Identification of discrepancies on water quantity and quality data according to lysimeter types

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Abstract

Data from lysimeter studies allow to get a better understanding on water and nutrient transport in the unsaturated zone of the soil. However, different lysimeter types exist and may induce inconsistencies on data interpretation as they function differently. In HBLFA Raumberg-Gumpenstein, research on nutrient leaching are carried out with three lysimeters types: monolithic, gravitational and seepage water collector (SWC). This study identified monolithic lysimeter as a good device for water quantity monitoring while seepage water collector appeared to better represent water quality parameters. Differences between zero-tension (monolithic) and tension (SWC) lysimeters have been discussed and may explain this distinction of purpose.

Introduction

Lysimeter studies are viewed as a way to explain better biogeochemical phenomena occurring in the soil and, therefore to explain potential causes of nutrient leaching under different agricultural systems. However, before to use lysimeter as a mean to understand nutrient cycling and appreciate which biogeochemical processes occur in the soil, it is important to assess the difference among lysimeters type to evaluate which one is the most suitable for the research to carry out. In HBLFA Raumberg-Gumpenstein, research on nutrient leaching are conducted with three types of lysimeters: monolithic, gravitational and seepage water collector (SWC). This report focuses on identifying differences among lysimeters and determines which lysimeter type is the most suitable according to the research goals.

Literature review

Lysimeters can be classified under 2 types: (1) tension lysimeter and (2) zero-tension lysimeter. Suctions cup or seepage water collectors are two types of tension lysimeter based on the principle to apply a pressure into the soil vadose zone to extract the pore water and sample soil solution. Zero-tension lysimeter (monolithic, gravitational) collect soil water from the saturated flow by gravitation force. Water sampled from this device appears to represent better water flowing into the groundwater.

Tension lysimeter for water quality parameters

In term of water quality monitoring, difference among lysimeter may induce a disparity in nutrients concentration according to the lysimeter type used to collect soil water. HAINES et al. (1982) discussed the relevance of using tension lysimeter for sampling the non-saturated flow. In support of these conclusions, AVILA et al. (1995) stated that free flowing soil water is representative of saturated flow while soil solution collected by tension lysimeter can be more predictable in term of solutes concentration. Water collected from non-saturated flow experiences natural processes such as nutrient uptake, cation exchange and drying-wetting cycle, due to a longer retention time inducing sorption and biological processes to better take place. As well, seasonal variability was observed in water collected from the tension lysimeter while free flowing samples did not reveal any temporal variability (AVILA et al., 1995). This conclusion reinforces the demonstration of the higher incidence of biological processes on soil solution sampled by tension lysimeter.

Water flow and Artificial boundaries effect

It is well accepted in the literature (HAINES and WAIDE, 1979; BINKEY et al., 1982; GROSSMANN and UDULF, 1991; AVILA et al., 1995) that collected volume of water by tension lysimeter is not a good representation of water flow to determine solute loads and that only solutes concentration data in soil solution are valued for interpretation. Tension lysimeter exerts a pressure into the soil to sample water present in the pores of the soil. This corresponds to a non-saturated flow that is not representative of the amount of water that will leach into the groundwater. At the reserve non-tension lysimeter, based on gravity forces, collects water that is susceptible to leach in deeper layer of the soil and to groundwater.

Furthermore, lysimeter are devices build with artificial boundaries, which may create discrepancies in the natural flow that water may undertake (LOGSDON et al., 2002). As well, these artificial boundaries may favored some vertical flow and not consider integrally the possible lateral flow occurring in nature as a response to concentration gradient and variability on water velocities within the soil material. At the opposite, the use of tension lysimeter, by applying pressure into the vadose zone, may replicate the natural condition of vertical flow induced by ET and flow to groundwater.

In sum, differences among lysimeters type are well recognized but not yet really well understood and/or documented. This study aims to identify differences among lysimeters and determine which lysimeter type is the most suitable according to the research that will be carried out.

Materials and Methods

Three kinds of lysimeters -monolithic, gravitational and seepage water collector- are used to collect soil water under different land uses in "HBLFA Raumberg-Gumpenstein", Austria. For each lysimeter type, 5 different land use managements are examined, combining 3

