Terrestrial denitrification and nitrous oxide emissions: global estimates and uncertainties

David E. Pelster[1], Clemens Scheer[2], Kathrin Fuchs[2] and Klaus Butterbach-Bahl[2]

[1] Agriculture and Agri-Food Canada, Quebec Research and Development Centre, 2560 Blvd Hochelaga, Quebec City, QC, Canada
[2] Institute for Meteorology and Climate Research, Atmospheric Environmental Research, Karlsruhe Institute of Technology, D-82467 Garmisch-Partenkirchen, Germany

E-mail: david.pelster@canada.ca

Abstract

Synthetic N fertilizer use has grown exponentially causing severe environmental consequences. Most reactive nitrogen (N_r) is ultimately removed by denitrification, however estimates of denitrification are highly uncertain. Quantifying denitrification is key for understanding N_r sinks and emissions of nitrous oxide (N_2O). Unfortunately, denitrification from upland soils is not well quantified, with the magnitude of total denitrification losses (N_2 + N_2O) virtually unknown for the vast majority of agro-ecosystems. To narrow the uncertainty, we compared global terrestrial denitrification rates estimated using measured N_2:N_2O product ratios with rates estimated using an N mass balance and with previous published studies.

Keywords: denitrification, nitrous oxide, N_2:N_2O ratio

1. Introduction

The agricultural revolution was primarily fueled by the use of synthetic nitrogen (N) fertilizers and increased cultivation of N-fixing crops (Battye et al., 2017), both of which have increased the amount of reactive N (N_r) in the biosphere. Accumulation of N_r has caused alterations to the global N cycle (Steffen et al., 2015) causing severe environmental problems including biodiversity loss, eutrophication, human health problems, and increased radiative forcing (Galloway et al., 2003). The primary sink for N_r is denitrification, where nitrate can eventually be reduced to dinitrogen (N_2). However, due to the large atmospheric N_2 background, N_2 fluxes are difficult to measure causing high uncertainty when calculating global N budgets.

2. Methods

We reviewed recent literature estimates of terrestrial N_2O emissions (bottom up and top down) and N_2O:(N_2O+N_2) product ratios, as well as total terrestrial denitrification. Further, we determined global terrestrial denitrification using a N_r mass balance based on literature values, where we balanced N_r creation rates for the global land surface with outputs to the ocean and atmosphere. Terrestrial denitrification was then calculated as the difference. We also summarised datasets that measured field N_2O:(N_2O+N_2) product ratios and used this to infer global denitrification using estimates of global terrestrial N_2O flux.

3. Results and Discussion

Terrestrial N_2O emissions were 13.5 Tg N_2O-N yr^{-1} with 45% derived from agriculture using bottom up models, while top down estimates were 12.1 Tg N_2O-N yr^{-1} with 44% derived from agriculture. Recent literature estimates of total terrestrial denitrification ranged from 100 to 242 Tg N yr^{-1} (mean = 142), with 34% originating in agricultural soils; similar to the value calculated using the global mass N balance (147 Tg N yr^{-1}). However, both of these were lower than the estimate of total denitrification (164 Tg N yr^{-1}) determined by scaling up field-derived measures of the N_2O:(N_2O+N_2) ratios.

4. Conclusion

The amount of N_r in the biosphere has doubled during the last 100 years, causing severe environmental disturbances. While different methods provide consensus on the magnitude of global denitrification, much uncertainty persists, particularly at smaller scales. Additional studies of $N_2O:(N_2O+N_2)$ product ratios for a range of terrestrial ecostystems are required to provide more accurate measures of denitrification that can guide decision makers when developing strategies to manage N_r.

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