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Paul Belleville, Fabien Ferchaud, Frédéric Bornet, Benjamin Dumont, Jérôme Duval, Eric Gréhan, Bernard Heinesch, Frida Keuper, Bruno Mary, Guillaume Vitte, et al.

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## ➤ Using a long-term experiment with a wide range of management practices to challenge N<sub>2</sub>O emission modelling with the STICS model

P. Belleville<sup>1</sup>, F. Ferchaud<sup>1,2</sup>, F. Bornet<sup>1</sup>, B. Dumont<sup>1,3</sup>, J. Duval<sup>1</sup>, E. Gréhan, B. Heinesch<sup>1,4</sup>, F. Keuper<sup>1</sup>, B. Mary<sup>1</sup>, G. Vitte<sup>1</sup>, J. Léonard<sup>1</sup>

<sup>1</sup> INRAE, UMR Transfrontalière BioEcoAgro

<sup>2</sup> INRAE, UMR Eco&Sols

<sup>3</sup> Liege University, Gembloux Agro-Bio Tech, AgroBioChem/TERRA, Biosystems Dynamics and Exchanges (BIODYNE)

<sup>4</sup> Liege University, Gembloux Agro-Bio Tech, AgroBioChem/TERRA, Crop Science Unit

## ➤ Introduction

- N<sub>2</sub>O is a problematic gas when released into the atmosphere because of its global warming potential
  - Agriculture is one of the main sources of N<sub>2</sub>O emissions worldwide
  - Cropping systems have different N<sub>2</sub>O emission levels
- Modelling has great potential to synthesize existing knowledge and identify best cropping systems to mitigate N<sub>2</sub>O emissions
- N<sub>2</sub>O emissions are challenging to predict due to high spatiotemporal variability and complex interconnected drivers
- Our aim is to assess STICS ability to simulate long-term N<sub>2</sub>O emissions for contrasted cropping systems and to describe and analyse the error



## ➤ Method - N<sub>2</sub>O modelling withing STICS

STICS models two processes which set-up the order of magnitude of the nitrogen possibly available for N<sub>2</sub>O emissions:

- nitrification of NH<sub>4</sub><sup>+</sup> - driven by [NH<sub>4</sub><sup>+</sup>], pH, T°C, water content - and
- denitrification of NO<sub>3</sub><sup>-</sup> - driven by [NO<sub>3</sub><sup>-</sup>], T°C, water filled pore space

N<sub>2</sub>O-N emissions are described as a proportion of nitrification and denitrification rates:

- The share of N-nitrified emitted as N<sub>2</sub>O is driven by WFPS
- The share of N-denitrified emitted as N<sub>2</sub>O is driven by pH, water filled pore space, [NO<sub>3</sub><sup>-</sup>]

Known limits:

- Carbon availability is not involved in the N<sub>2</sub>O-module
- Instant, no-loss diffusion of N<sub>2</sub>O from soil to the atmosphere

## ➤ Method - Experimental site and treatments

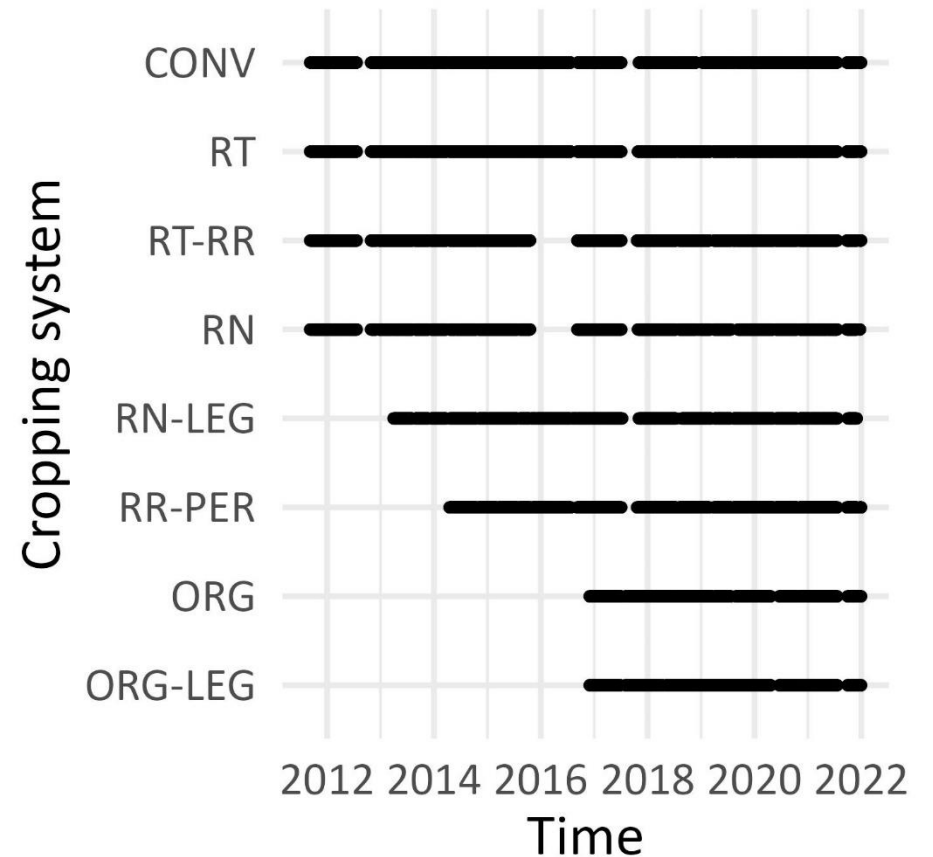
- Estrées-Mons – deep silt loam – oceanic with continental influence
- 6 treatments in a randomized complete 4-blocks design (11 ha) + 2 treatments in another randomized complete 3-blocks design (3 ha).

