessels are still operating is missing, exact figures cannot be provided and the total number of vessels and sites has to be higher. *Figure 3* shows that the **majority** of lysimeter vessels (84.2 %) are **non-weighable**. More than two thirds (68.5 %) of the non-weighable lysimeters are backfilled, whereas about 46 % of all ponderable lysimeter vessels are filled monolithically. Weighability of about 117 vessels could not be determined. About 239 groundwater lysimeters are in use - 236 of them in Germany, three in Scotland.

The **oldest vessels** still operating were installed around 1880 at the site of Rothamsted Research, United Kingdom (two non-weighable monolithic gravitation lysimeters), and at the facility Limburgerhof, Germany, 234 non-weighable back-filled gravitation lysimeter vessels built in the years 1927/30 are still working. The **largest number** of lysimeters at one site was counted in Szarvas, Hungary, where 320 non-weighable backfilled vessels are implemented, and at Limburgerhof, Germany (252 backfilled and monolithic lysimeters). In 2004, **new lysimeters** were built in several countries (sites): Austria (Wagna), France (Villié-Morgon), Germany (Munich/Freimann and Braunschweig/Völkenrode), Ireland (Johnstown Castle, Wexford) and United Kingdom (Allt a'Mharcaidh Experimental Site, 5 plots).

Lysimeters/SWS in Europe are used predominantly for **agricultural research**, see *figure 4*: More than half (1590) of all vessels and 62 % of all lysimeters (1511) but only 16 % of all SWS are installed in arable land/fields, or crops, vegetables, etc. are cultivated on the lysimeters. As the use of many SWS is not known, the number of SWS installed in arable land could be much higher.

On about one fourth (755 lysimeters/SWS, 553 lysimeters), different types of **grass** are planted (including peatland vegetation) and 126 lysimeters (5 %) are used under bare soil. The figures change from season to season because of crop rotation (e.g. bare soil is then cultivated) and the purpose of 104 vessels is variable. In **forests**, only 1 % of all lysimeters (including four large lysimeters/test areas) are employed but the proportion of SWS used in forests is much higher (8 %). A reason for this might be that smaller trays are easier to install in forests than large lysimeters. 10 % (298) of the vessels were not classified. Lysimeters and test areas at eight sites are used to investigate leaching of **dumps/landfills** or testing **surface-sealing systems**.

31 SHMS were counted, where **probes** for measuring soil water content, matric potential or for gaining samples of soil water (TDR probes, gypsum blocks, tensiometers, or suction cups, etc.) are installed.