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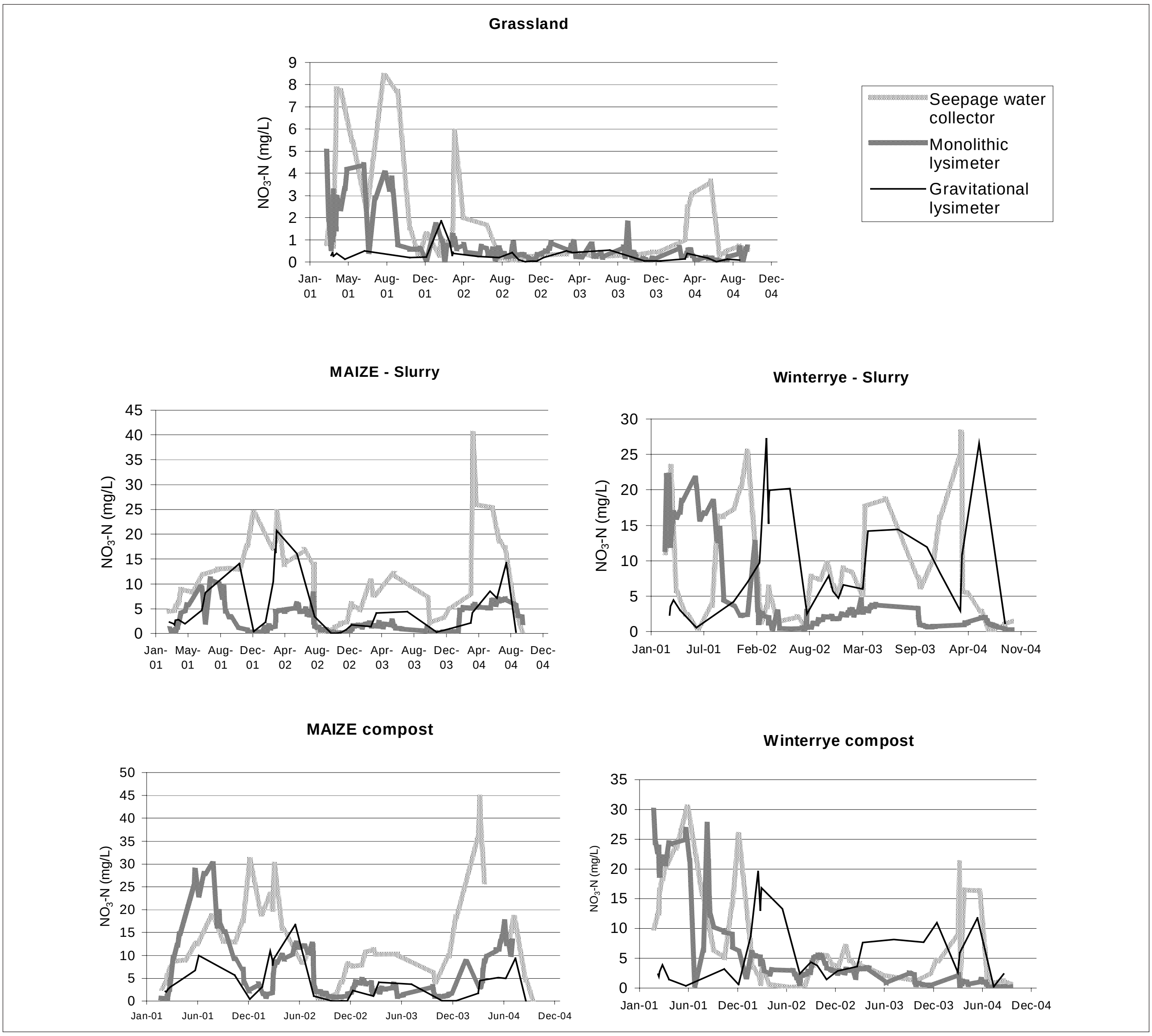

Figure 1: **Nitrate-N concentration under different land use according to lysimeter type**

types of culture (maize, winter rye and grassland) and 4 fertilization schemes (2,7 GVE and 2 GVE as manure or compost). Detailed description of lysimeters can be found in EDER, 1991. We collect water samples after each rain event. Data from chemical analysis have been examined from January 2001 to September 2004. Nitrate concentration (trend and descriptive statistic) and amount of water collected (descriptive statistic) have been compared according to lysimeter type in this report.

Results and Discussion

Data from each lysimeter type (especially for monolithic lysimeter, *Figure 1*) showed clearly that, during the first year of establishment, water chemistry data varied with no consistent pattern and within a higher range than the following years. As lysimeters are set up, site conditions (soil, vegetation) are disturbed and to get back to a stable state, experiment demonstrated that a minimum of 1 year after establishment was needed to obtain accurate data.

Nitrate concentration: Seepage Water Collector (SWC) for water quality monitoring

Higher and more variable nitrate-N concentrations have been observed in water collected by the tension lysimeter (SWC: up to 45mg/L) followed by data from the gravitational lysimeter (*Table 1*). Seasonal variability in nitrate concentration was observed with more consistency in water collected from SWC (*Table 2*). In SWC, nitrate concentrations in winter (from Nov, 1st to April,30th) appeared to be higher than in summer. This may reveal the importance of snowmelt occurring in early spring and nutrient uptake by plants during the growing

Table 1: **Nitrate-N concentration (in mg/L) according to lysimeter type (2001-2004)**

	SWC	Monolithic	Gravitational
Mean	8,51	4,00	4,91
Max	44,57	29,99	27,34
Min	0,04	0,00	0,00
St.dev.	8,83	5,64	5,80
CV (%)	96	71	85

