

Tropicalization of the STICS model: insights from sugarcane calibration and nitrogen dynamics in tropical volcanic soils

Florent Kebalo¹, Mathias Christina² and
Antoine Versini¹

¹ CIRAD, UPR Recyclage & Risque

² CIRAD, UPR AIDA

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Challenges of tropicalization

Original cropping systems !

Sugarcane, major tropical crop

Giant C4 perennial grass



Original soils !

Volcanic and tropical soils



Mineralogy

2:1 clay in STICS

1:1 clay in tropical soils

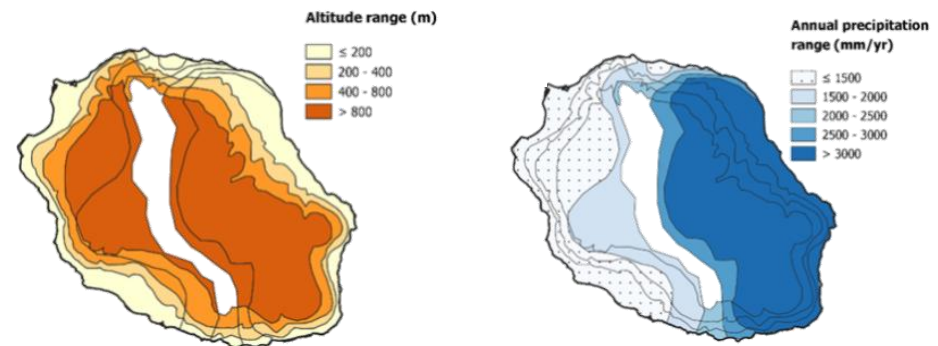
Allophane in andosols

pH

Often < 5,5

Original climates !

Rainfall pattern, temperature, wind, humidity



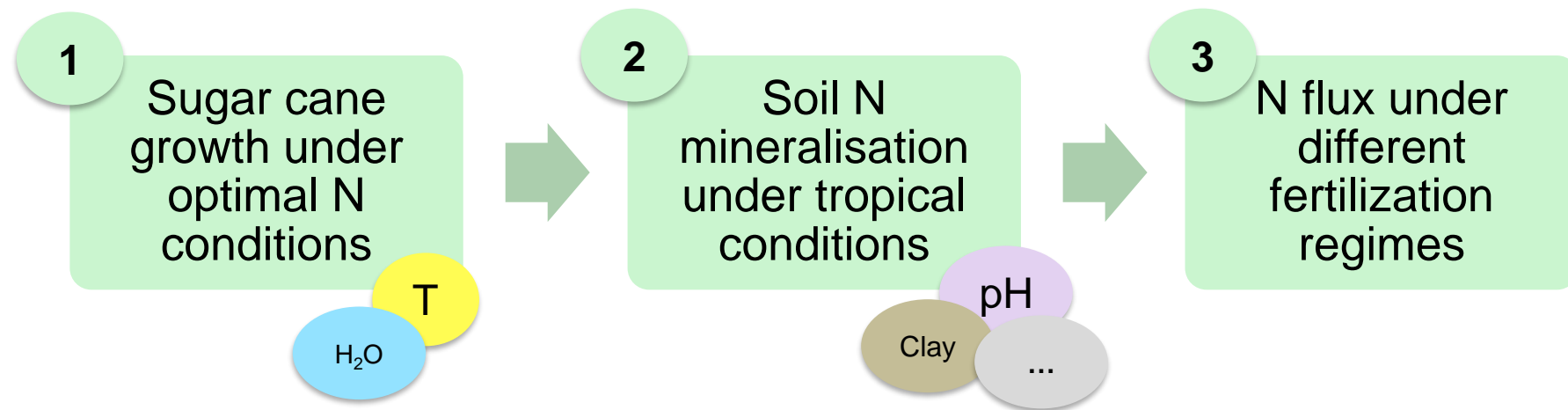
Why STICS?

- Island agriculture in La Réunion → Need to **assess agro-environmental impacts** for local organic fertilizer and sugarcane x legume associations
= STICS as a **generic model** for assessing varied conditions!

Need for Tropicalization ?

- Adapt the model through parameterization ?
- OR Need for new formalisms ?

