

The global distribution of soil nitrification and the fraction of associated N₂O emission by using stochastic gradient boosting models



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Introduction

- Nitrification is a major pathway of N₂O production in aerobic soils.
- Robust prediction of gross nitrification rate (R_{nit}) and associated N₂O 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 N₂O production using a global literature-based database.
- To extend the simulation of R_{nit} and the fraction of nitrification as N₂O emissions ($f_{N_2O_{Nit}}$) using SGB models.

Methods

- Dataset based on 186 observations from 25 papers.
- Using the same input variables, *viz.* soil NH₄⁺ 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 N₂O production.
- Stepwise variable selection & 10-fold cross-validation for SGB models

Conclusions

- Large spatial variation in nitrification and its fraction as N₂O 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.

Table 1. Comparison of observed and predicted nitrification and associated N₂O 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 ₂ O_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

[§] N₂O emission from nitrification, RMSE: root mean square error and NSE: the Nash–Sutcliffe model efficiency.

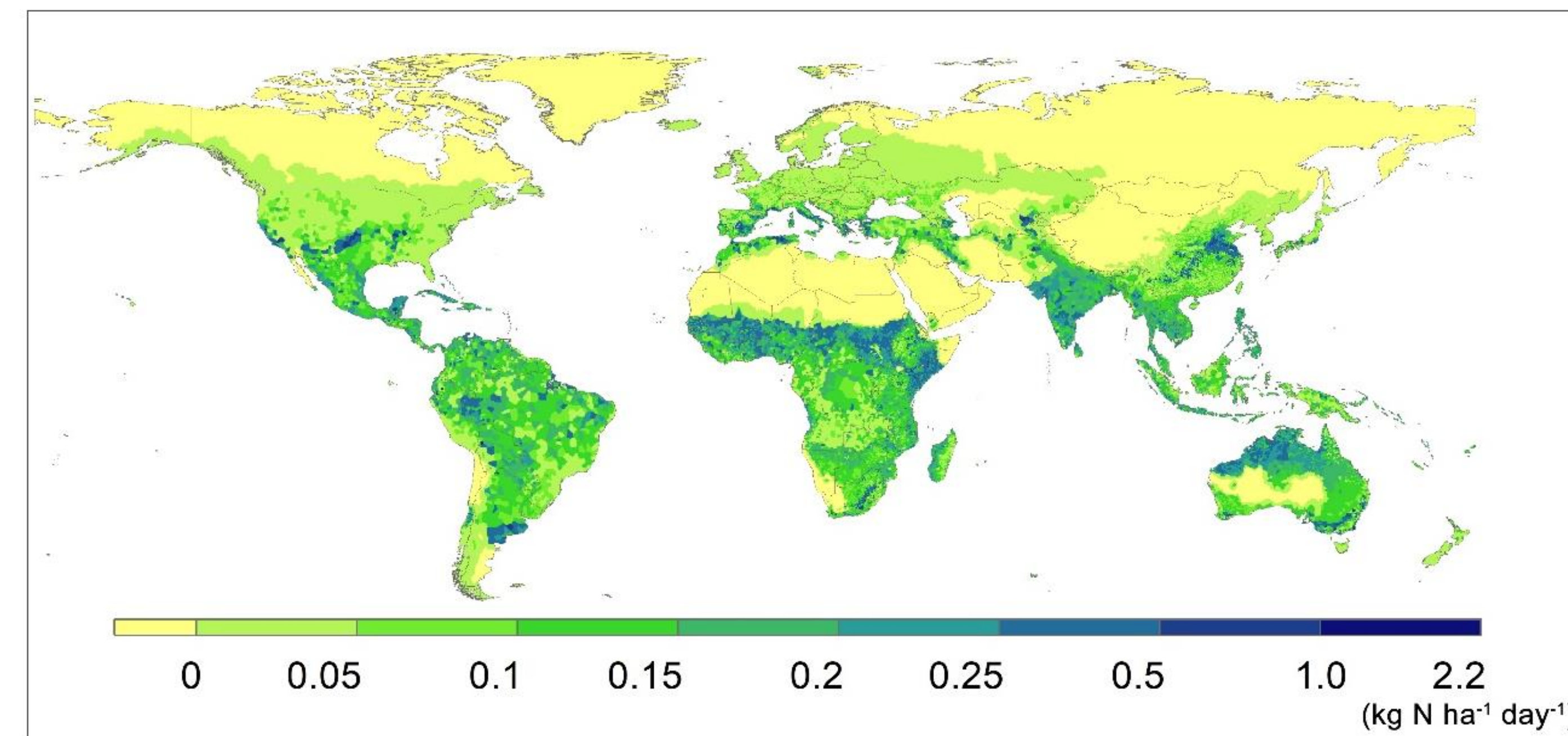


Figure 1. Global distribution of R_{nit} predicted by SGB model

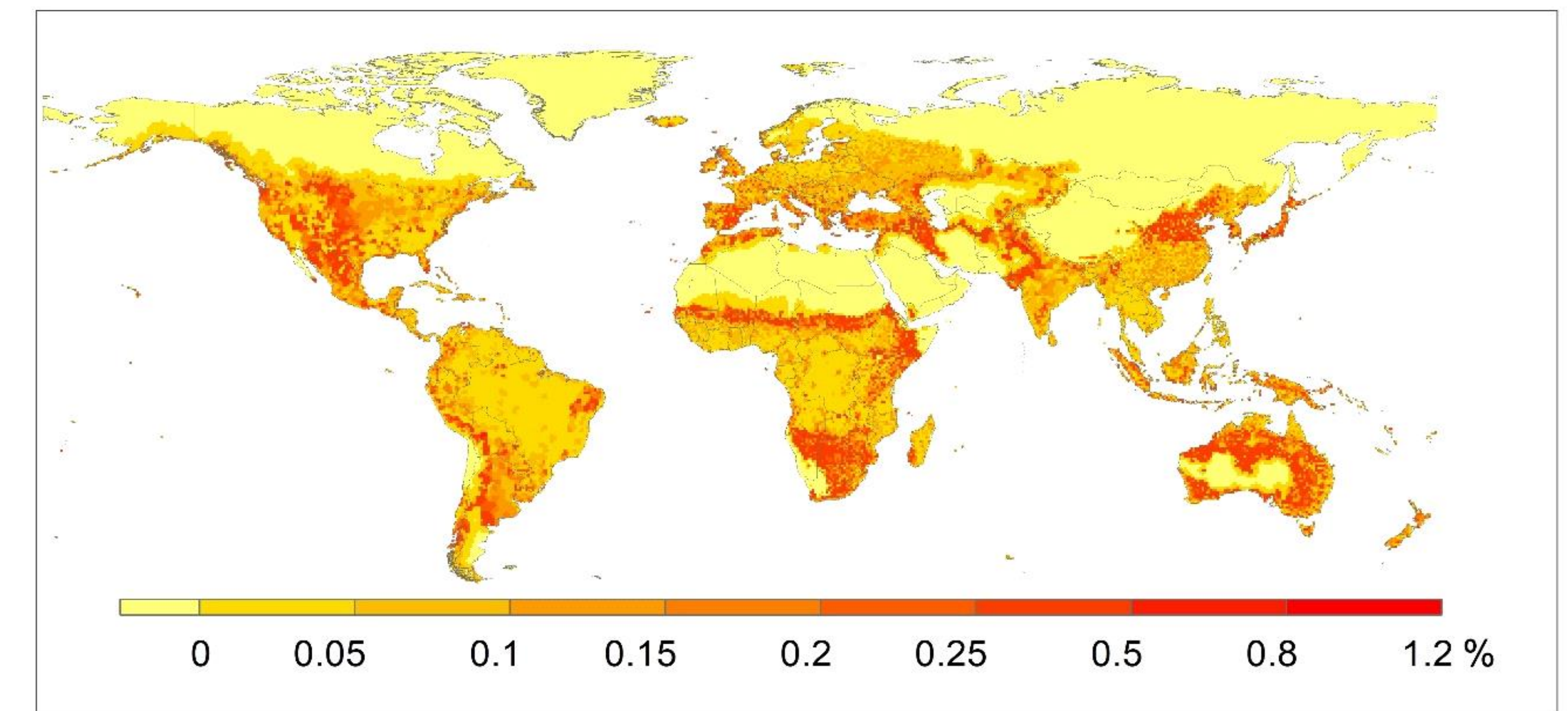


Figure 2. Global distribution of $f_{N_2O_{Nit}}$ predicted by SGB model

Results

- SGB1 better predicts nitrification and associated N₂O emissions than the three widely used process-based models using the same input variables (soil NH₄⁺ 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.

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 N₂O emissions in global terrestrial ecosystems. *Environmental Research Letters*, 16(3), 034053.