| Treatment                         | CONV | RT   | RT-RR | RN  | RN-<br>LEG | RR-<br>PER | ORG | ORG-<br>LEG |
|-----------------------------------|------|------|-------|-----|------------|------------|-----|-------------|
| Plowing                           | ✓    | ✗    | ✗     | ✓   | ✓          | ✗          | ✓   | ✓           |
| Exportation of cash crop residues | ✗    | ✗    | ✓     | ✗   | ✗          | ✓          | ✗   | ✗           |
| Mineral N (% of ref. dose)        | 100% | 100% | 100%  | 35% | 35%        | 100%       | 0%  | 0%          |
| Legumes' frequency                | low  | low  | low   | low | high       | low        | low | high        |
| Perennial crops within succession | ✗    | ✗    | ✗     | ✗   | ✗          | ✓          | ✗   | ✗           |
| Chemical protection               | ✓    | ✓    | ✓     | ✓   | low        | ✓          | ✗   | ✗           |

## ➤ Method - Experimental site and treatments



Automatic chamber monitoring N<sub>2</sub>O fluxes



## ➤ Method – STICS parameters

- Default parameters
- Gap in the order of magnitude of N<sub>2</sub>O emissions → find a value for **vpotdenit** (kg<sub>N</sub>.ha<sup>-1</sup>.day<sup>-1</sup> over 0-20 cm) yielding in close cumulative emissions for CONV

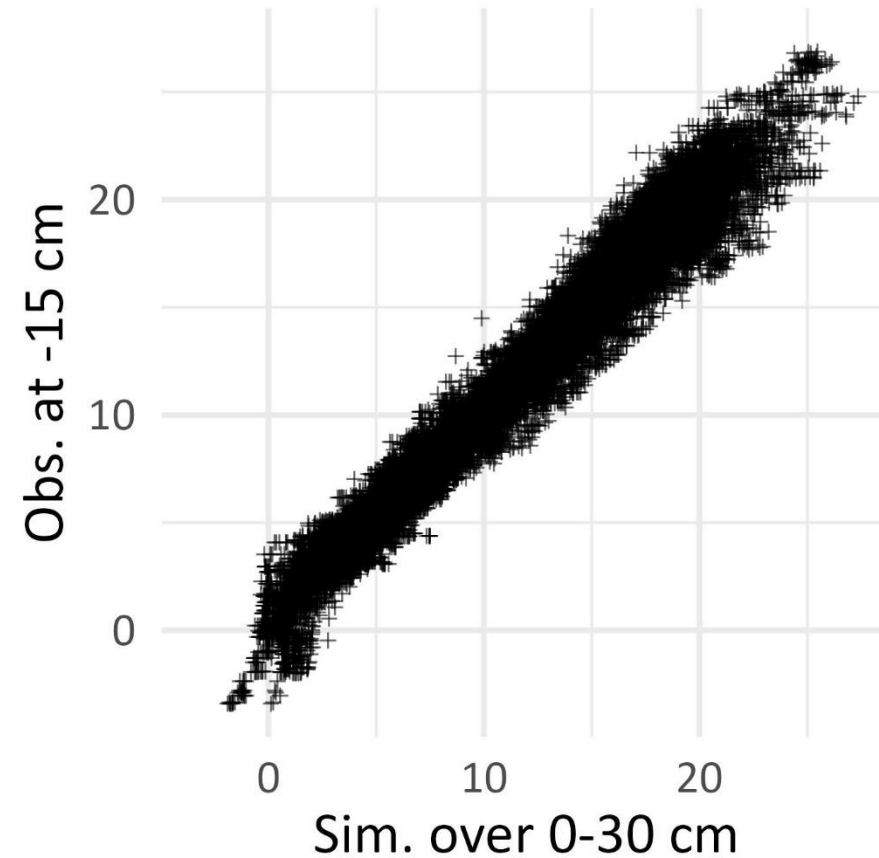
$$vdenit = \mathbf{vpotdenit} \times f(NO_3^-) \times f(Td) \times f(WFPS)$$

## ➤ Method - Simulation assessment and errors

- Variables of interest
  - Soil moisture, temperature,  $[\text{NH}_4^+]$  and  $[\text{NO}_3^-]$  +  $\text{N}_2\text{O}$  emissions
- Simulations assessment
  - Simulations vs Observations: scatterplot, temporal dynamic, cumulatives, standard indicators ( $R^2$ , RMSE)
- Describe prediction error
  - Is the difference between observed and simulated values explained by other variables? Is it possible to « predict » the error from other simulated values, and better understand the limits of the model?