Work phases



1 Sugarcane growth T & H₂O

Calibration procedure

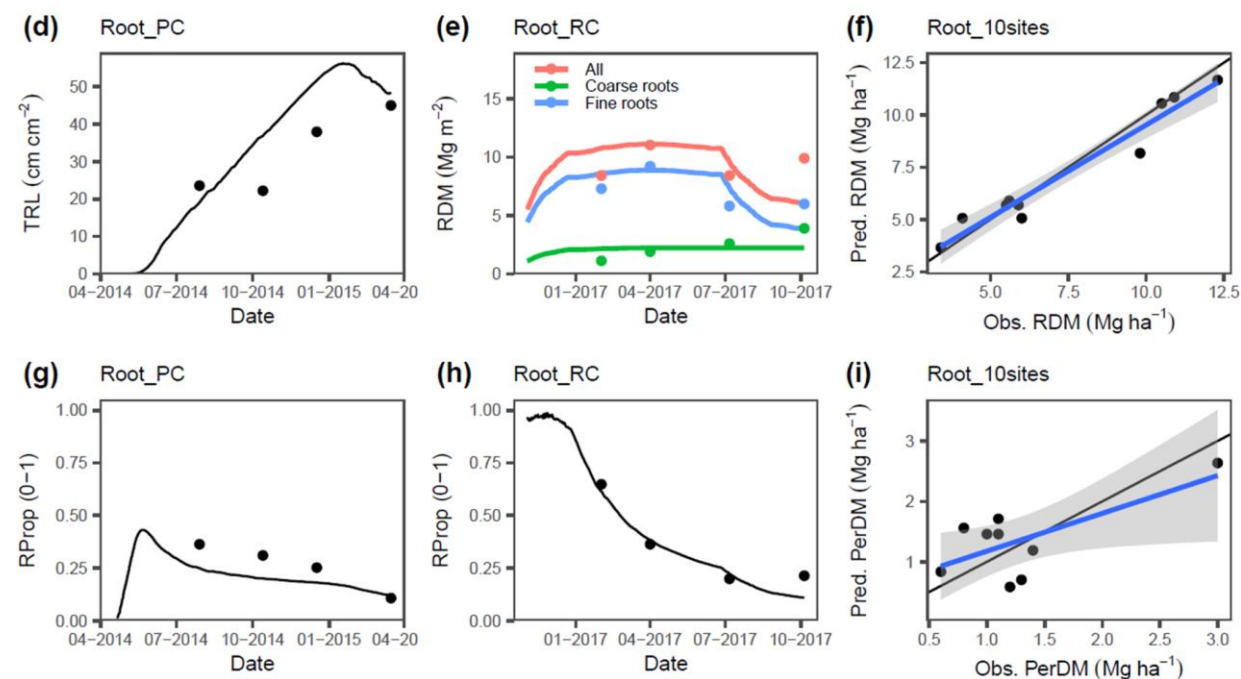
1) Calibration of the belowground compartment

- Root front & distribution
- Root length and root biomass dynamics (two root class)
- Perennial reserve



Dataset	La Réunion
2 sites	Dynamics over growth
10 sites	Biomass at harvest

Chevalier, 2025 (PhD)



1

Sugarcane growth T & H₂O

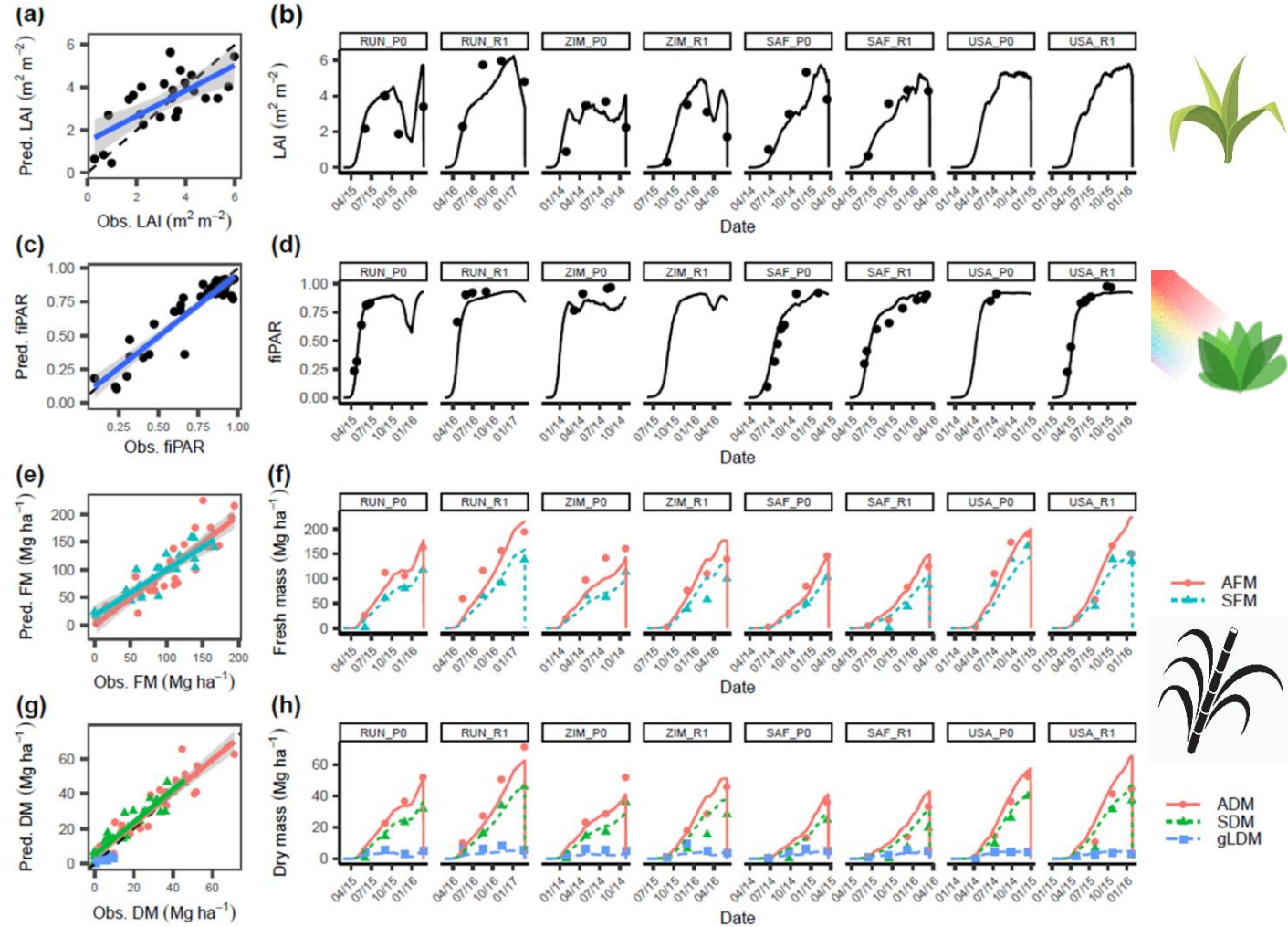
Calibration procedure

2) Calibration of the aboveground compartment

- LAI and fiPAR
- Stem and leaf biomass

Dataset	ICSM
4 countries	Plant and ratoon crop
1 variety	R570

Jones et al., (2021)



