Transit times of water particles in the vadose zone
across catchment states and catchments functional units

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Introduction

The fate of soil water and its solutes is subject of numerous studies with respect to groundwater recharge and groundwater contamination.
We test the following hypothesis:

1. Pore water isotopes can be used for prameterization of soil physical models.
2. Transit times through soils differ with respect to soil types and seasonality.
3. The methodology can be applied for nitrate leaching studies.

Methods

Model: Hydrus 1-D; Water flow: Richards Equation; Solute transport: advection-dispersion Equation; Evapotranspiration: Hargreaves Formula; Root-Water-Uptake: Feddes model.

Study sites: Three sites within the Attert Catchment in Luxembourg with a similar climate, but different pedology developed on different geology: a structured loamy Cambisol on Schist, a clayey Stagnosol on Marls and a sandy entic Podzol on Sandstone.

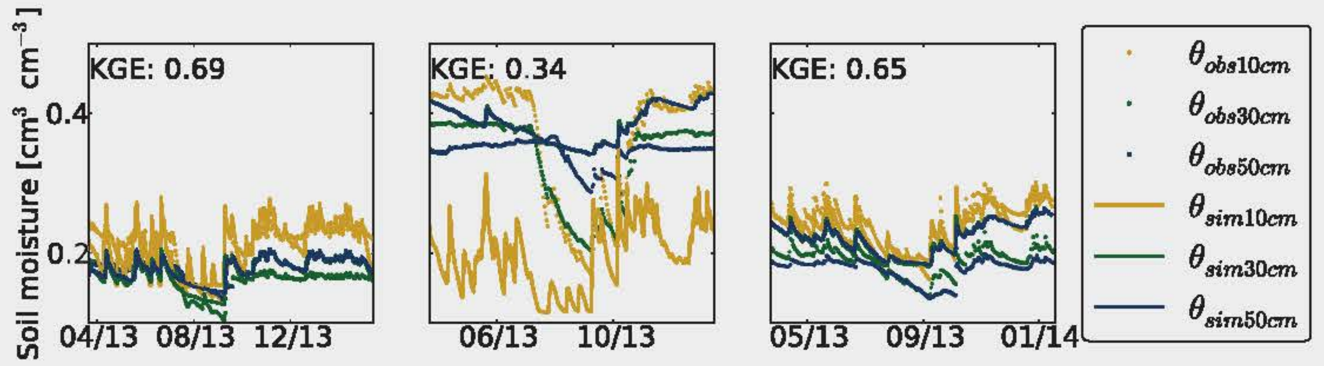
Parameterization: Optimization algorithm: SCE-UA; Objective function: Kling-Gupta-Efficiency (KGE) of simulated and observed soil moisture and pore water isotope concentration. Mualem-van Genuchten and dispersivity parameter for two soil layers.

Transit times: The model was run foreward with the best parameter set while tracing the water particles of each rain event, to derive event transit times distributions (ETTD). For each event, the mean transit time (MTT) through the soil profile and through transpiration was calculated as 50% of the total flow. A master transit time (MTTD) was inferred by averaging the ETTD (Heidbüchel et al., 2012).