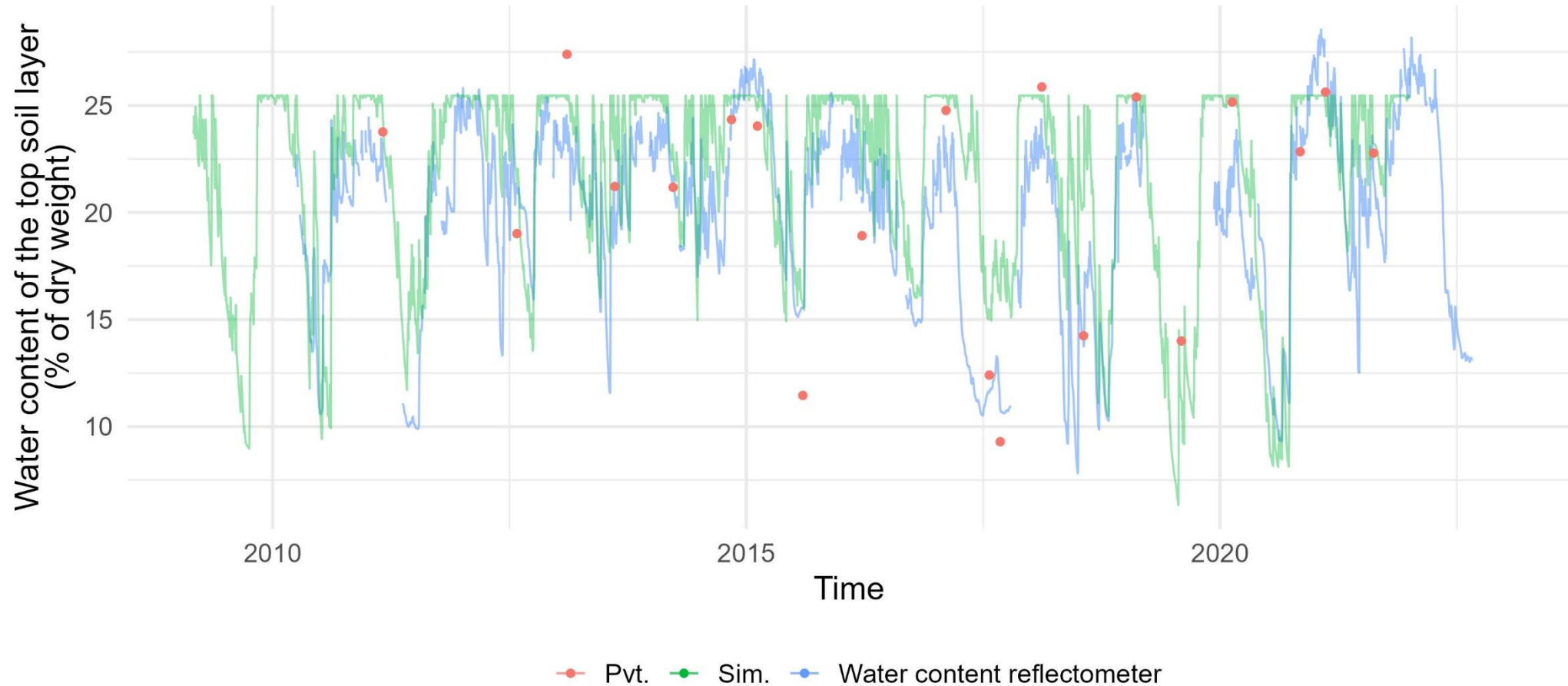


## ➤ Results – Simulation of N<sub>2</sub>O drivers



Obs. vs. Sim. Daily mean temperature (°C)