1 Sugarcane growth T & H₂O

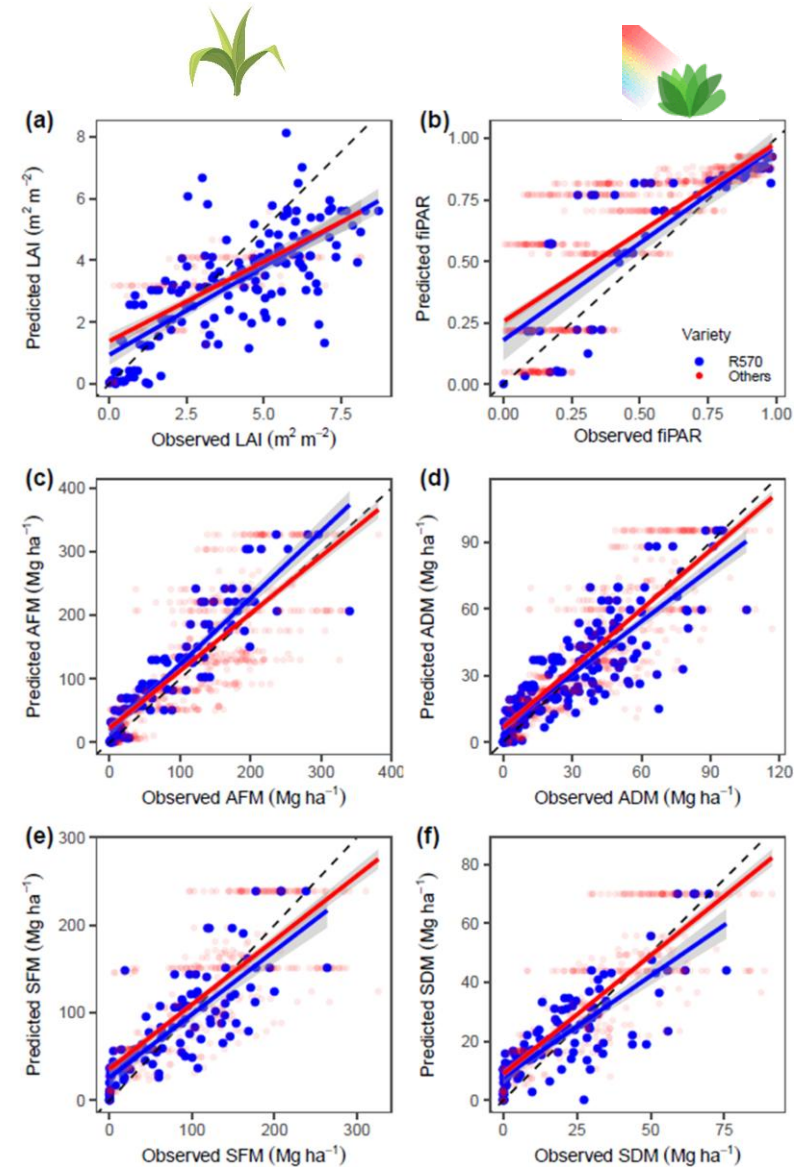
Validation procedure

3) Validation on an independent dataset

- LAI and fiPAR
- Above and stem dry and fresh mass

R570 variety (blue)
30 Other varieties (red)

Dataset	ECOFI database (Christina et al., 2020)	
4 countries	16 sites	R570 variety
3 countries	11 sites	Other varieties

