Historical tracking of nitrate in contrasting vineyards using water isotopes and nitrate depth profiles

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Introduction

Viticulture is seen as a relevant factor influencing high nitrate concentrations in the groundwater of SW Germany. Therefore, we address the following questions:

Q1: Can we trace back the timing of nitrate mobilization using pore water stable isotope data?
Q2: How do young vineyards and old vineyards differ with regard to the risk of nitrate leaching?
Q3: Can a permanent green cover reduce the nitrate loads into the subsoil?
Q4: Does soil tillage in winter increase the risk of nitrate leaching?

Study sites

Four sites in a catchment of an aquifer in SW-Germany
Climate: temperate, average T = 10.5 °C, P = 722 mm/year
Soils: silty Pararendzina on deep Pleistocene loess
Young vineyards: installed May 2011
Old vineyards: installed in 1998

NewST: Young vineyard with soil tillage in interrows

NewGC: Young vineyard with green cover in interrows

OldGC: Old vineyard with green cover in interrows

OldST: Old vineyard with soil tillage in interrows

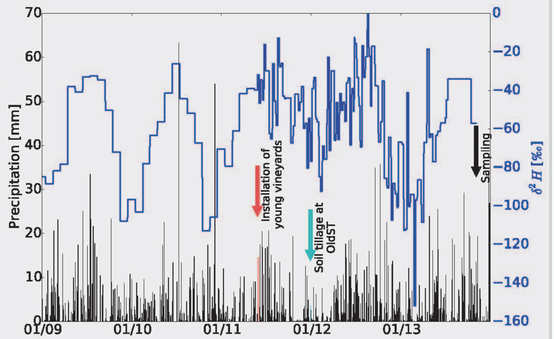
Methods

Sampling: Split sampling in Nov. 2013 in 5 cm intervals down to 380 cm soil depth; subsequent analysis for nitrate and water stable isotopes (Wassenaar et al., 2008).

Model: Hydrus-1D; water flow: Richards equation; δ^2H transport: advection-dispersion equation; evapotranspiration: Hargreaves formula; root-water-uptake: Feddes model.

Parameterization: Objective function: Kling-Gupta-Efficiency of simulated and observed soil water δ^2H concentration (Sprenger et al., 2015).

Water tracking: Tracing precipitation input through the soil profiles with site specific soil physical model.



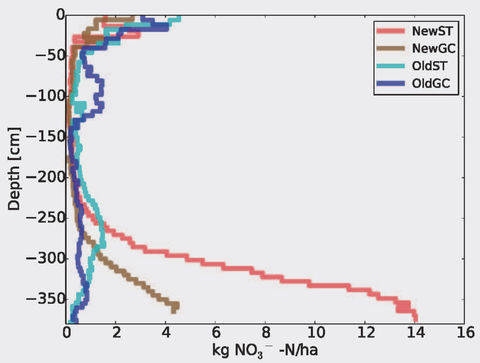
Results: Observations

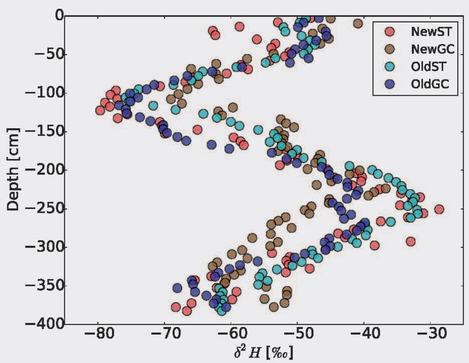
Nitrate depth profiles:

- Elevated nitrate concentration below young vineyards
- Reduced nitrate where green cover was seeded
- Higher nitrate concentrations where soil tillage was applied

Isotope depth profiles:

- Seasonal variation of the rainfall signal is preserved over the depth profiles
- Relative little variation among sites





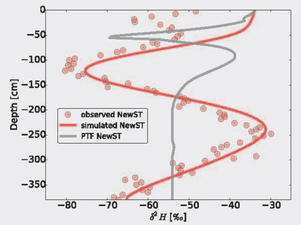
Conclusion

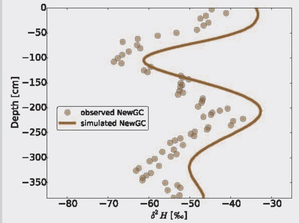
- Water stable isotope depth profiles preserve information about percolation over the last years (Q1).
- Transient modeling allowed to consider time variance (Q1).
- Nitrate mobilization due to vineyard installations leads potentially to nitrate leaching (Q2).
- Green cover between grapevines are efficient to reduce the nitrate leaching (Q3).
- Elevated nitrate concentration in old vineyards can be attributed to soil tillage in winter (Q4).

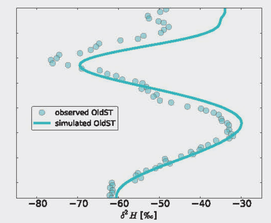
Results: Simulations

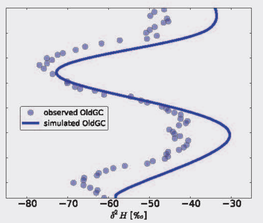
Isotope depth profiles:

- Peak depths are well met
- Partially offset
- Pedotransferfunction (PTF) fails
- Peaks do not simply reflect annual cycles due to a warm dry winter 2011/2012



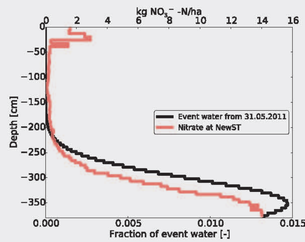


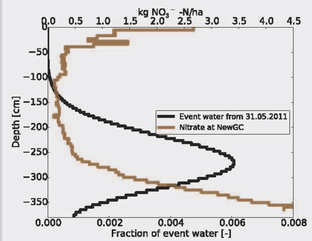


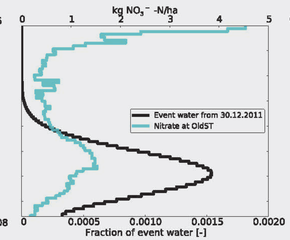


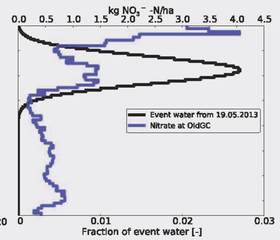
Water tracking related to nitrate concentrations:

NewST: High nitrate concentrations related to installation the of vineyard
NewGC. Unsatisfying calibration results
OldST: Elevated nitrate concentration related to soil tillage in winter
OldGC: Nitrate mobilization in May









References:
Sprenger et al., 2015, Estimating flow and transport parameters in the unsaturated zone with pore water stable isotopes, HESS
Wassenaar et al., 2008, High Resolution Pore Water δ^2H and $\delta^{18}O$ Measurements by H_2O (liquid) -H_2O (vapor) Equilibration Laser Spectroscop, Environ. Sci. Technol.

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