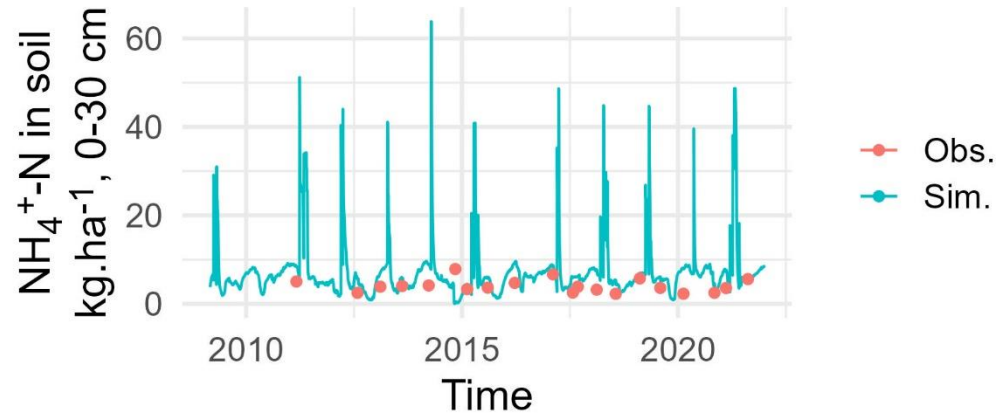
## ➤ Results – Simulation of N<sub>2</sub>O drivers



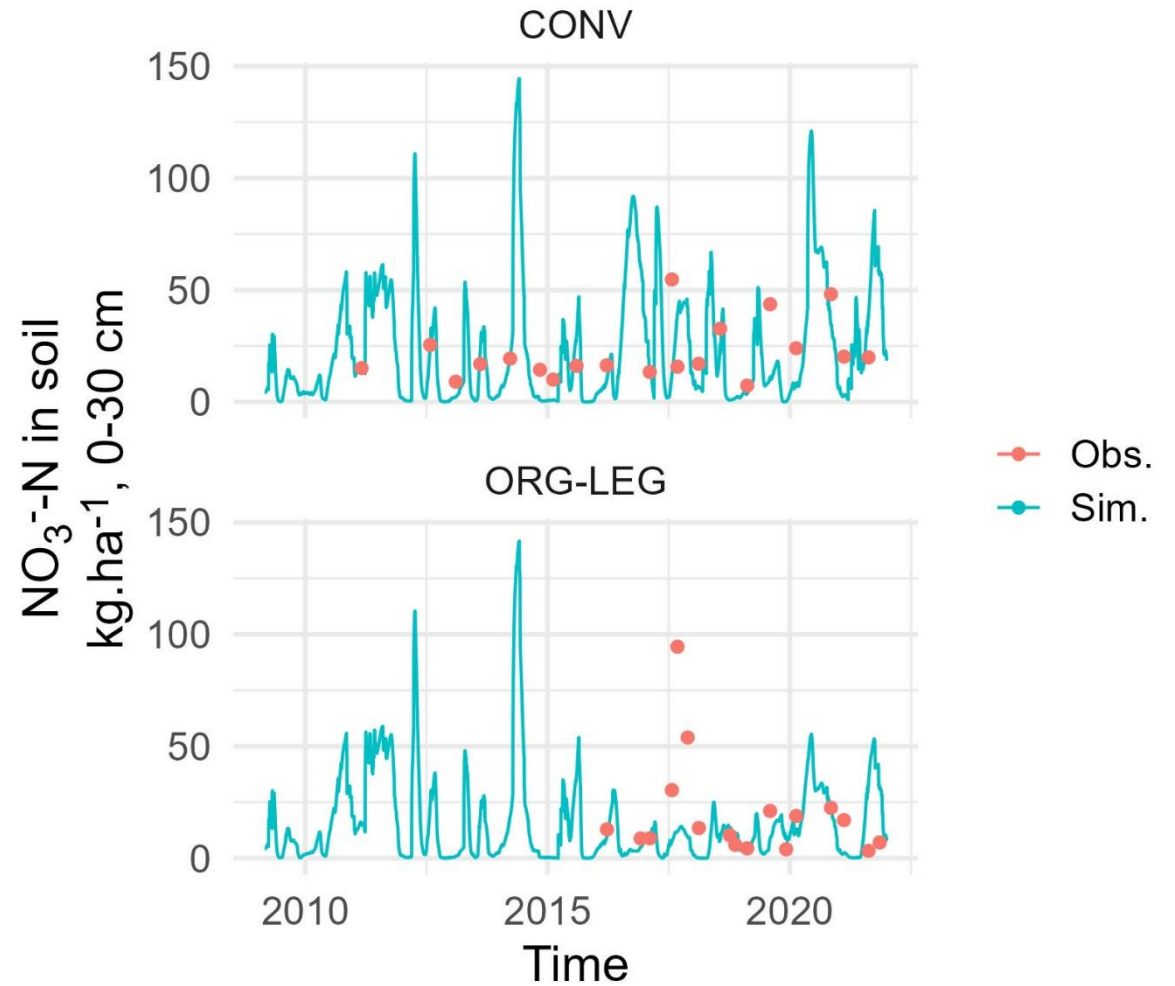
Comparison of three data sources for the estimation of the topsoil water content of the CONV treatment

