Monitoring of nitrous oxide emissions during soil drying with X-ray computed tomography

Eva Rabot, Marine Lacoste, Isabelle I. Cousin, Catherine Hénault

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Monitoring of nitrous oxide emissions during soil drying with X-ray computed tomography

E. Rabot*, M. Lacoste, I. Cousin**, *C. Hénault*

INRA, UR Science du Sol, Orlans, France

*isabelle.cousin@orleans.inra.fr

Nitrous oxide (N^2O) has long been recognized to play a role in stratospheric ozone depletion and global warming. Soils are a major source of N^2O, as soils under natural vegetation are estimated to account for 60% of natural N2O sources while agriculture accounts for 60% of anthropogenic sources [1]. Water in soil is known to be a key factor for controlling N^2O emissions, because N^2O is mainly produced by denitrification under anoxic environments. Moreover, the quantity and the distribution of the water-filled pores at a given pressure head, an element of the soil structure, appeared to play a role in N^2O production and emission processes, as it regulates flow of water and gases.

In this study, we investigated the effect of wetting and drying cycles on the N^2O emissions of a soil sample, and also studied the effect of the water hysteresis. The experiment consisted in controlling the hydric status of a soil sample with a multistep outflow system while measuring N^2O emissions. An undisturbed soil core (13.2-cm inner diameter, 7-cm height) was first saturated for three days, and then submitted to a 100 hPa pressure at its bottom. The wetting and drying cycle was applied two times (C1 and C2 cycles). Both the water content and water potential were continuously monitored during the experiment. Nitrous oxide emissions were measured using the closed-chamber technique. The soil core was scanned with X-ray computed tomography (resolution: 300 μm), one time at saturation, and seven and nine times for C1 and C2, respectively, during the drying phase. The image processing was realized with the ImageJ software [2] and the C library QuantIm v.4 [3]. The air phase was separated from the soil matrix and the water phase by using the k-means segmentation method. Quantitative and qualitative indicators of the pore network were calculated from the segmented images: the volume of macropores and the connectivity of the pore space.

Nitrous oxide emissions were lower during C2 than during C1, both for the wetting and the drying phases. Fluxes increased quickly after the beginning of the drying phase to reach a peak approximately 5 hours after the beginning of the soil drying. Maximum N^2O fluxes were reached at approximately 45 cm water column, when pores with radius ¿ 66 μm were drained, according to the Jurin-Laplace law. Air-filled pore volume increased quickly during the first hour of drying, and then increased more slowly. The Euler number, above zero during the whole experiment, reveals that the segmented pore network was not entirely connected at the image resolution. Emissions may have occurred from the soil upper part connected to the atmosphere. The connectivity of the air phase was higher at C1 than at C2. The soil matrix, drier for C2 than for C1, revealed a higher anoxia level during C1 than during C2, and consequently explained higher N2O fluxes during C1.

The results of the present study are consistent with the hypothesis that N^2O has been entrapped both in the gaseous and the liquid phases during wetting, and that the increase in the gas diffusion through the increase in the connectivity to the soil surface was responsible for the N^2O peaks observed during drying. This study highlighted the need to find and measure dynamic indicators of the soil structure, to enhance our understanding of the dynamic nature of N^2O emissions by soils.

References

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