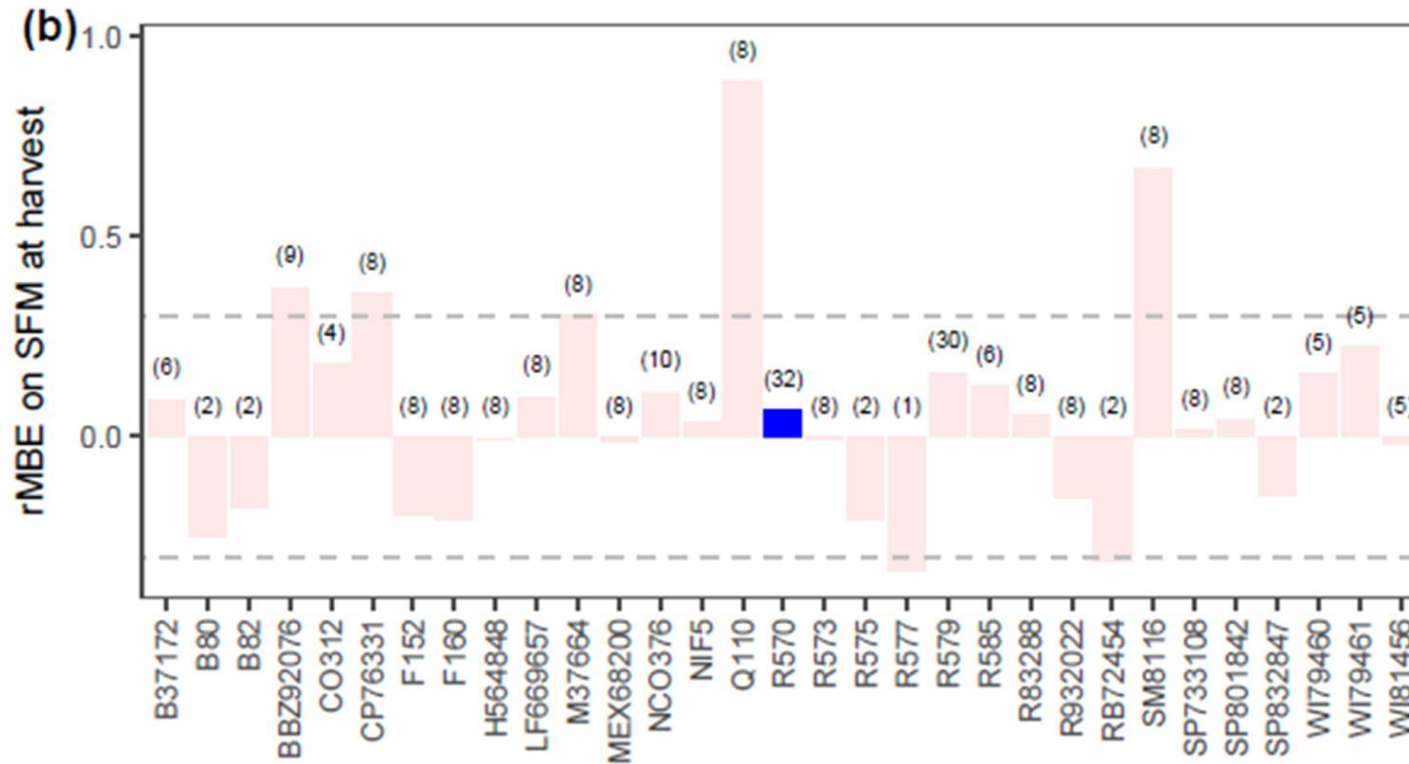


1 Sugarcane growth T & H₂O

Robustness of the calibration depending on variety

The calibration was mainly performed on R570 variety but can we use this calibration for other variety ?

Relative mean bias error at harvest on sugarcane yield



1

Sugarcane growth T & H₂O

1st Take home message

Calibration strategy:

- only **3 parameters were optimized** (*dlaimaxbrut*, *remobres*, *krepracperm*),
- all other were obtained from measurements (on-field or literature), crop similarity (e.g. miscanthus), and previous prototype

Model not able to represent **root-to-shoot plasticity**

→ site-specific calibration of *krepracperm* or change in formalism?

Robust calibration for sugarcane **yield** in stalk fresh mass (stem) regarding **climate**

→ Can be applied in many other varieties as a first step

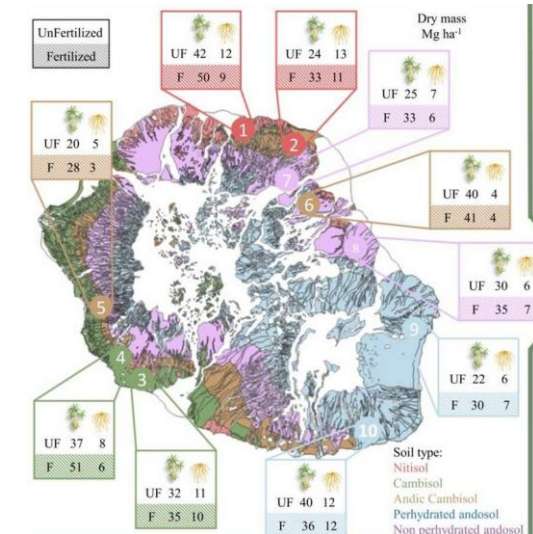
BUT currently not able to simulate sucrose yield !

2

Soil N mineralization and fertilizer N uptake

Calibration procedure of soil N mineralization

Dataset	La Réunion
12 sites	Yield and N uptake for 0N and 100N fertilization rates

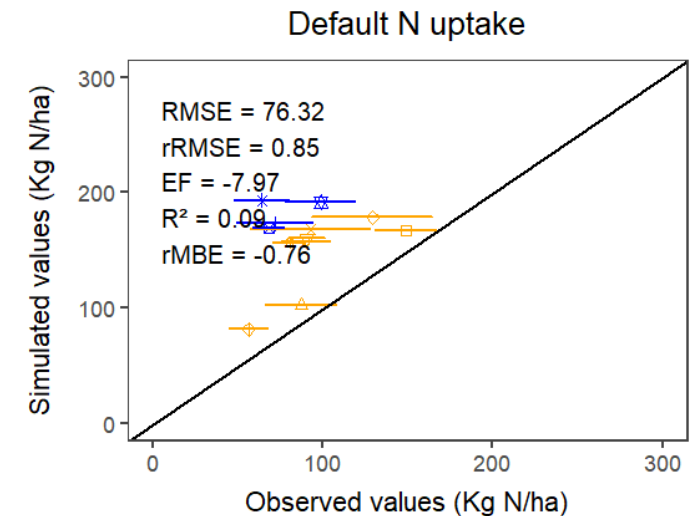


- Hypothesis: total N mineralization
 \approx N uptake by sugarcane in the 0N fertilization treatment