## ➤ Results – Simulation of N<sub>2</sub>O drivers

NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup>



Ammonium-nitrogen in soil through time for the CONV treatment

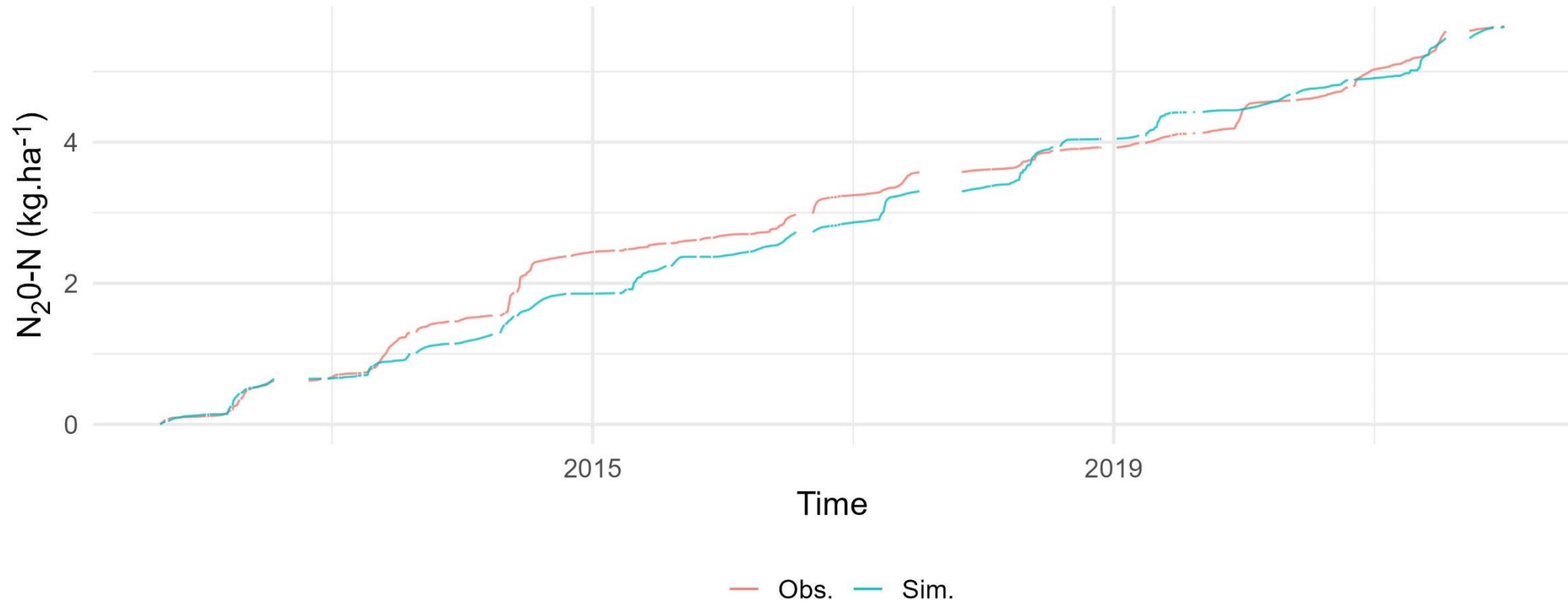


Nitrate-nitrogen in soil through time for the CONV and the ORG-LEG treatments



## ➤ Results – Adjusting the value of vpotdenit

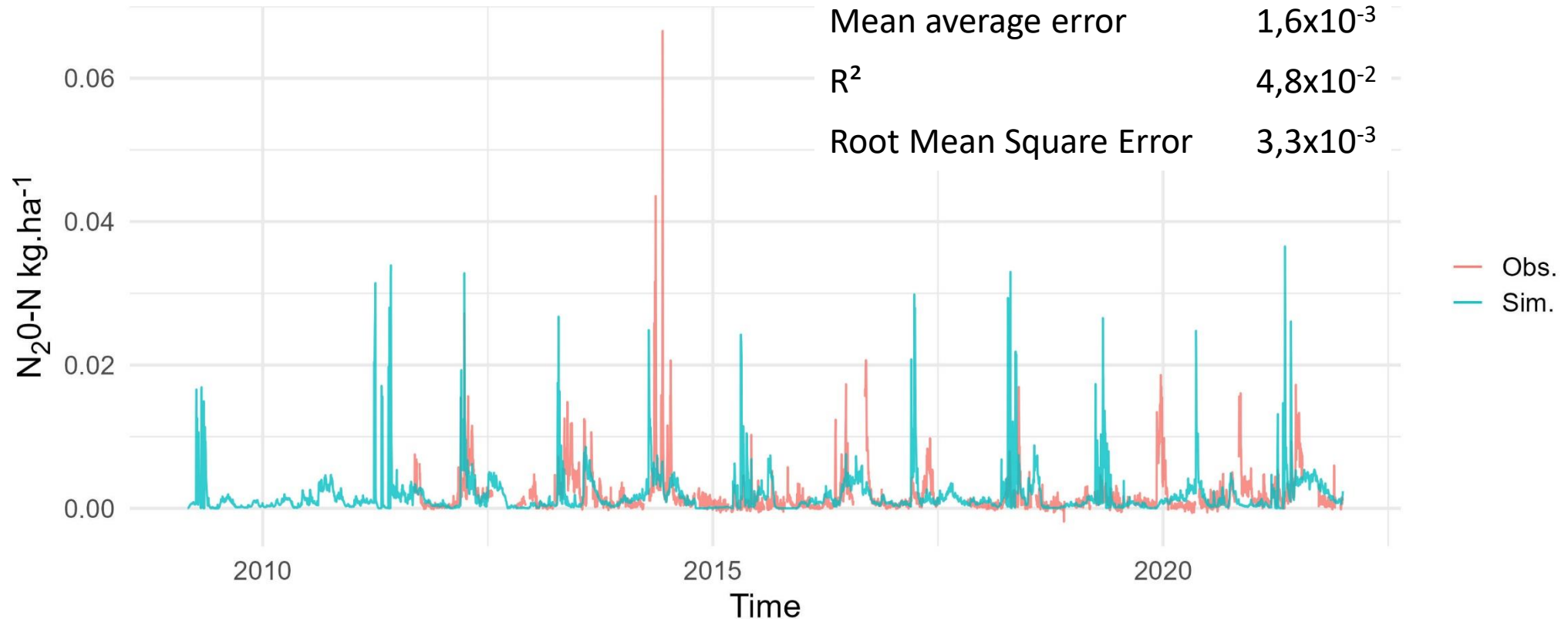
