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Quantifying gross N_2O flux and production using $^{15}N_2O$ pool dilution technique and direct gas-flow core method

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Soils are not only a major source but also a potential sink for atmospheric nitrous oxide (N_2O), a potent greenhouse gas and the most important substance for stratospheric ozone depletion. Net N_2O flux at the soil-atmosphere interface is the balance of simultaneously occurring gross N_2O production and consumption. N_2O is consumed via reduction to N_2, i. e. the terminal product of the denitrification process, which is difficult to measure against the high atmosphere background. The enigmatic lack of measurements on gross N_2O flux or N_2 production still impedes our understanding of the controls on soil N_2O emissions and the closure of the global nitrogen cycle. Here, we combined the $^{15}N_2O$ pool dilution technique and direct gas-flow core method to disentangle 1) gross N_2O fluxes at the soil-atmosphere interface, and 2) gross N_2O production and consumption in the soil. The $^{15}N_2O$ pool dilution method entails adding $^{15}N_2O$ to the chamber headspace, measuring $^{14}N_2O$ and $^{15}N_2O$ concentrations and applying a model to simultaneously solve for gross N_2O flux and consumption rate at the soil-atmosphere interface. The direct gas-flow core method substitutes the soil air and chamber headspace with helium to a nearly N_2-free atmosphere in order to directly measure both N_2O and N_2fluxes; N_2 flux is the gross N_2O consumption and its sum with N_2O flux is the gross N_2O production in the soil. Soil samples were taken from grassland, cropland, beech and pine forest soils, representing a broad range of land uses and soil types. Additionally, we compared measurements from intact soil cores (reflecting inherent soil bulk density and porosity) and sieved soils (eliminating heterogeneity in porosity). Gross N_2O production rate in the soil was highest in the silty grassland soil (41.04±4.6 μg N kg^{-1} h^{-1}) and lowest in the sandy pine forest soil (1.84±1.82 μg N kg^{-1} h^{-1}). The intact soil cores and sieved soils showed similar trends. Gross N_2O production rates in the soil exceeded gross N_2O fluxes at the soil-atmosphere interface by at least an order of magnitude, suggesting that most of the N_2O produced is possibly directly consumed and diffused as N_2. The gross N_2O consumption rate at the soil-atmosphere interface only accounted for 7% of N_2 production in the soil, suggesting that N_2O in the soil air that is diffusing to the atmosphere is seldom consumed. Gross N_2O fluxes at the soil-atmosphere interface, gross N_2O production in the soil and N_2 production were all significantly correlated with soil water content, NH_4^+, dissolved organic C, microbial biomass C and N (p <0.05). The fraction of gross N_2O consumption at the soil-atmosphere interface to N_2 production in the soil increased with decreasing soil water content (p=0.055). Overall, this study shows that gross soil N_2O reduction to N_2 within microbial cells and/or soil microsites is of paramount importance for the regulation and avoidance of soil N_2O losses and that gross N_2O consumption at the soil-atmosphere interface is contributing to only a small part of N_2 production.