Rather poor performance with the default settings

Allophanic soils

1:1 clayey soils



2

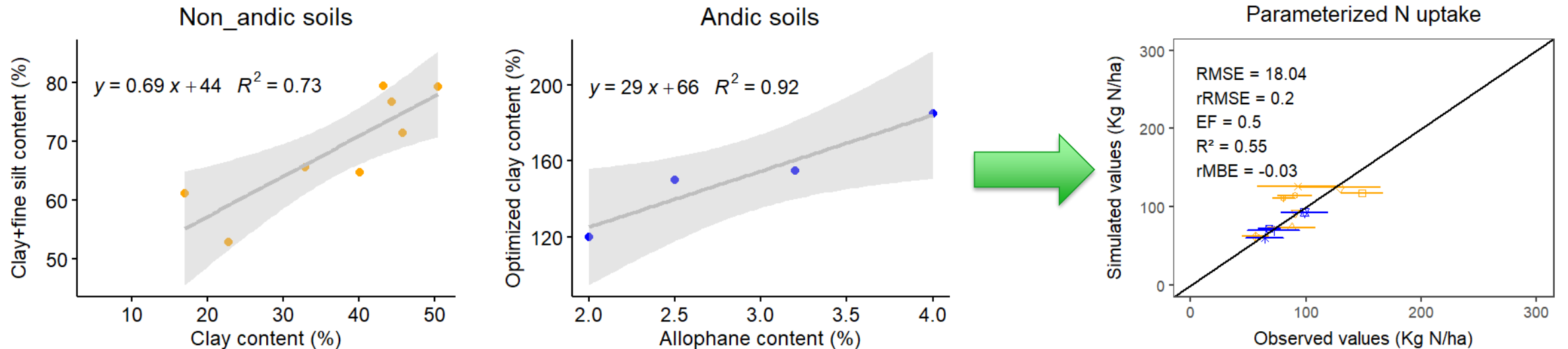
Soil N mineralization and fertilizer N uptake

Adaptation of soil N mineralization in STICS

Transformation of the clay variable

1:1 clay tropical soils : addition of fine silt

Allophanic soils : clay **optimization** and related to allophanes %

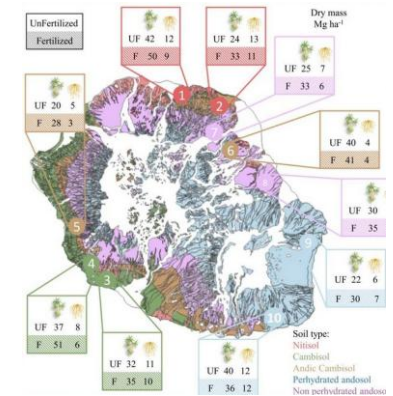


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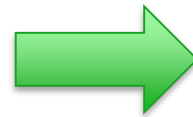
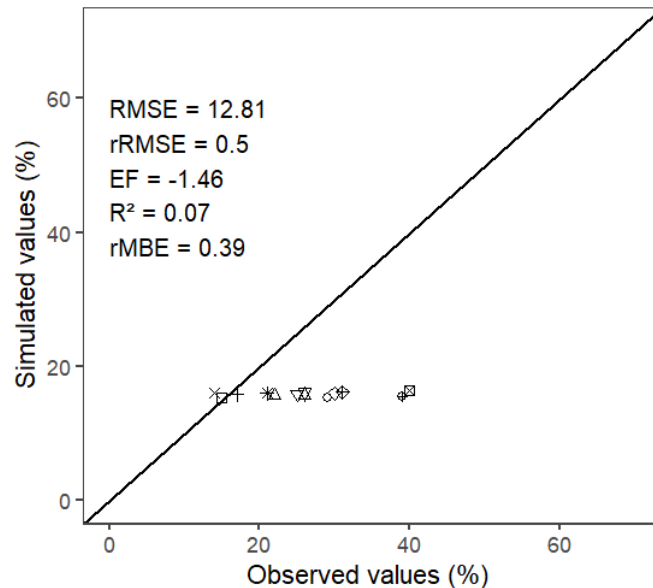
Soil N mineralization and fertilizer N uptake

Adaptation of fertilizer use efficiency

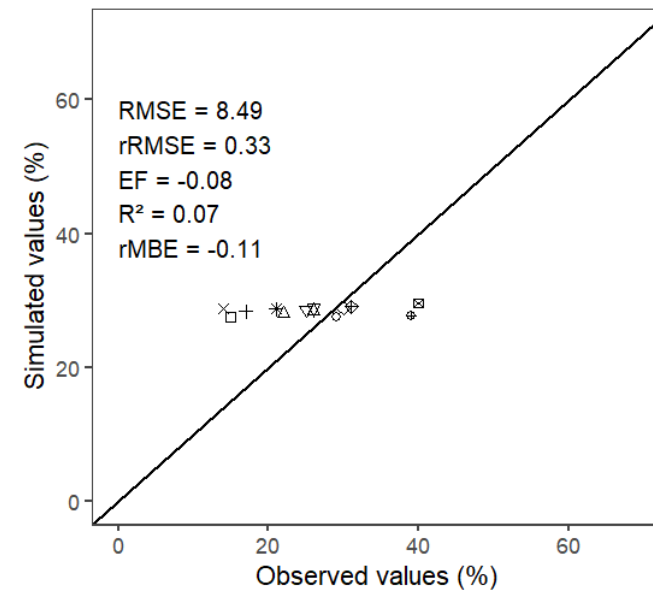
Dataset	La Réunion
10 sites	Fate of ¹⁵ N-labelled fertilizers in the soil-plant system