Figure 1: **Lysimeter sites in Europe (according to the survey 2004)**

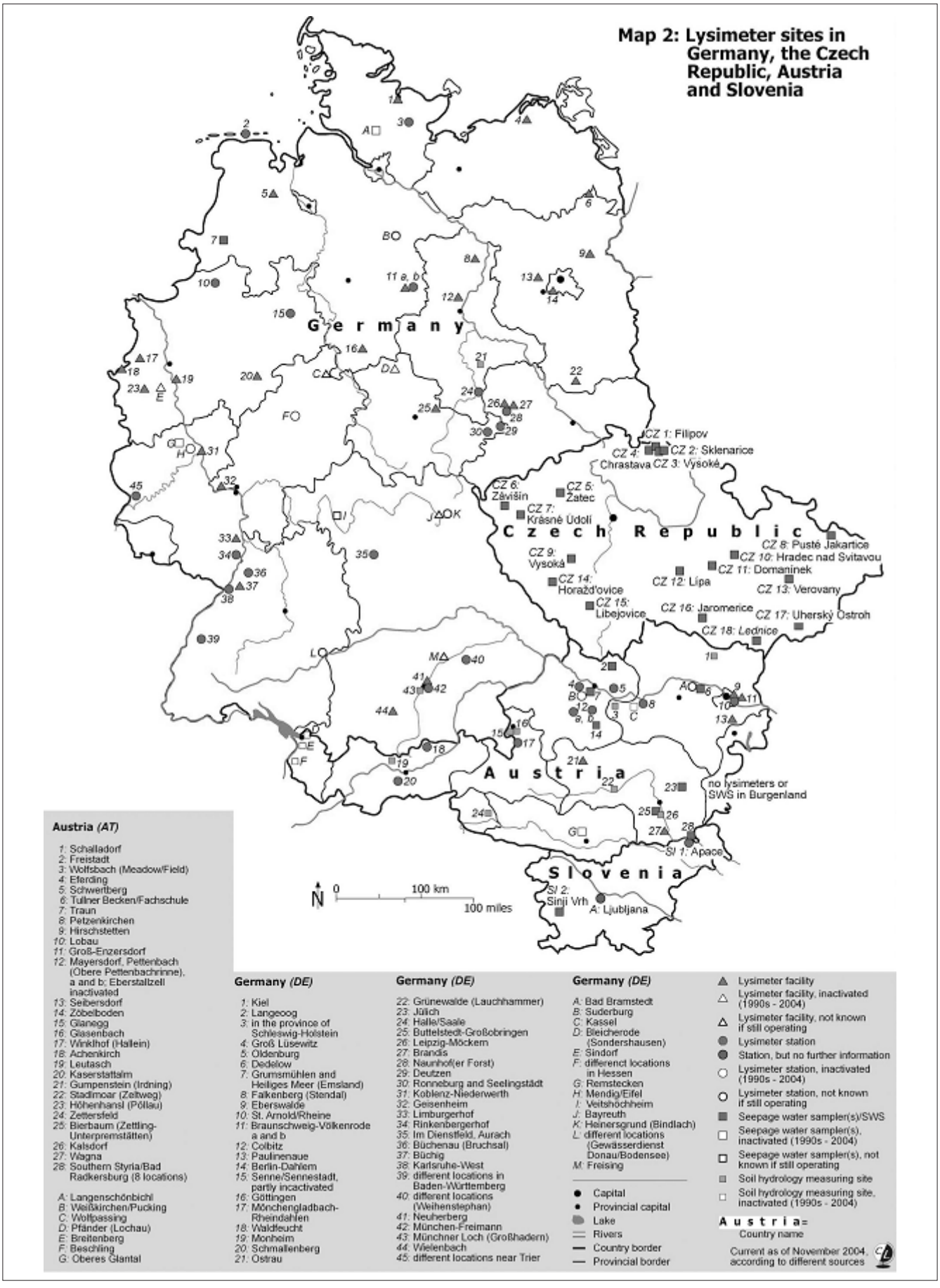

Figure 2: **Lysimeter sites in Germany, the Czech Republic, Austria and Slovenia (according to the survey 2004)**

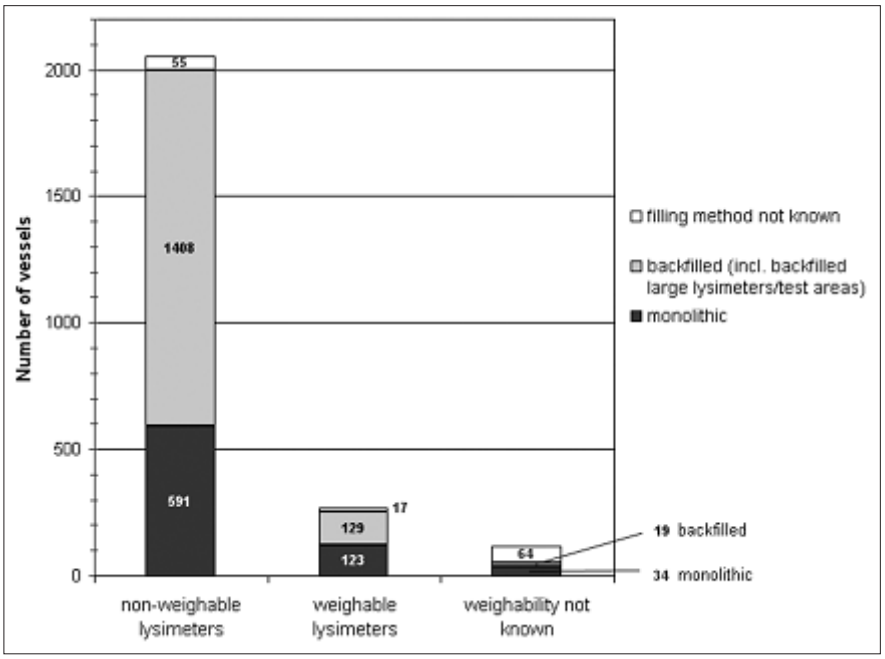

Figure 3: **Division of non-weighable and weighable lysimeters and their soil filling method (backfilled or monolithic, according to the survey 2004)**

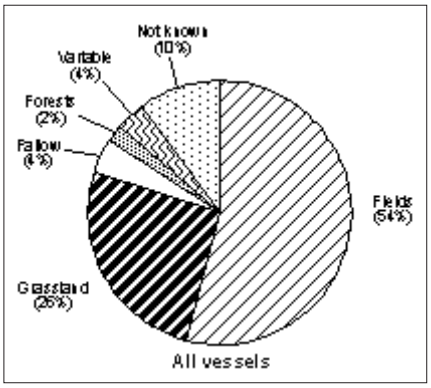

Figure 4: **All lysimeters and seepage water samplers installed in Europe according to their main vegetation type (according to the survey 2004)**

Lysimeter Platform on the Internet

To show clearly arranged descriptions about lysimeter and soil hydrology measuring sites and to provide access to their research results on a Web site for making an exchange of experience possible and information easily accessible, the **European Lysimeter Platform (EuLP)** has been established. It was designed for researchers interested in lysimeter studies, operators of lysimeter stations who want to get information about other sites or who want to get in contact with researchers in other countries, or research centres looking for cooperation. The EuLP Web site is integrated in the homepage of the Austrian Lysimeter Research Group/AG Lysimeter http://www.lysimeter.at → Stationen; it is directed at all users of this homepage. **Maps** with clickable symbols for lysimeter locations, **photos** and **sketches** of lysimeters and facilities increase the information content; **research reports** of studies are provided for **downloading** (pdf files).

Conclusion and Future Perspectives

An important question in the survey was to find out the future developments and goals that lysimeter/soil hydrology is aiming at. While some lysimeters (mostly old, outdated vessels) were inactivated during the past few years, new lysimeters were installed, even as recently as 2004 (see section 4). Several new containers were/are going to be implemented at large facilities, some at smaller ones supply data for specific project studies. The **most important research goals for the future are**:

- to determine seepage water quality and quantity for modelling; to calibrate and verify water movement and solute transport models; to determine water/nutrient balances,
- to investigate soil and groundwater protective cultivation systems (organic farming),
- to compare lysimeter data with data of undisturbed soil outside the vessels and to compare results (leaching) of different soil types but under same cultivation conditions,
- seepage water prediction: source term determination (contaminants released of contaminant materials/waste soils), (long-term) monitoring of fate of pollutants in soil,
- to determine soil hydraulic parameters.

Measuring results with high precision in time and space combined with results of lysimeters/soil hydrological probes in different depths are important for calibrating new and adjusting existing numeric water balance and nutrient transport models (SEEGER et al. in BÖHM et al. 2002). In order to assure sustainable soil and groundwater protective ground cultivation it is important to control soil water budget and seepage water processes using lysimeter studies.

Acknowledgement

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