C. R. Geoscience 347 (2015) 317–327

Contents lists available at ScienceDirect

Comptes Rendus Geoscience

www.sciencedirect.com

Hydrology, Environment (Surface Geochemistry)

Insights into stable isotope characterization to monitor the signification of soil water sampling for environmental studies dealing with soil water dynamics through the unsaturated zone

Agnès Brenot [a,c,*], Marc Benoît [b], Jean Carignan [a], Christian France-Lanord [a]

[a] *CRPG, Centre de recherches pétrographique et géochimiques, 15, rue Notre-Dame-des-Pauvres, 54501 Vandœuvre-lès-Nancy, France*
[b] *INRA, station Sciences pour l'action et le développement, 662, avenue Louis-Buffet, 88500 Mirecourt, France*
[c] *BRGM, Regional Service, 151, boulevard de la Bataille-de-Stalingrad, 69626 Villeurbanne, France*

ARTICLE INFO

Article history:
Received 30 January 2015
Accepted after revision 1st May 2015
Available online 2 July 2015

Keywords:
Drainage samplers
Porous ceramic cup samplers
Stable isotope
Soil–water
Rainwater
Residence time

ABSTRACT

Porous cup samplers and drainage samplers are two of the broadly used techniques to monitor soil water for agronomical studies. This study provides further insight into the sample signification of these two sampling techniques. For that purpose, temporal variations of soil water δD and δ^{18}O values collected by these two techniques have been monitored for an experimental field studied by INRA. The stable isotope data acquired provide further evidence that soil water samples collected by these two techniques are not equivalent and correspond to different water dynamics in soils: 1) quick infiltration along preferential flow paths for drainage (short residence time) and 2) water with longer residence time for porous cups. This implies that stable isotopic tools could be useful to provide additional information to "classical" monitoring of soil water. This could be of particular interest to estimate the residence time of soil water and could be relevant to follow the effectiveness of agricultural pressure reduction programs on natural water ecosystems.

1. Introduction

Comprehension of water movement in soils is of primary importance, in particular to understand how the contaminants are transported from the sub-surface, through the soils, to surface water and groundwater reservoirs. This understanding is a key point to help decision makers adjust their choices when managing water-quality problems, especially those related to agricultural pressures. Numerous approach have been studied to assess and quantify preferential flow in soils (for laboratory and field techniques used to evaluate preferential flow in soil, see Ladouche et al., 2001; Viville et al., 2006, and the review by Allaire et al., 2009, and for water flow and tracer transport model applications used at different scales, see the review by Köhne et al., 2009a,b). The use of natural tracers, and in particular δD and δ^{18}O values for the water molecule (Négrel and Petelet-Giraud, 2010), has the main advantage of allowing us to distinguish between old and new water and of permitting fast and high-resolution studies (Allaire et al., 2009). This application is based on the typical winter–summer cyclic H and O isotopic variations of precipitations under continental climate (Gat and Dansgaard, 1972). As this isotopic signal potentially propagates into the upper

* Corresponding author at: CRPG, centre de recherches pétrographique et géochimiques, 15, rue Notre-Dame-des-Pauvres, 54501 Vandœuvre-lès-Nancy, France.
E-mail address: a.brenot@brgm.fr (A. Brenot).

http://dx.doi.org/10.1016/j.crte.2015.05.001
1631-0713/

parts of the soil, the output signal of soil water to these cyclic variations could be used to trace water movements. Stable isotopic compositions (δD and δ^{18}O values for the water molecule) have been successfully used to document preferential flow of soil water in previous studies (Gazis and Feng, 2004; Lindstrom and Rohde, 1992; McGuire et al., 2002; Mueller et al., 2014; Stewart and McDonnell, 1991). Investigations on stable isotopic compositions (δD and δ^{18}O values for the water molecule) of soil water can be proceeded either on water collected within the soil profile or pore waters from sediment cores (i.e. Landon et al., 1999; Stumpp and Hendry, 2012). Only few studies compare the use of stable isotopes tracers depending on soil water sampling techniques, whereas abundant literature has been addressed to these techniques—for devices/methods and flow regime of water and pore water source collected by these methods, see Weihermüller et al. (2007) and Allaire et al. (2009). For example, there are numerous studies that illustrate how soil water samplers bias different water flow paths and flow mechanisms (Giesler et al., 1996; Haines et al., 1982; Hansen and Harris, 1975; Litaor, 1988; Ranger et al., 1993). Furthermore, these studies provide evidence of water residence time and water source in terms of pore structure given that they examine soil solution sampling techniques.