orgeng 35 (default)



orgeng optimized to 63 based on ¹⁵N measurements



Validation on TERO project

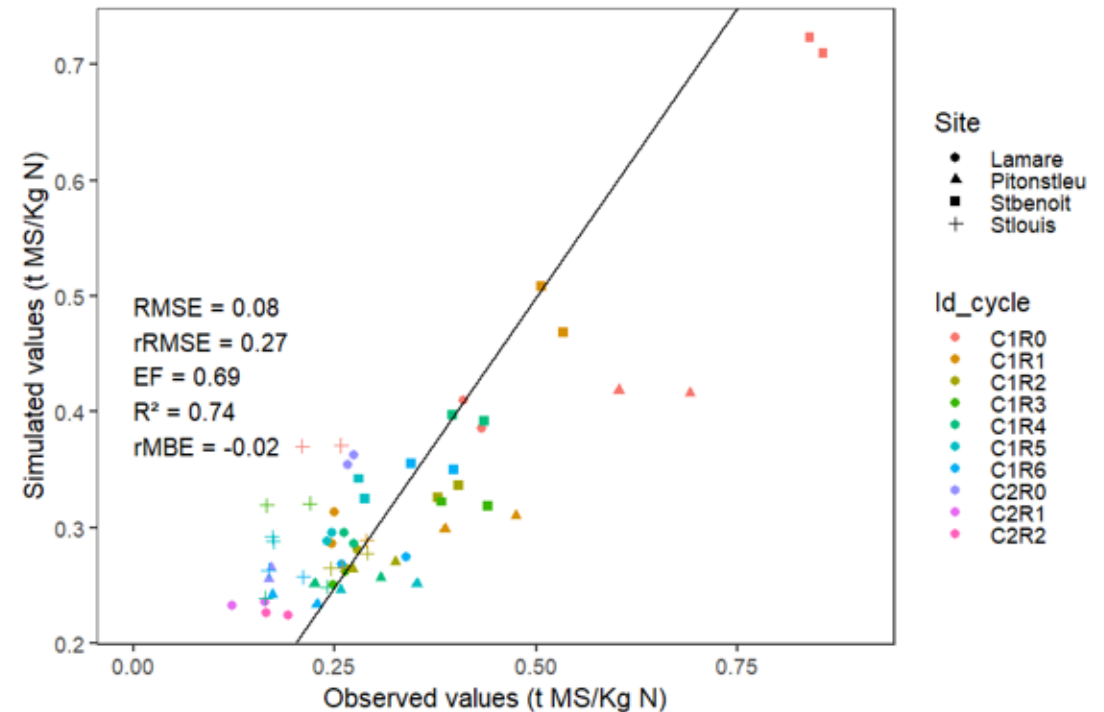
Validation dataset (TERO project):

- 4 sites x 7-10 years x 2 fertilization levels (0N and 100N)
- Measurements: N mass, aboveground biomass
- Contrasted soil: andic and non-andic, and climate (rainfall and temperature)

Valoriser la ressource canne
ercane



Partial-factor productivity (PFP): Yield / Fertilizer N



3 N losses under tropical conditions

Datasets and calibration procedure



Calibration dataset SOERE-PRO project:

- 1 sites x 11 years x organic and mineral fertilizers
- Measurements: N uptake, N volatilization, N₂O emissions, N lixiviation