$v_{potdenit_s} = 0.07 \text{ kg}_N \cdot \text{ha}^{-1} \cdot \text{day}^{-1}$  over 0-20 cm (default is 2)



Cumulated N<sub>2</sub>O-N emissions for the CONV treatment using  $v_{potdenit} = 0,07$

## ➤ Results – Simulations of N<sub>2</sub>O emissions

$v_{potdenit_s} = 0.07 \text{ kg}_N \cdot \text{ha}^{-1} \cdot \text{day}^{-1}$  over 0-20 cm (default is 2)

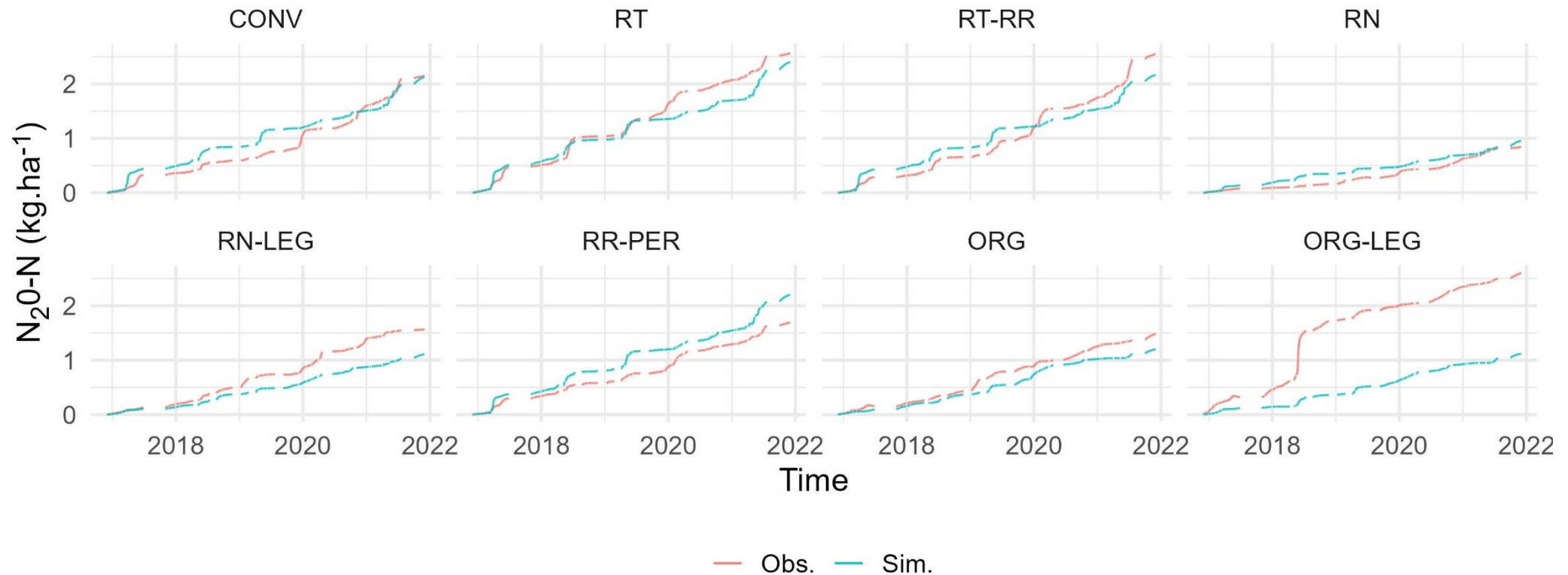


Observed and simulated N<sub>2</sub>O-N emissions through time for the CONV treatment



