Geophysical Research Abstracts
Vol. 18, EGU2016-1073, 2016
EGU General Assembly 2016

Subsurface N cycling under variable paddy flood management: what role does it play in N2O emissions?

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There is increasing pressure to grow rice with less water in order to save water and mitigate methane (CH4) emissions. However, there is frequently a trade-off with yield declines and increased nitrous oxide (N2O) emissions, potentially increasing the global warming potential of the system. A field trial in Northern Italy was established with two water regimes: continuously flooded (flooded) and alternate wetting and drying (AWD), to investigate the impact of such water management on N2O emissions and N cycling along a depth profile. Surface gas fluxes were complimented by depth profile measurements of soil gas, inorganic N, DOC, dissolved gas concentrations, redox potential and moisture. Sampling was concentrated around two periods during the 2015 growing season which were hypothesized to show significant variation in N dynamics; a fertilization event and final season drainage. For N cycling and N2O emissions, stable isotope measurements were taken to obtain process-level information in situ.

During the first field campaign, maximum mean daily N2O emissions did not peak at fertilization but rather a week earlier, demonstrating a greater response to soil conditions (i.e. higher redox and lower moisture) than inorganic N concentrations. This was especially the case in the AWD treatment where emissions peaked at 82.3 $\pm$ 126.0 g N2O-N ha-1 d-1 relative to a peak of 2.83 $\pm$ 1.1 g N2O-N ha-1 d-1 in the flooded treatment. Considering the upper depths (0-15 cm), peak emissions corresponded well to higher redox potentials in the AWD treatment (72-406 mV versus -100 to -12 mV for AWD and flooded treatments, respectively). These emissions also correlated well to pore space N2O concentrations at 5 and 12.5 cm, suggesting important production of N2O at these depths and subsequent diffusion to the soil surface. Pore space and dissolved N2O concentrations were much lower in the flooded treatment and no such spikes were observed. No significant N2O emissions were observed in either treatment during the period of final drainage, a phenomenon that has often been observed in other rice studies. While the soil environment during this drainage period was favorable for N2O emissions, inorganic N supply was negligible and likely precluded the production of N2O. Over all soil redox potential (Eh) and moisture showed characteristically opposing trends, however at 50 and 80 cm a moderate decoupling of moisture and Eh was observed during extended drainage periods (i.e. final drainage), with the Eh rising at all depths while the soil remained saturated at 50 and 80 cm. In the AWD treatment, soil Eh and WFPS reached zones amenable to nitrification at multiple points in the growing season, yet we were not able to detect changes in NH4+ or NO_3- pools during these times nor for the most part, N2O emissions. Through further analysis of δ15N and δ18O isotope ratios in surface and subsurface N2O and NO_3- and NH4+ substrates we hope to clarify the role of mineralization, nitrification and denitrification to N2O emissions under these variable soil environmental conditions.