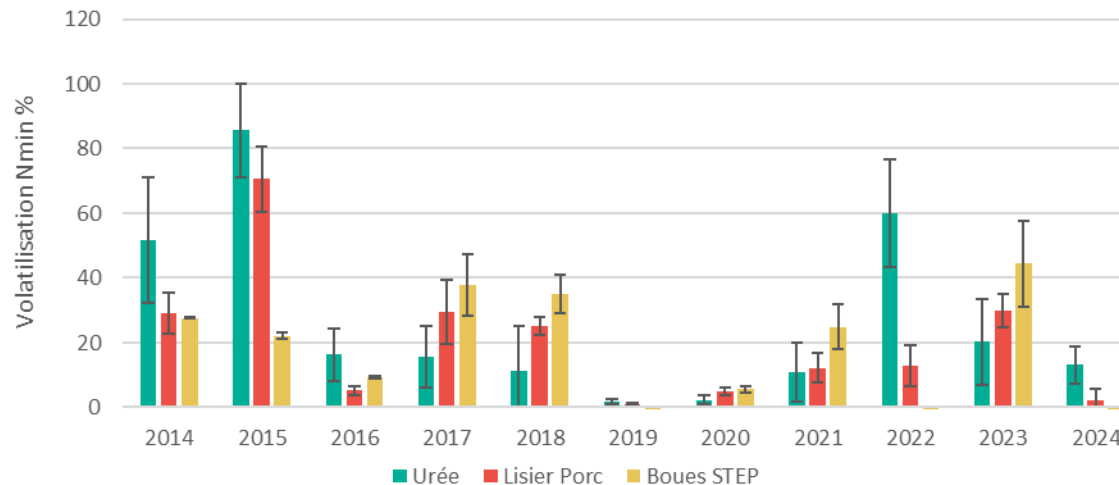


3 N losses under tropical conditions

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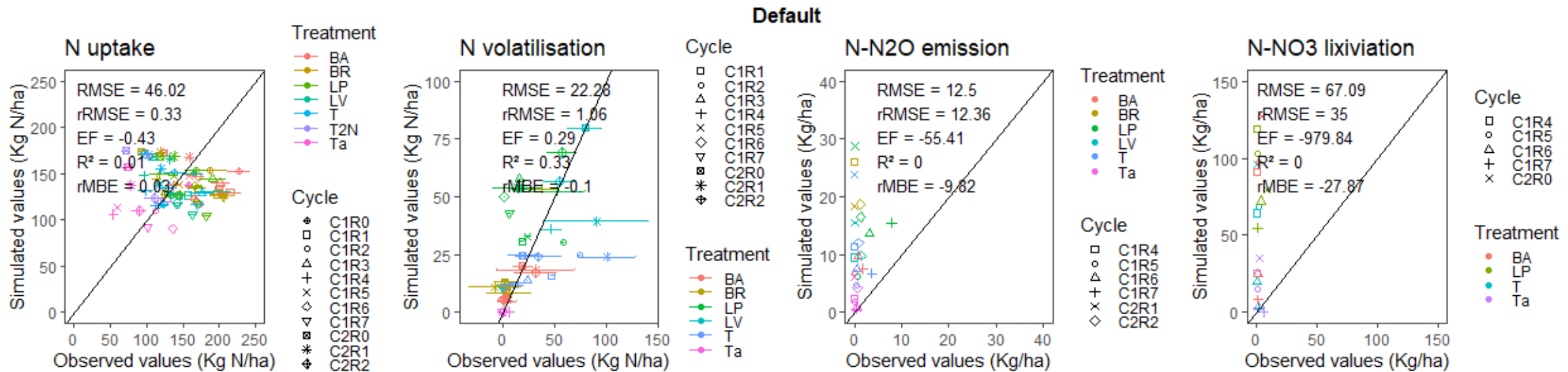
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3 N losses under tropical conditions

Calibration of N fluxes

Volatilization is acceptable but N₂O and NO₃ are strongly overestimated

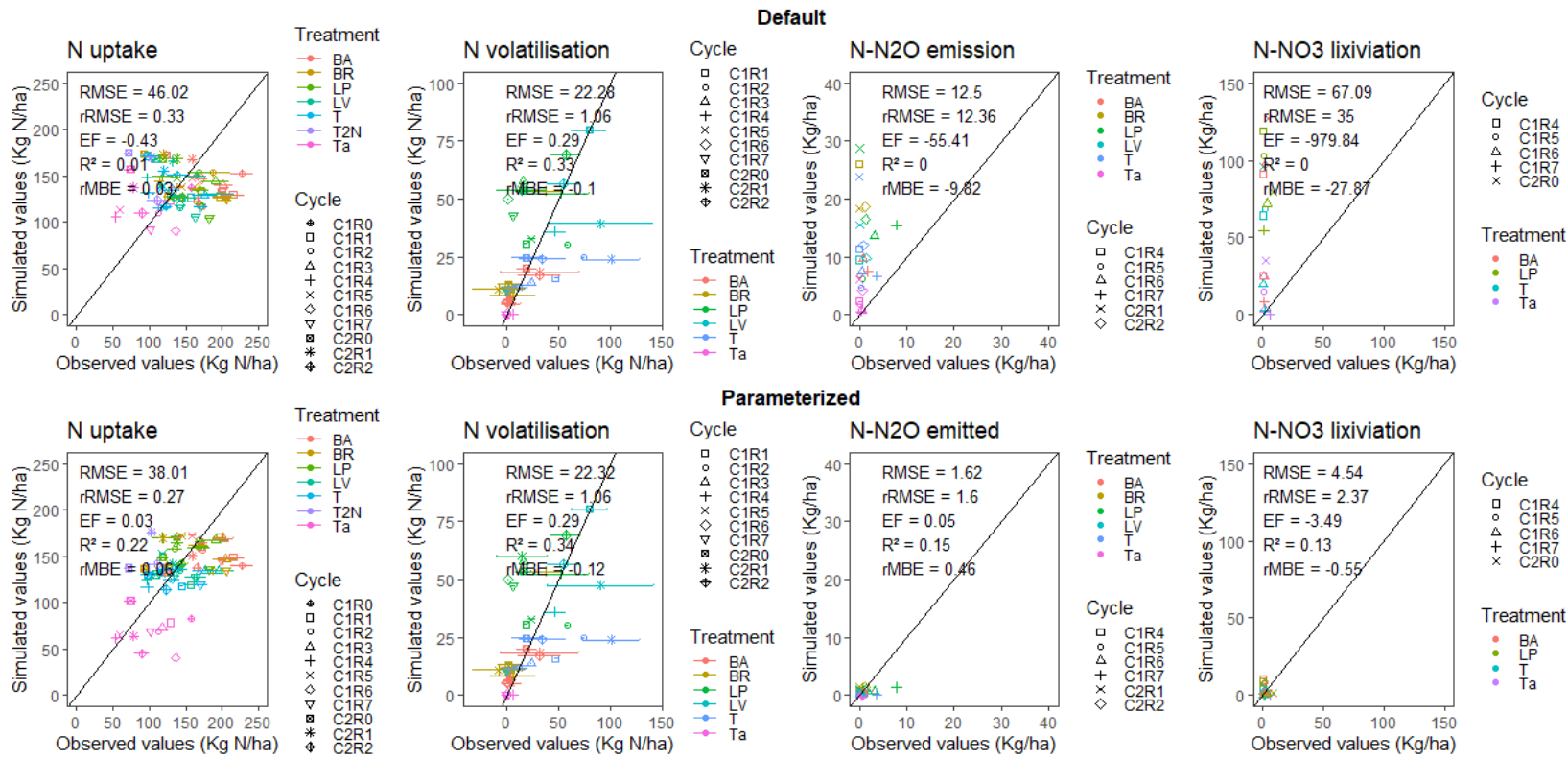


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N losses under tropical conditions

