Review of APSIM's soil nitrogen modelling capability: Lessons and implications

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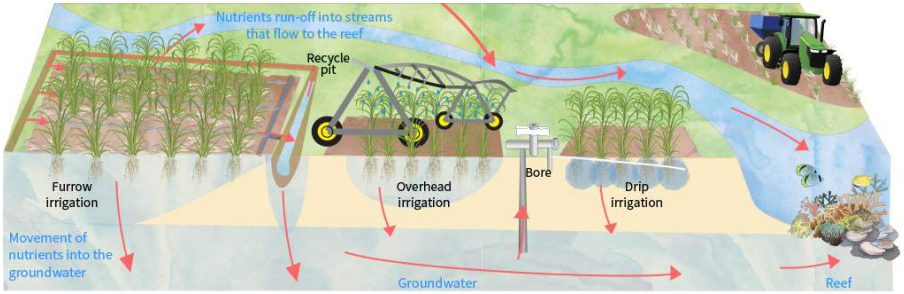
Why?

- 26 yrs of APSIM-Soil N

APSIM's Water and Nitrogen Modules and Simulation of the Dynamics of Water and Nitrogen in Fallow Systems

M. E. Probert,[a] J. P. Dimes,[a] B. A. Keating,[a] R. C. Dalal[b] & W. M. Strong[b]

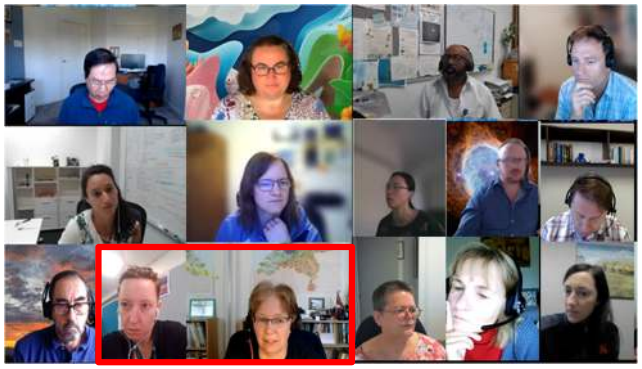
- Increased focus on environmental impacts



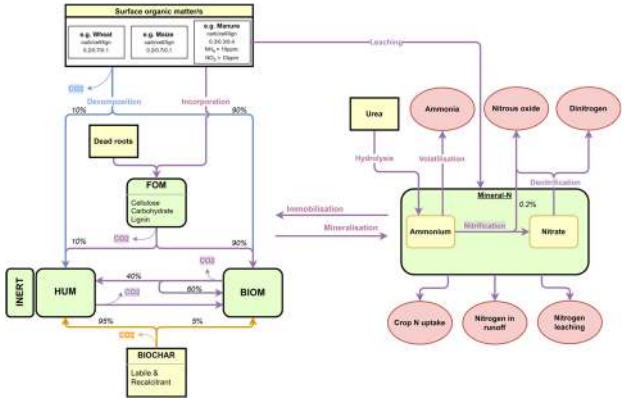
- Aim:
  - Provide a detailed reflection on APSIM's soil N modelling capability → inform and prioritise future development needs
  - Bring all documentation of model features in one place
  - **Share the lessons learnt**

How?

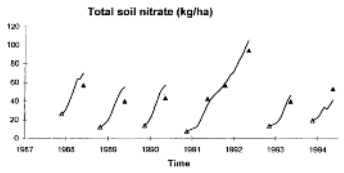
- Approach
  - Insights from 23 co-authors