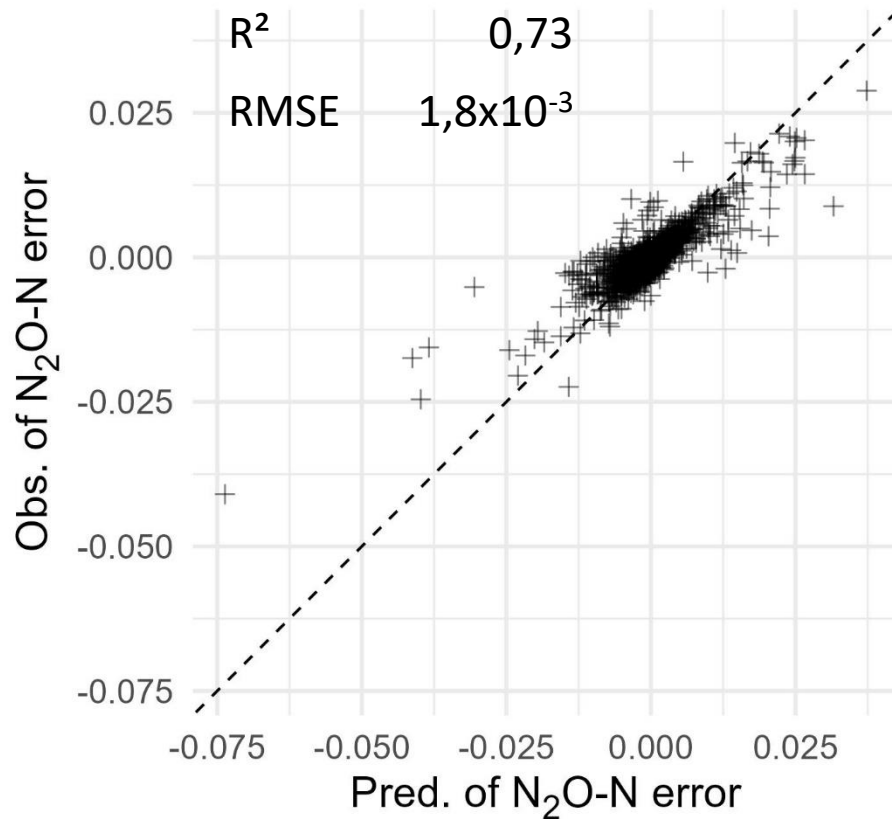
## ➤ Results – Simulations of N<sub>2</sub>O emissions

$v_{potdenit_s} = 0.07 \text{ kg}_N \cdot \text{ha}^{-1} \cdot \text{day}^{-1}$  over 0-20 cm (default is 2)



Cumulated N<sub>2</sub>O-N emissions for all treatments

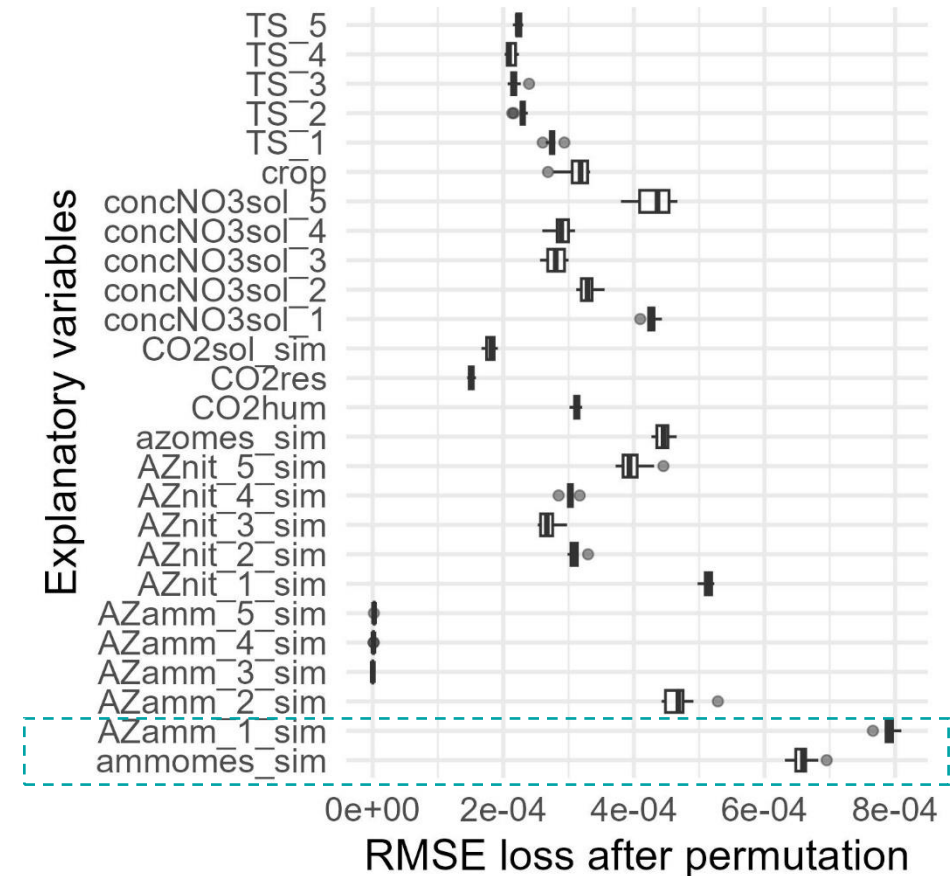
## ➤ Result – Predict STICS error on N<sub>2</sub>O emissions