Calibration of N fluxes

Volatilization is acceptable but N₂O and NO₃ are strongly overestimated



→ Reduction of the maximum nitrification rate *f_{nx}*, from 0,8 to 0,0007

Field measurement estimation of 0,07

2nd Take home message

A way to improve N mineralization for tropical conditions is by **adjusting the soil's clay**

Increase the fertilizer N immobilization in tropical conditions

N volatilization was quite well simulated by the default model despite the wide range of fertilizers

The overestimation of N₂O emission and N leaching by the model was improved by **reducing the maximum nitrification rate**

Perspectives

STICS « plant » perspectives

Modelling cane x legume **intercropping**

Viaud, 2023 PhD
(data)

De Freitas, 2026 PhD
(STICS cereal-cowpea)



Optimization of crop management
→ Balance between sugarcane
and cowpea yield



Perspectives

STICS « plant » perspectives

Modelling **sucrose accumulation in the stalk**

→ use of temporary reserve in STICS? Or add a grain in the stem?



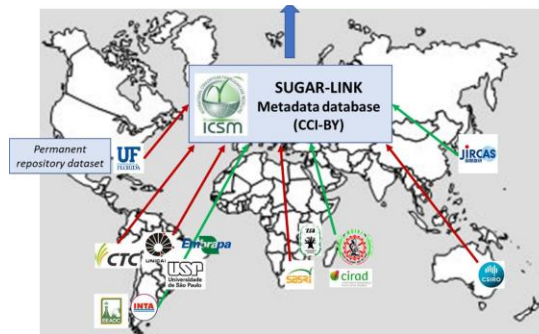
Comparison of **sucrose accumulation formalisms** in sugarcane crop models



next generation

MOSICAS

QCANE



Test the feasibility of different approaches as sucrose accumulation in the stem in STICS

Perspectives

STICS « soil » perspectives

Modelling volcanic and tropical SOM mineralization

- ❑ Accounting for 1:1 and amorphous clays in STICS : new function or calibration ?
- ❑ Improving tropical SOM mineralization in soil-crop models



Marie Ruillé, 2025-2028
Post-doc



Multimodel simulation of
SON mineralization vs.
observed crop N uptake



STICS simulations of **SOC dynamic**
in tropical long-term experiments

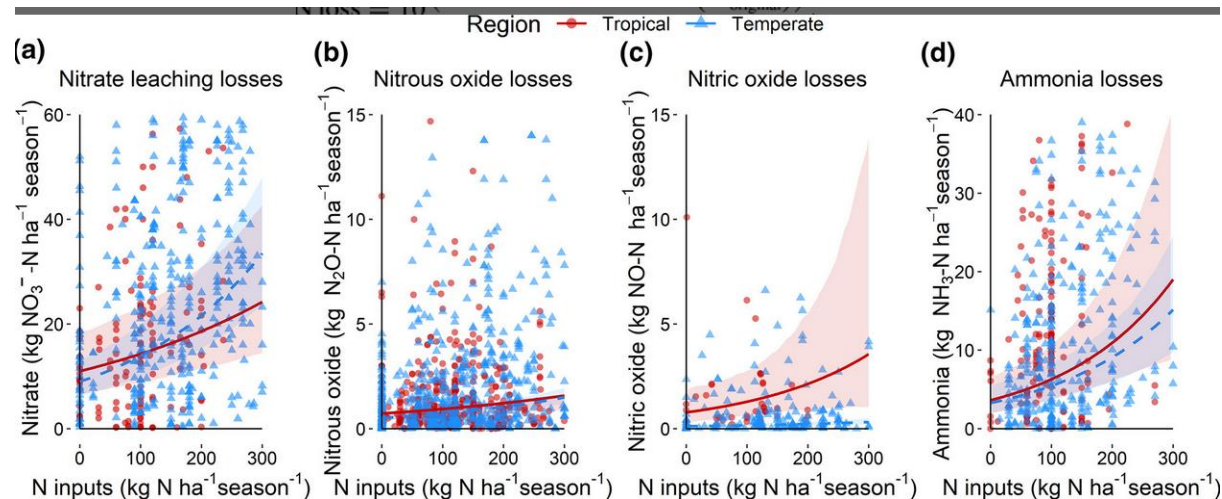


Perspectives

STICS « fertilizer » perspectives

Modelling N fluxes toward atmosphere and hydrosphere

- N₂O and NH₃ datasets mixing temperate and tropical measurements
→ STICS ability to simulate these fluxes with the same formalisms and parameterization ?



- Modeling makes it possible to determine whether the processes involved differ between temperate and tropical contexts

Huddell *et al.* 2019. GCB



Merci à tous !



Florent Kebalo (post-doc): disponible pour contrats de recherche!