Table 2: **Nitrate-N concentration (mg/L) per season and land use**

		SWC		Monolithic		Gravitational	
		mean	winter/summer	mean	winter/summer	mean	winter/summer
Maize-Slurry	summer*	9,40		4,14		6,25	
	winter**	11,99	1,28	2,04	0,49	4,29	0,69
Maize-Compost	summer	8,42		10,93		5,73	
	winter	16,10	1,91	3,81	0,35	3,04	0,53
Winterrye-Slurry	summer	6,21		4,86		9,36	
	winter	11,95	1,92	5,64	1,16	8,41	0,90
Winterrye-Compost	summer	6,62		5,38		4,85	
	winter	9,07	1,37	7,87	1,46	5,91	1,22
Grassland	summer	1,96		1,00		0,34	
	winter	1,86	0,95	0,95	0,95	0,32	0,94

* summer from May, 1st to Oct, 31st; ** winter from Nov, 1st to April, 30th

Table 3: **Amount of water collected (in mm) according to lysimeter type and land management scheme from 2001 to 2004**

		Seepage water collector		Monolithic		Gravitational	
		Total amount of water collected	%cf preci-pitation**	Total amount of water collected	%cf preci-pitation**	Total amount of water collected	%cf preci-**pitation
Land use	Grassland	1049	26	1764	43	1286	32
	Maize	1323	33	2073	51	1260	31
	Winter Rye	1967	48	1872	46	1131	28
Fertilization management*	Slurry	1645	41	2092	52	1160	29
	Compost	1645	41	1853	46	1231	30
Average		1645	41	1972	49	1196	29

*Excluding grassland; **total precipitation from 01-01-01 to 01-09-04 = 4058,3 mm

season (summer). Water collected from SWC is the result of the extraction of non-saturated flow in the soil. Therefore, this device may be more sensitive to any changes of soil-water dynamics and may be of greater value to assess biogeochemical processes happening in the soil materials. As AVILA et al. (1995) demonstrated water chemistry from tension lysimeter might be the result of longer retention time inducing sorption and biological processes to better take place in the soil solution. Results from this study are in agreement with these conclusions, no matter the field setting (land use and fertilization scheme). Furthermore, important differences in the winter/summer ratio can be observed among lysimeter types and land use management (*Table 2*). These disparities reinforce the distinction between tension and zero-tension lysimeters, explained previously, and underline the importance of management practices in preventing nutrient leaching.

Water amount: Monolithic lysimeter for water quantity monitoring

Overall, more water is collected from monolithic lysimeter than from any other lysimeter type. Interestingly, more water is collected from seepage water collector than from gravitational lysimeter (*Table 3*).

According to literature (HAINES and WAIDE, 1979; BINKEY et al., 1982; GROSSMANN and UDULF, 1991; AVILA et al., 1995), tension lysimeter -SWC- are representative of non-saturated flow, while non-tension lysimeter -monolithic and gravitational- collect water from saturated flow and appear to be more representative of the amount of water that leached through the soil. Also, as a consequence, it seems that more water is collected from these lysimeters (HAINES et al., 1982). These statements had been verified for monolithic lysimeter, but interestingly, seepage water collectors tend to accumulate more water than the gravitational lysimeter (except for grassland, *Figure 1*). This can be attributed to the location of our gravitational lysimeters, situated at the top of the slope, so no collection of downhill surface and subsurface flow can occur and the devices are more subject to wind (e.g. oasis effects).

As well, it can be inferred that the amount of water collected from monolithic lysimeters is more representative than the one for SWC: its artificial boundaries allow to sample accurately water on a 1m² basis, while for SWC surface and subsurface lateral flow may interfere in the computation of amount of water collected in a 1m² basis. In this specific case, the artificial boundaries of the lysimeter may be of benefit, even if it is not well representative of natural conditions (LOGSDON et al., 2002). Furthermore, it seems that nitrate-N concentration data from monolithic lysimeter are more precise than in the others lysimeter (*Figure 1*). This may reflect the higher rate of water collected that allow to get more data and therefore maybe an apparent better precision.

Leaching loads issues

Potential nutrient loss and its impact on surface and groundwater quality depend essentially on the type of solutes observed and the rate and pathway of water movement through the soil (EDIS and WHITE, 2003). Models based on transport volume functions processes explained the solutes-water interaction leading to nutrient leaching. Lysimeter studies are based on the controlled of nutrient input and allow to measure nutrient output, by collecting soil solution. Therefore, use of lysimeter data -representative of water movement and type of solutes in the soil solution- to validate these models can be of great importance. Lysimeter studies could help to enlighten the biogeochemical processes leading to nutrient leaching and should help to define best management practices (BMP) to preserve the mountains water quality.

However, it appears that difficulties for nitrate loads comparison and interpretation of observations occurred as one type of lysimeter appears to assess quite accurately the amount of water that percolates through the soil while this other is of better use to assess nitrate concentrations in water collected. As nitrate loads or leaching are the result of these 2 components, accurate conjecture on leaching is difficult. It will be important to consider the potential lysimeters errors highlighted in this paper when interpreting and analyzing data and results, and advising BMP.

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