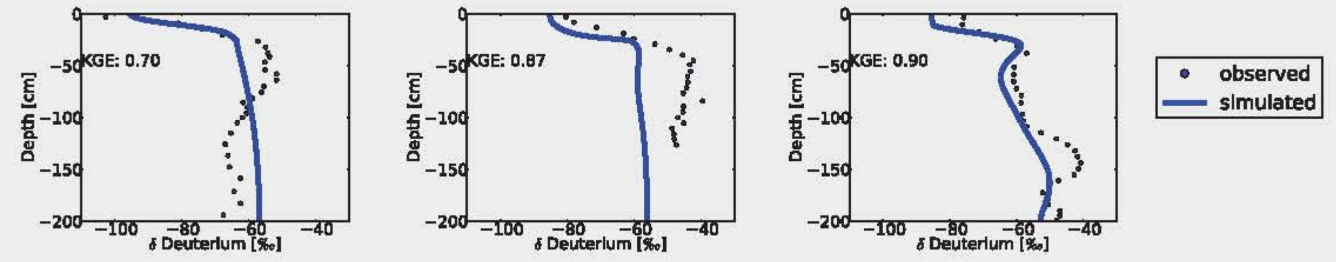
1 Inverse modeling

Cambisol **Stagnosol** **Podzol**

Observed and simulated soil moisture



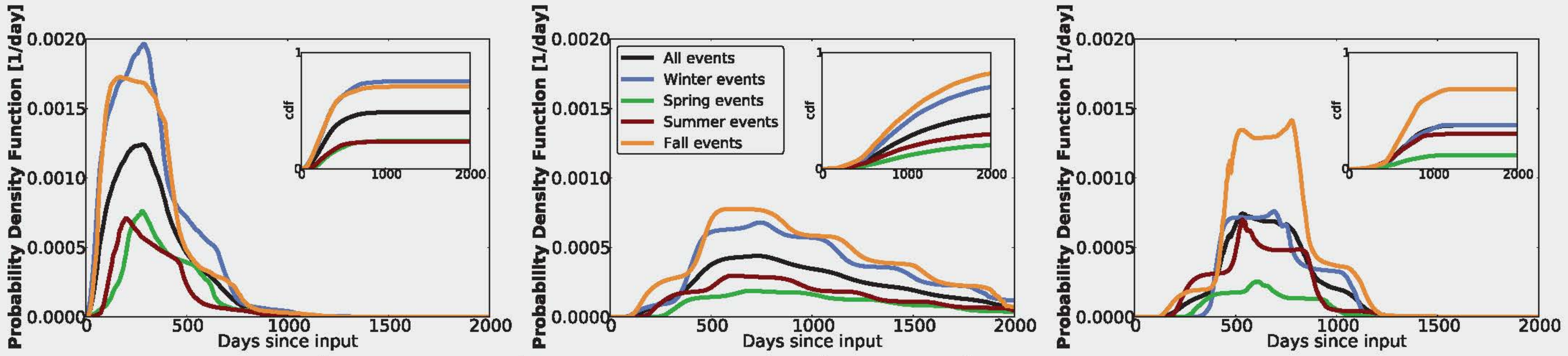
Observed and simulated isotope profiles



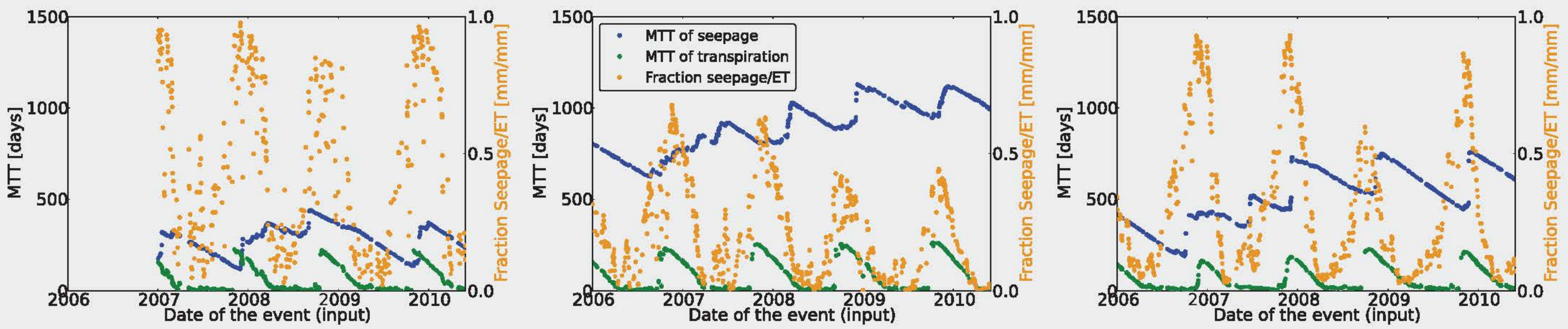
2 Tracking the water particles in the soil

Cambisol on Schist **Stagnosol on Marls** **Podzol on Sandstone**

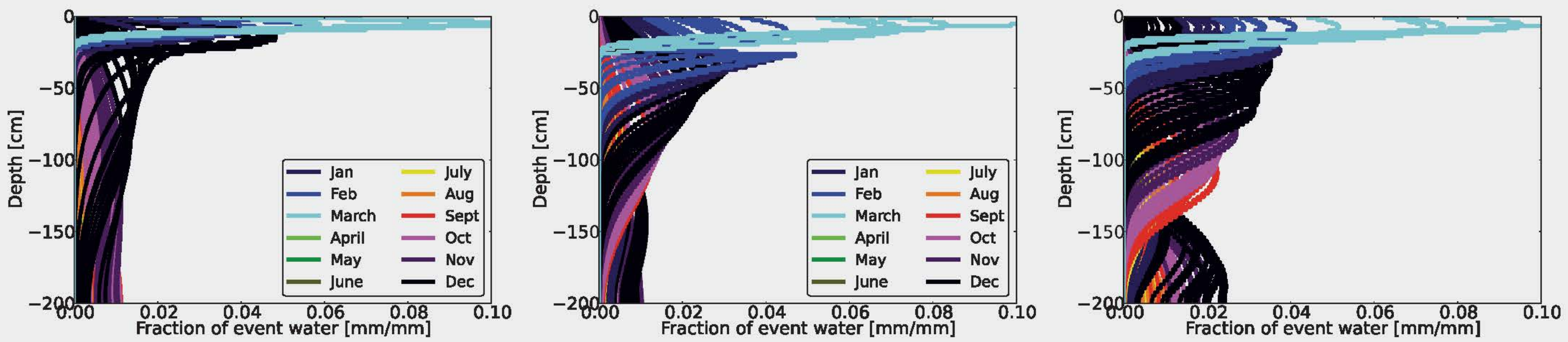
Master transit time distributions of seepage in -200 cm soil depth