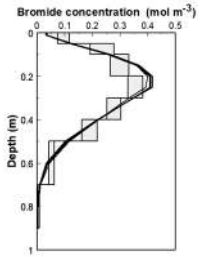
  - Full model description each process



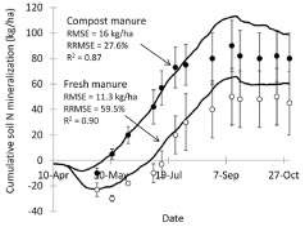
  - 132 model-data comparison studies



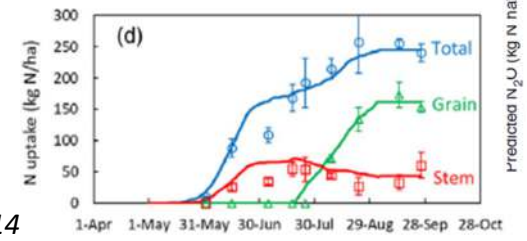
Probert et al. 1998



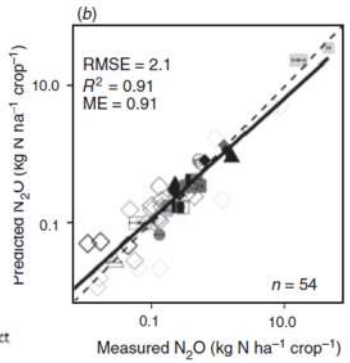
Bond et al. 1999



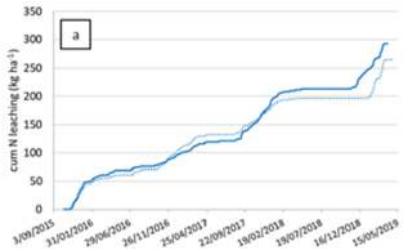
Archontoulis et al. 2014



Archontoulis et al. 2020

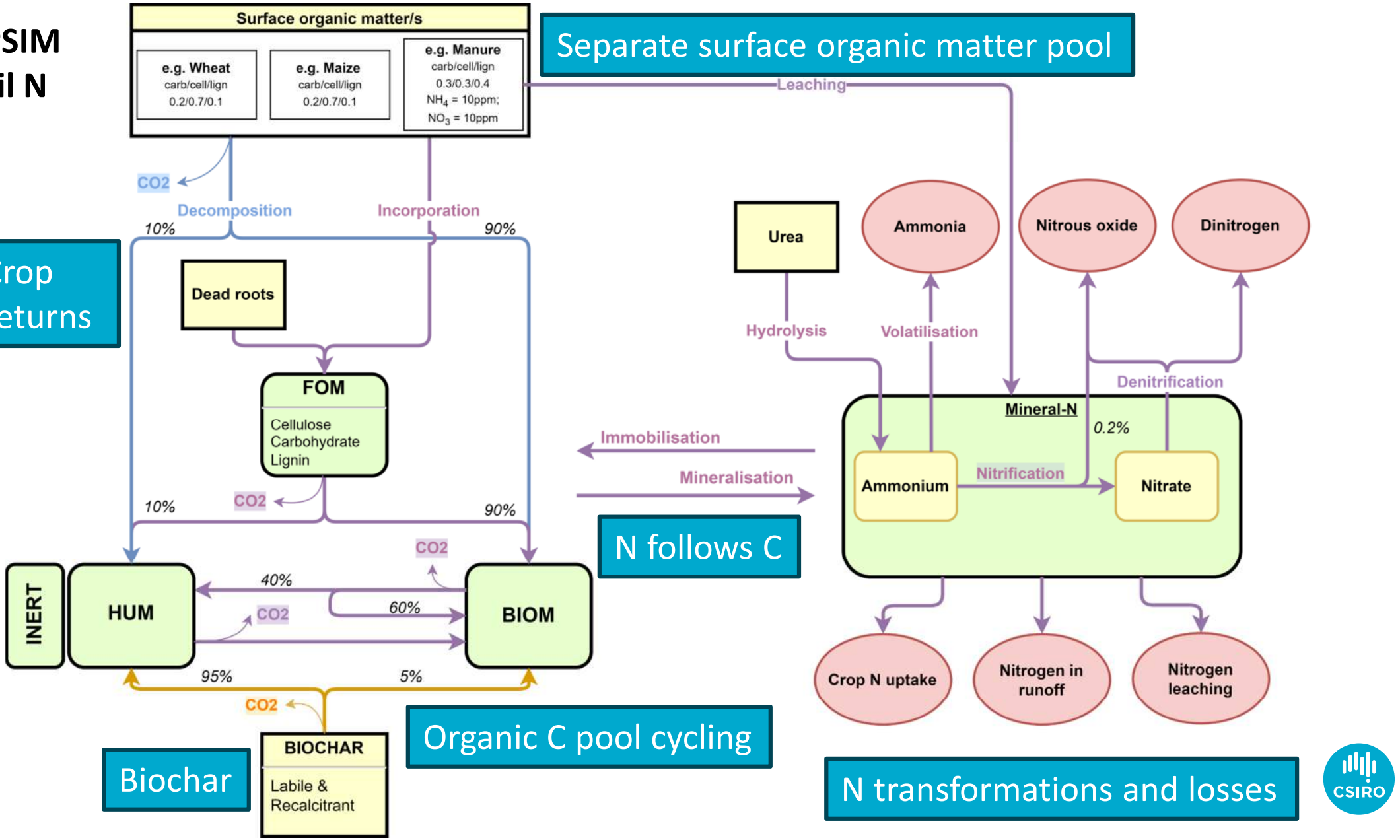


Mielenz et al. 2016



Vogeler et al. 2023

APSIM
Soil N


Surface organic matter/s
e.g. Wheat
carb/cell/lign
0.2/0.7/0.1
e.g. Maize
carb/cell/lign
0.2/0.7/0.1
e.g. Manure
carb/cell/lign
0.3/0.3/0.4
NH4 = 10ppm;
NO3 = 10ppm
Separate surface organic matter pool
Leaching
CO2
Decomposition
Incorporation
10%
90%
Crop returns
Dead roots
FOM
Cellulose
Carbohydrate
Lignin
10%
CO2
90%
CO2
