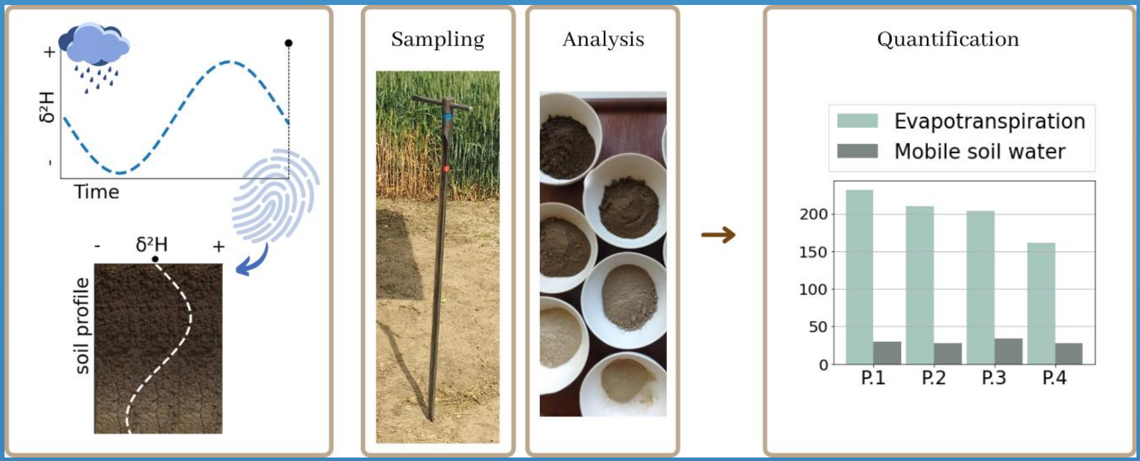
FACTSHEET

TRACER METHODS



Key information

Stable water isotopes (δ18O and δ2H) are used as a tool to assess water flow and retention in soils. Pore water isotope ratios can also be used to calibrate flow and transport parameters in physically based models to improve accuracy in studies of subsurface water movement or surface-vegetation-groundwater interactions.

Target audience: researchers

This project has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No 858735.

A. Brief Introduction:

Tracer methods can provide valuable information on the water transport in soils. The isotopic composition of oxygen and hydrogen isotope in precipitation water varies throughout the year, which depends on factors such as temperature and water vapor sources. These changes have a pronounced sinuosity with a minimum and maximum value in winter and summer in the climates covered by the project (i.e., Boreal, Continental and Pannonian). This isotopic signal ($\delta 18O$ and $\delta 2H$) can also be followed and observed in soil water in the vertical direction, as precipitation water pushes water from previous precipitation events downwards. Depending on the soil type, climatic characteristics and sampling timing, one or two peaks might still be observable in vertical soil profiles. It is, therefore, possible to track the movement of water and quantify the water flux in the soil. Soil water flux below the root zone basically equals the potential groundwater recharge, which is essential for renewing groundwater resources. By means of a water balance, other inputs and outputs, such as evapotranspiration, can be estimated.

One of the main advantages of this method is the ease of quantifying average water fluxes in fields that are difficult to access or have little data available by carrying out a single sampling campaign. It is also an advantage over other complex methods that require more resources, time and expertise, such as process-based models.

B. Design concept:

In order to use this simple method, a soil core is extracted and divided into 5 - 10 cm subsections. Soil samples are stored in sealable, inflatable and leak-tight bags, the isotopic composition of the water is analyzed, and the water content is determined. The isotopic signal of soil water can be compared with that of precipitation water to identify winter or summer peaks, considering the accumulated precipitation and isotopic composition. The volume of water per m^2 in the subsections [mm] has to be related to the elapsed time [yr] to obtain the water flux. Other hydrological processes can be estimated by performing a water balance, e.g. evapotranspiration.

Sampling recommendations indicate the best sampling time and depth intervals according to soil type and climate (check WATERAGRI simplified model).

C. Technical information:

Detailed procedure:

i. Sampling campaign:
   a. Soil core sampling down to 60 - 150 cm or even deeper if possible, divide and store samples every 5-10 cm. Repeat the soil core sampling in the same plot to obtain a composite sample.
   b. The soil samples are disturbed and placed into a sealable, inflatable and leak-tight bag (usually a plastic Ziploc® bag or laminated Al-bags)

ii. Analysis of isotopic composition (if using a laser-based isotope analyser):

   a. The bags are filled with dry air for three days to reach isotopic equilibrium in the head-space.
   b. Analysis of the isotopic composition of soil water ($\delta^{18}O$ and $\delta^{2}H$) using a laser-based isotope analyser (e.g. Picarro L2140-i).

iii. Analysis of gravimetric water content by drying the soil samples to determine the weight loss corresponding to the water content. To determine volumetric water content (θ_w) if soil bulk density is known or can be assumed. Based on the soil type, residual water content (θ_r) can also be estimated.

iv. Comparison of the temporal variation of the isotopic composition of soil water with precipitation and identification of a common period or peak.

v. Peak-shift method to quantify water flux (mm/yr): Sum of the water content in the identified soil interval ($z_{t+T} - z_t$), in mm, divided by the elapsed time T, in yr [Eq. 1].

$$q_{(z,T)} = \frac{1}{T}\sum_{i=0}^{m}(\theta_w - \theta_r)(z_{i+1} - z_i) \qquad \text{[Eq. 1]}$$

D. Costs and Benefits:

- Costs related with materials for sampling and analysis of measurement of oxygen and hydrogen isotopes ($\delta^{18}O$ and $\delta^{2}H$) and water content.
- Farming benefits: Provides information on the hydrological processes occurring in the field (e.g., infiltration, soil water retention, evapotranspiration). It can help to achieve a more sustainable management of water resources if appropriate solutions are adopted, reducing the extra costs of irrigation water or drainage infrastructure.
- Environmental and social consequences: In the medium to long term, better management of water resources in agriculture can contribute to the water security of the region's ecosystems and communities.

E. Challenges and opportunities

Challenges:

- In sandy soils or soils with a high dispersivity it may be complicated if not impossible to differentiate a peak, and therefore the method could not be applied.
- Very heterogeneous soils can pose a challenge, due to a greater need for sampling to cover areas with different fluxes, or due to the presence of horizontal flows that divert water or preferential flow bypassing the soil profile, resulting in greater uncertainty.

Opportunities:

- Several periods with different rates can be identified in the soil, depending on soil properties, precipitation characteristics and sampling time.
- It can be used to compare the effect of different management practices in the water retention capacity of soils.
- Isotopic composition of precipitation water can be gained onsite, using the data from the nearest location available in WISER portal (GNIP-IAEA) or from prediction tools (https://isotope.bot.unibas.ch/PisoAI/).

TRL: Applicable solution

F. Reference and demonstration:

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