Mean transit times of seepage and root water uptake; fraction of seepage/ET

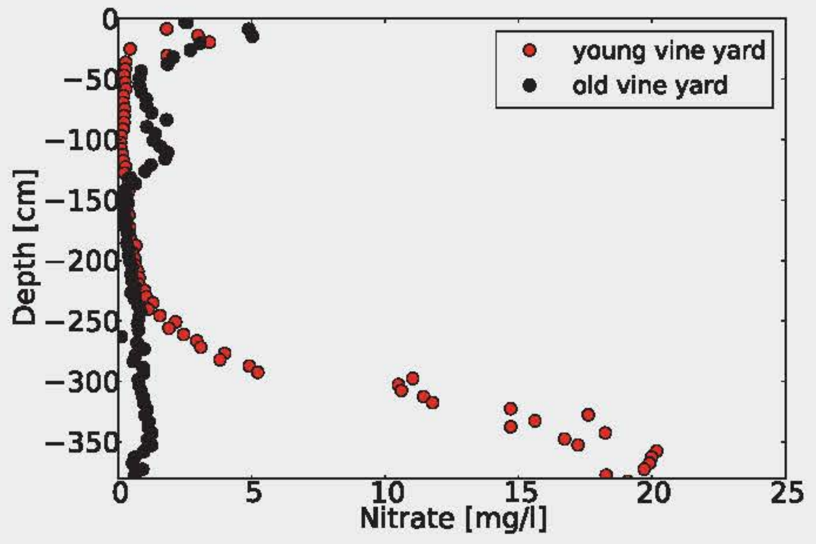


Composition of pore waters at the end of March 2013

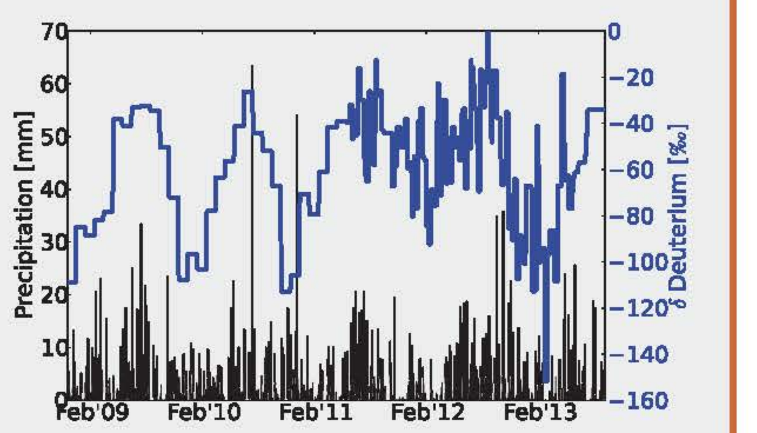


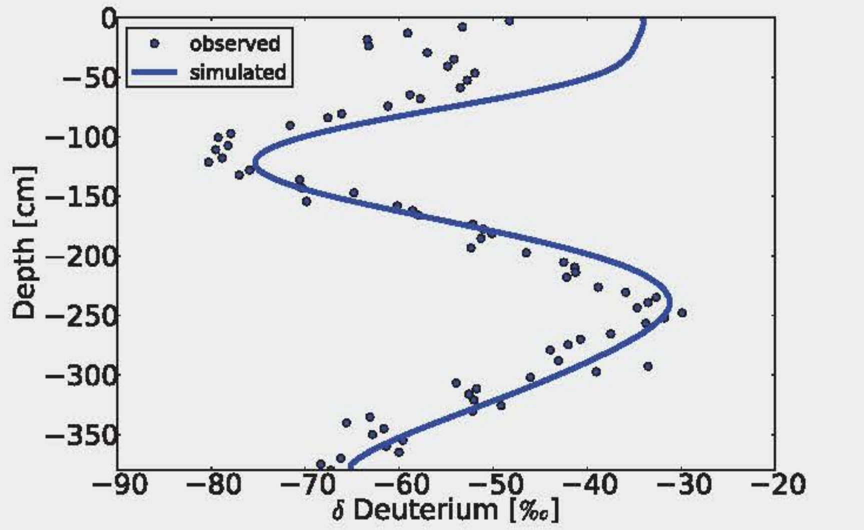
3 Application

Where does the nitrate come from?