INERT
HUM
40%
60%
BIOM
CO2
95%
5%
CO2
BIOCHAR
Labile &
Recalcitrant
Biochar
Organic C pool cycling
Urea
Ammonia
Nitrous oxide
Dinitrogen
Hydrolysis
Volatilisation
Denitrification
Mineral-N
0.2%
Immobilisation
Mineralisation
N follows C
Ammonium
Nitrification
Nitrate
Crop N uptake
Nitrogen in runoff
Nitrogen leaching
N transformations and losses

Model Strengths

- Strong performance across all processes
- Customisable coding structure
- Robust model review process

Model Challenges

- Sensitivity to initialisation approach
- Uncertainty in measured data
- Daily timestep simulating sub-daily processes

Cautionary Tales

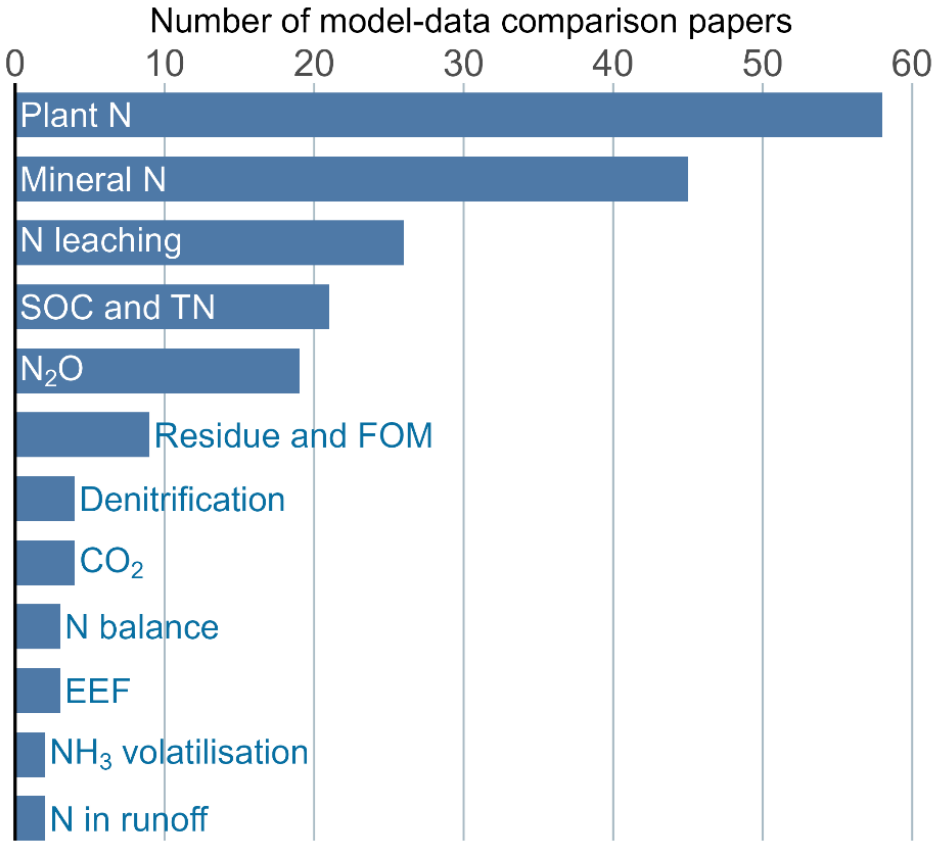
- Parameter optimisation focused on one system
- Simple measurements for complicated processes
- Equifinality in carbon pool parameterisation