In this study, we propose to compare stable isotopic compositions of soil water monitored by two sampling techniques commonly used in agronomy: ceramic porous cups and drainage. Both techniques tend to collect different water compartments of the soil. Comparing isoproturon concentrations in soil water collected by the two methods in the experimental field "La Justice", located near Mirecourt (NE France), Perrin-Ganier et al. (1996) demonstrated that the drainage technique collects water moving rapidly through the soil along preferential pathways, whereas porous cups technique samples water infiltrating slowly in the soil profile. To go further in this approach on the experimental field "La Justice", the objectives of the present study are to discuss these results with a more direct tracer of water (i.e. H and O isotopic composition of the water molecule) and to investigate the possibilities to constrain the residence time of soil water. In this study, we analysed the temporal variations of the H and O isotopic compositions of soil water collected both by porous cups and drainage during two periods: October 2001 to June 2002 and December 2003 to May 2004 in the experimental field "La Justice". We compare this dataset with the seasonal fluctuation of the H isotopic composition of rainwater sampled on a daily basis between October 2003 and September 2004.

2. Material and methods

2.1. Field description and sampling methods

2.1.1. Experimental field "La Justice"

The experimental field "La Justice" (7.5 ha) located near Mirecourt (NE France), is studied by the "Institut national de la recherche agronomique" (INRA, France). This experimental field is located in an area dominated by agricultural land use at the altitude of 289 m. It is composed of a loamy-clay brown soil whose physicochemical characteristics are described in detail, depending on sampling depth, in Perrin-Ganier et al. (1996). For sampling depths up to 120 cm, the mean physicochemical characteristics are: clay content = 34%, fine silt content = 31%, coarse silt content = 16%, fine sand content = 13%, coarse sand content = 6%, pH = 6.7, C = 0.9%.

The slope of the experimental field does not exceed 3°. Soil water was sampled at 90 cm depth after each rainy period, by two different techniques simultaneously: drainage samplers collecting gravitationally soil water (drainages 1 to 3, Fig. 1) and porous ceramic cup samplers (PCS1, PCS2 and PCS3, Fig. 1). Nevertheless, the synchronism of the sampling techniques could not always be respected. Drainage samplers collect water by gravity and the amount of water sampled is measured by a flow meter and is reported as m^3/ha/d. Soil water collected by drain

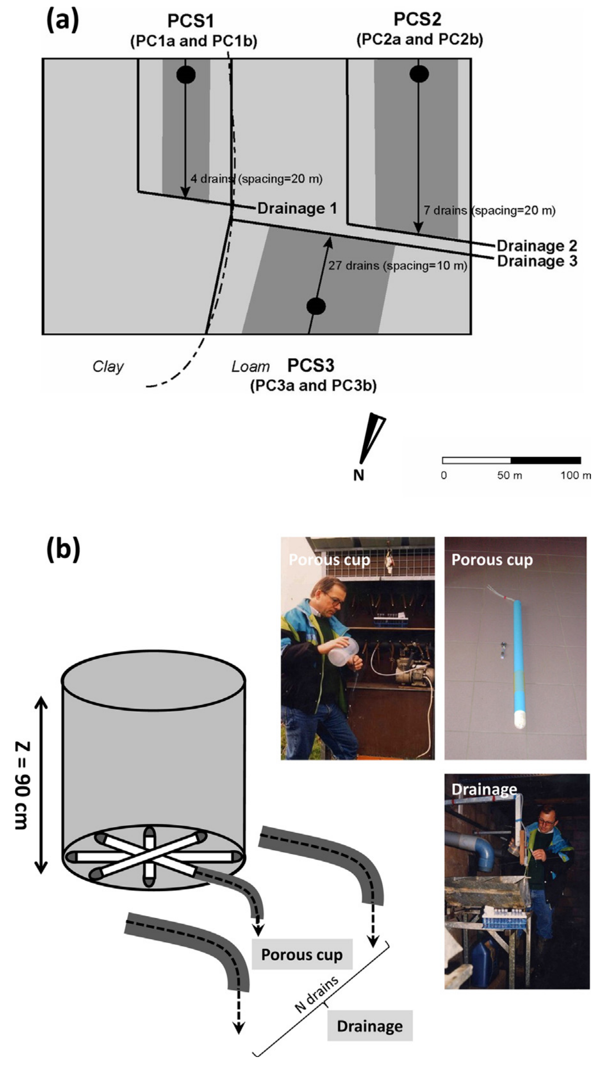

Fig. 1. (Colour online.) Sampling sites on the experimental field "La Justice", map (a) and cross-section (b). Soil water collected by drainage (drainages 1, 2, and 3) and by porous cups (PCS1, PCS2 and PCS3). Areas in dark grey correspond to the different areas submitted to drainage 1, 2 and 3, respectively 0.7, 1.9 and 2.0 ha.