Prediction of N<sub>2</sub>O-N sim-obs error using  
Random Forest model on test dataset

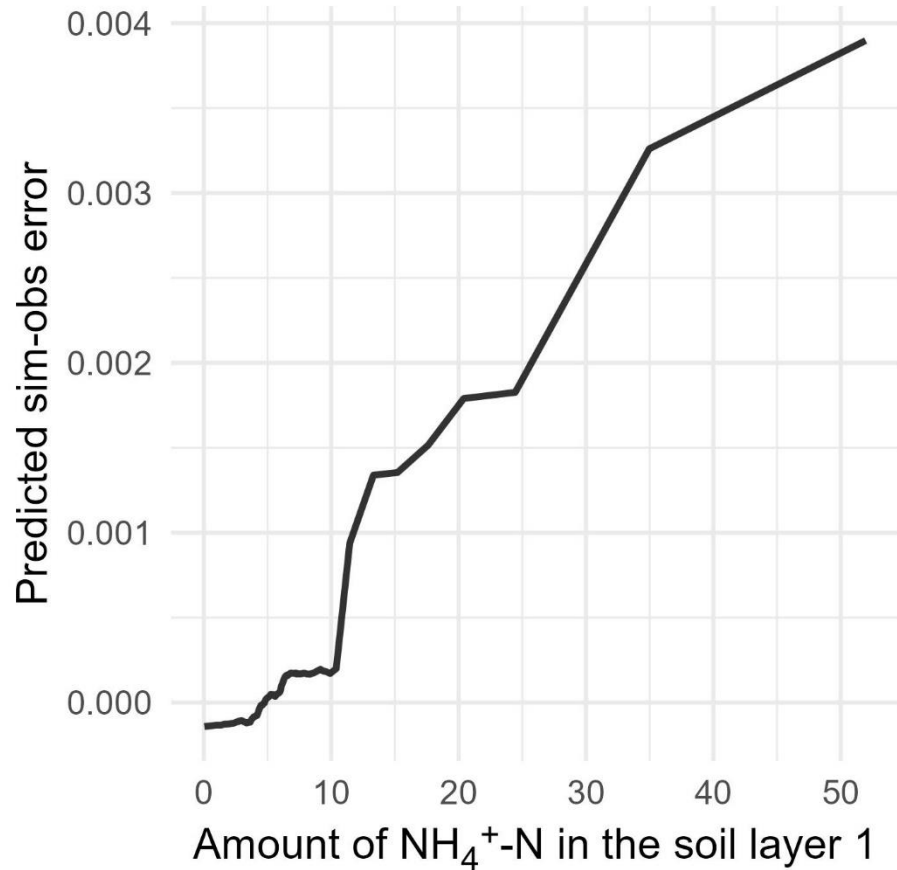
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2023-11-15 / Paul Belleville



Assessment of the variable importance for  
predicting the sim-obs error

## ➤ Results – Interpreting the random forest model



Accumulated-local profile of the main variable influencing the error



## > Conclusion

- Simulation of N<sub>2</sub>O emissions drivers
  - Soil temperature and soil moisture are considered as good enough
  - [NO<sub>3</sub><sup>-</sup>] is treatment-dependent
  - [NH<sub>4</sub><sup>+</sup>] is good for low concentration values but unknown for high concentration values.
- Simulation of N<sub>2</sub>O
  - Despite bad R<sup>2</sup>, the RMSE is low and the overall seasonality is simulated
  - Cumulative values are good except for the ORG-LEG treatment
- Understanding the error:
  - STICS error can be estimated using a random forest model fuelled by simulated variables
  - The amount of NH<sub>4</sub><sup>+</sup> is the main variable contributing to the random forest

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➤ Thank you for your attention!

5 mins for questions