Integrated control and Modelling of Denitrification in Agricultural Soils at various scales (DASIM) – first data sets for model evaluation

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Denitrification, the process of nitrate reduction allowing microbes to sustain respiration under anaerobic conditions, is the key process returning reactive nitrogen as N_2 to the atmosphere. The different reaction steps (NO_3^- -> NO_2^- -> NO -> N_2O -> N_2) are enzymatically mediated by a broad range of prokaryotes and some eukaryotes. Actively denitrifying communities in soil show distinct regulatory phenotypes (DRP) with characteristic controls on the single reaction steps and end-products. It is unresolved whether DRPs are anchored in the taxonomic composition of denitrifier communities and how environmental conditions shape them. Despite being intensively studied for more than 100 years, denitrification rates and emissions of its gaseous products can still not be satisfactorily predicted. While the impact of single environmental parameters is well understood, the complexity of the process itself with its intricate cellular regulation in response to highly variable factors in the soil matrix prevents robust prediction of gaseous emissions. Key parameters in soil are pO_2, organic matter content and quality, pH and the microbial community structure, which in turn are affected by the soil structure, chemistry and soil-plant interactions. In the coordinated research unit DASIM, we aim at the quantitative prediction of denitrification rates as a function of microscale soil structure, organic matter quality, DRPs and atmospheric boundary conditions. Combining state-of-the-art experimental and analytical tools (X-ray µCT, ^{15}N and ^{18}O tracing, isotopomers, NanoSIMS, micro-sensors, advanced flux detection, NMR spectroscopy, and molecular methods including next generation sequencing of functional gene transcripts), we study denitrification processes at unprecedented spatial and temporal resolution. Improved numerical methods and computational power will allow us to integrate results from the different groups and to develop denitrification models ranging from the microscale to the field/plot scale.

Until now, denitrification data suitable to validate field-scale N_2 fluxes in denitrification models are currently missing due to previous methodical limitations and the extreme spatio-temporal heterogeneity of denitrification. It was thus not possible to evaluate accuracy of models to predict denitrification at the field scale. Therefore, it is necessary to obtain activity data at this scale to better understand denitrification control and as a basis to support the evaluation and upscaling of modelling concepts.

We will present the concept and structure of DASIM. Moreover, we will show lab data using new and improved stable isotope approaches to provide denitrification data sets comprising as much detail on activity and regulation as possible as a basis to evaluate existing and new denitrification models. This includes N_2 and N_2O fluxes, and the apportionment of N_2O fluxes to nitrate and other N sources. Moreover, several approaches are used to determine the anaerobic soil volume fraction

CO_2 and N Fluxes as well as the anaerobic volume will also modelled based on experimental settings. First comparisons of measured and modelled data will be shown.

Keywords: denitrification, modelling, nitrous oxide, dinitrogen

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