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

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Introduction

- Nitrification is a major pathway of N_2O production in aerobic soils.
- Robust prediction of gross nitrification rate (R_{nit}) and associated N_2O production is difficult due to uncertainty in existing process-based models and limited measured data to improve those models.

Objectives

- To compare the performance of SGB models and process-based models in predicting nitrification rate and associated N_2O production using a global literature-based database.
- To extend the simulation of R_{nit} and the fraction of nitrification as N_2O emissions (f_{N2ONit}) using SGB models.

Table 1. Comparison of observed and predicted nitrification and associated N_2O emissions by SGB1, APSIM, Crop-DNDC and WNMM models

Output	SGB1				APSIM				Crop-DNDC				WNMM			
	n	R^2	RMSE	NSE	n	R^2	RMSE	NSE	n	R^2	RMSE	NSE	n	R^2	RMSE	NSE
Log_Nit*	186	0.73	0.40	0.63	99	0.27	0.71	-0.02	162	0.31	0.68	-1.04	98	0.24	0.66	-0.45
Log_N_2O_Nit§	186	0.61	0.54	0.61	99	0.10	0.84	-0.51	162	0.20	0.73	-14.2	98	0.11	0.68	-0.89

§ N_2O emission from nitrification, RMSE: root mean square error and NSE: the Nash–Sutcliffe model efficiency.

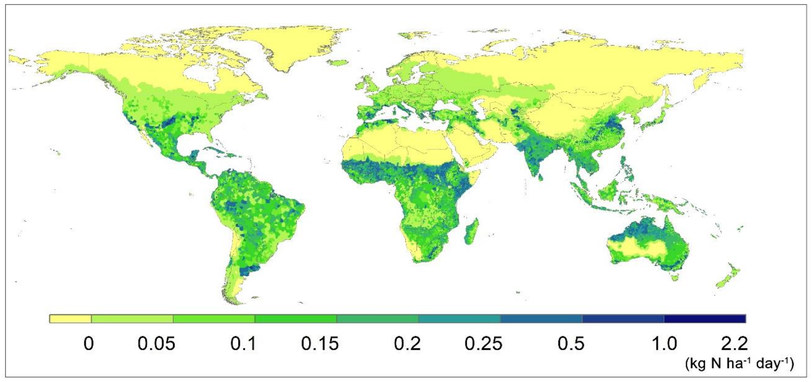

Figure 1. Global distribution of R_{nit} predicted by SGB model

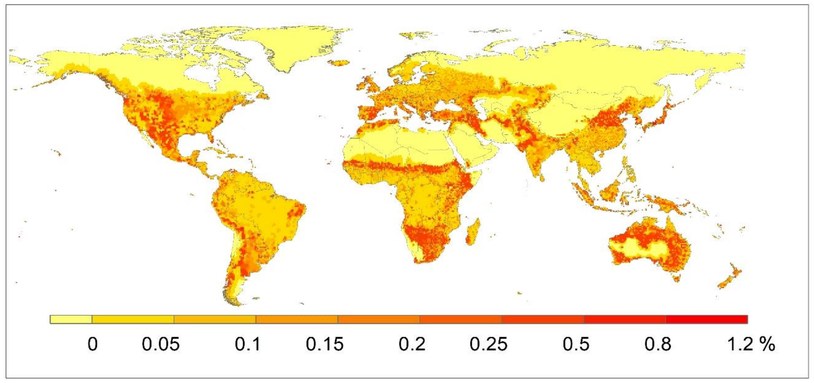

Figure 2. Global distribution of $f_{N_2O\_Nit}$ predicted by SGB model

Methods

- Dataset based on 186 observations from 25 papers.
- Using the same input variables, *viz.* soil NH_4^+ content, soil pH, soil water content and soil temperature to compare the performance of SGB and APSIM, Crop-DNDC and WNMM in predicting R_{nit} and associated N_2O production.
- Stepwise variable selection & 10-fold cross-validation for SGB models

Results

- SGB1 better predicts nitrification and associated N_2O emissions than the three widely used process-based models using the same input variables (soil NH_4^+ content, soil pH, soil water content and soil temperature) (Table 1).
- Nitrification rate varied spatially, spanning a wide range of 0.1-2190 g N ha^{-1} d^{-1} with an average of 110 g N ha^{-1} d^{-1}, using SGB with input variables soil pH, soil C/N ratio and MAT (Figure 1).
- $f_{N_2O\_Nit}$ covered a broad range from 0.006 to 1.24% (Figure 2) with an average of 0.13%, predicted by MAP, soil clay content, soil pH, soil total nitrogen.

Conclusions

- Large spatial variation in nitrification and its fraction as N_2O emissions was mainly driven by long-term environmental and edaphic factors.
- This study provides insights into advancing process-based models for projecting N dynamics and greenhouse gas emissions using a machine learning approach.

For more details,

Pan, B., Lam, S.K., Wang, E., Mosier, A. and Chen, D., 2021. New approach for predicting nitrification and its fraction of N_2O emissions in global terrestrial ecosystems. *Environmental Research Letters*, *16*(3), 034053.