The global distribution of soil nitrification and the fraction of associated N_2O emission by using stochastic gradient boosting models

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Abstract

Nitrification is one of pathways of N_2O production in soils. Using stochastic gradient boosting models based on a global database, we quantified the global spatial distributions of gross nitrification rate and the fraction of associated N_2O emission. We found that the large variations of gross nitrification rate (0.008-9.1 kg N ha^{-1} d^{-1}) and the fraction of associated N_2O emission (0.005-1.24%) are driven by long-term environmental and edaphic factors (soil pH, C/N ratio and mean annual temperature; soil pH, total nitrogen, clay content and mean annual precipitation, respectively.) Appropriate mitigation strategies should be implemented to regulate nitrification and subsequent nitrogen loss.

Keywords: gross nitrification, N_2O production, machine learning, spatial variability

1. Introduction

Nitrification is the primary pathway of N_2O production especially in aerobic soils and its underlying mechanisms are complex. Stochastic gradient boosting could be effective in quantifying the non-linear N transformations like nitrification and its N_2O emission.
In this study, we first attempt to establish stochastic gradient boosting models derived from the database to predict nitrification rate (R_{nit}) and the proportion of N_2O from nitrification (f_{N2O_Nit}) on a global scale.

2. Methods and materials

2.1 Database compilation

Extensive keyword searches were performed. The resulting database consists of 186 observations from published papers between 1996 and 2018.

2.2 Stochastic gradient boosting modelling

Stochastic gradient boosting models were performed by TreeNet® (Salford Systems) and was evaluated by 10-fold cross-validation.
Soil properties were obtained from the World Inventory of Soil Emission (WISE) database (Batjes, 2015). The climate data was collected from Worldclim bioclimatic data (www.worldclim.org/bioclim).

3. Result and discussion

We found that the average nitrification rate in the topsoil was 1.4 kg N ha^{-1} d^{-1}, ranging widely from 0.003 to 27.5 kg N ha^{-1} d^{-1}. A small proportion of N_2O emitted from nitrification resulted in an average fraction of 0.46%.

After extrapolated to the global scale with stochastic gradient boosting models, we found that R_{nit} with an average of 0.4 kg N ha^{-1} $d^{-1}$is predicted by soil pH, soil C/N ratio and mean annual temperature (MAT). The distribution of f_{N2O_Nit}

ranged from 0.005% to 1.24% with an average of 0.13% predicted by soil pH, mean annual precipitation (MAP) and soil C/N ratio. The spatial patterns of predicted R_{nit} and f_{N2O_Nit} exhibited a large spatial diversity, due to their corresponding soil and environmental characters.

This study demonstrated that stochastic gradient boosting model was robust and effective in predicting nitrification rate and the fraction of associated N_2O emission and can be upscaled to a global estimation. Management strategies should be implemented to reduce nitrification and subsequent N_2O emission.

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