Elevated nitrate concentration were found in -250 to -400 cm soil depth below a young vine yard 2.5 years after planting. There is no such high concentrations under old plantations.

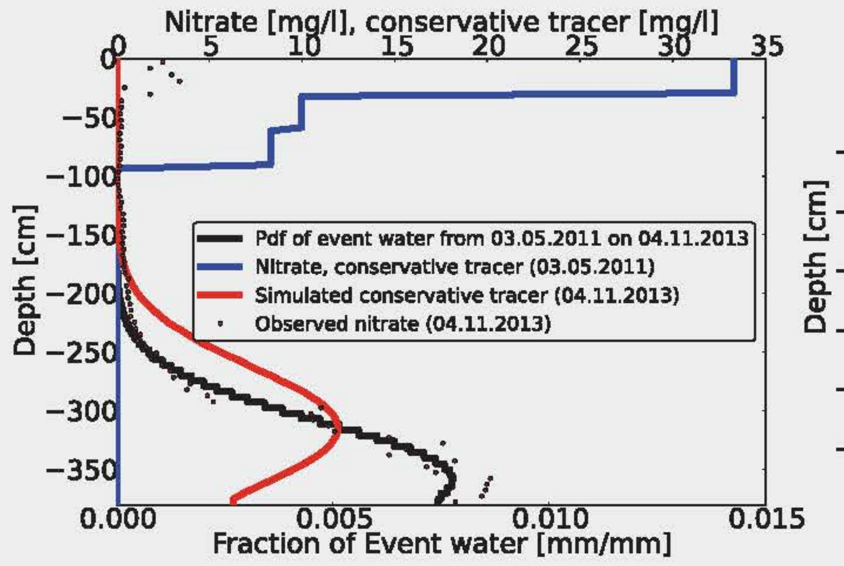


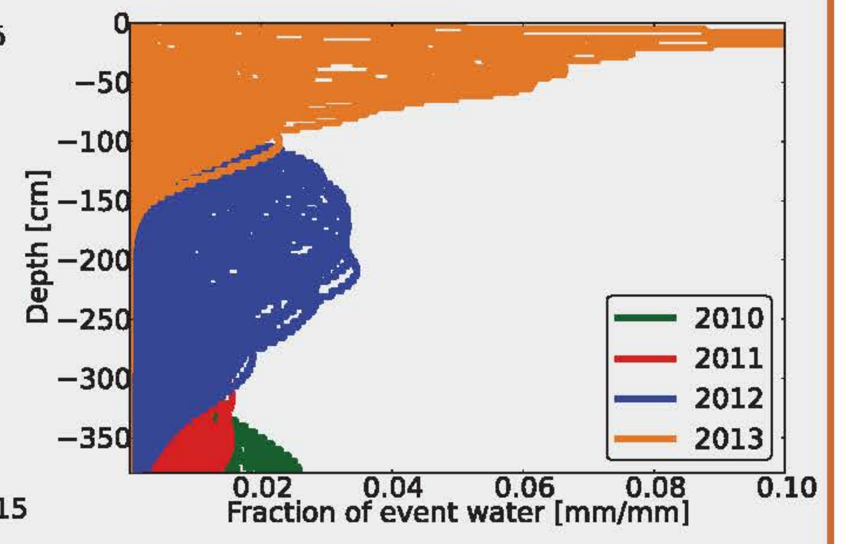


Parameterization of the Hydrus model with an isotope profile, simulatnously taken during the nitrate sampling (Nov. 2013).

Note the warm and dry Winter 2010/11 with enriched isotopic precipitation, that did not lead to a winter peak in the

The water from May 2011, when the young plantation was established, reached the depth between -250 and -400 cm. Simulating the fate of the nitrate that was mobilized in the upper -100 cm in May 2011 with the parameterization via the isotope profile, reflects the high nitrate concentrations found in -300 to -400 cm in November 2013.





Conclusion

1. Hydrus 1-D could simulate the soil moisture (limitations for Stagnosol) dynamics and the pore water deuterium concentration in a satisfacory manner.
2. Transit times are the shortest in Cambisols on Schist and longest in Stagnosols on Marls and generally shortest for rain water entering the soil in summer and spring.
   The highest seepage rates occur for rain water of events in fall.
3. Mixing of old water increases with depth, while some bigger rain events can have a higher share in the pore waters.
   Elevated nitrate concentrations below a young vineyard can be explained by soil treatment before and during plantation.

Reference

Heidbüchel et al., 2012, The master transit time distribution of variable flow systems, WRR.

Acknowledgements

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