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Greenhouse gases dissolved in soil solution - often ignored, but important?

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Flux measurements of climate-relevant trace gases from soils are frequently undertaken in contemporary ecosystem studies and substantially contribute to our understanding of greenhouse gas balances of the biosphere. While the great majority of such investigations builds on closed chamber and eddy covariance measurements, where upward gas fluxes to the atmosphere are measured, fewest concurrently consider greenhouse gas dissolution in the seepage and leaching of dissolved gases via the vadose zone to the groundwater.

Here we present annual leaching losses of dissolved N_2O and CO_2 from arable, grassland, and forest lysimeter soils from three sites differing in altitude and climate. We aim to assess their importance in comparison to direct N_2O emission, soil respiration, and further leaching parameters of the C- and N cycle. The lysimeters are part of the Germany-wide lysimeter network initiative TERENO-SoilCan, which investigates feedbacks of climate change to the pedosphere on a long-term scale. Soil water samples were collected weekly from different depths of the profiles by means of suction cups. A laboratory pre-experiment proved that no degassing occurred under those sampling conditions. We applied the headspace equilibration technique to determine dissolved gas concentrations by gas chromatography.

The seepage water of all lysimeters was consistently supersaturated with N_2O and CO_2 compared to water equilibrated ambient air. In terms of N_2O, leaching losses increased in the ascending order forest, grassland, and arable soils, respectively. In case of the latter soils, we observed a strong variability of N_2O, with dissolved concentrations up to 23 μg N L^{-1}. However, since seepage discharge of the arable lysimeters was comparatively small and mostly limited to the hydrological winter season, leached N_2O appeared to be less important than direct N_2O emissions. In terms of dissolved CO_2,our measurements revealed considerable leaching losses from the mountainous forest and grassland soils, based on concentrations up to 24 mg C L^{-1} and high seepage discharge. Such losses turned out to be similarly important like soil respiration, particularly during winter when temperature-dependent soil respiration declined.

In conclusion, the results of the first year of our measurements provide evidence that dissolved greenhouse gases should be considered in studies which aim to assess full greenhouse gas balances, particularly in ecosystems where hydrological conditions favour microbial activity and high leaching losses.