Next Steps

- Test prototypes (NH_3 volatilisation and runoff)
- Test proposed parameter changes
- Capitalise on advances in measurement techniques and process understanding

Model Strengths

Strong performance across all processes



Model Strengths

Strong performance across all processes

Climate Change and Management Impacts on Soybean N Fixation, Soil N Mineralization, N_2O Emissions, and Seed Yield

long-term impacts of cover crops

Greenhouse gas abatement

Can seasonal soil N mineralisation trends be leveraged to enhance pasture growth?

biochar effects on soils and crops and trade-offs

The effect of catch crops in spring barley on nitrate leaching and their fertilizer replacement value

IMPACTS OF TRASH RETENTION ON SOIL NITROGEN

Mitigating N_2O emissions from cropping systems after conversion from pasture

Why are the benefits of enhanced-efficiency fertilizers inconsistent

Model Strengths

Strong performance across all processes

Customisable coding structure

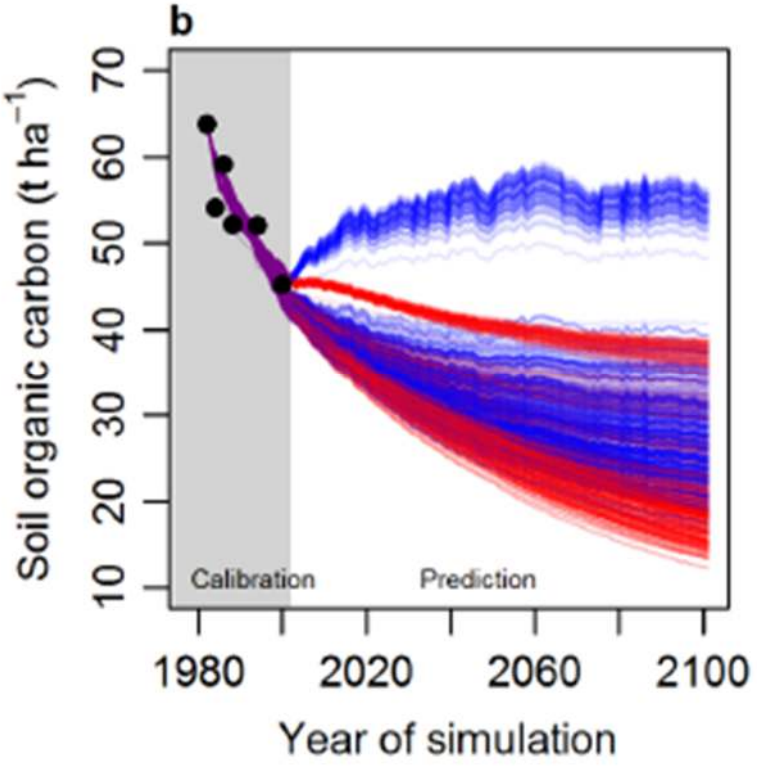
Robust model review process

Testing prototypes using flexible scripting

- Biochar
- N in runoff
- Ammonia volatilisation
- Nitrification inhibition
- Controlled-release fertiliser

Model Challenges

Sensitivity to initialisation approach



Luo et al. 2015

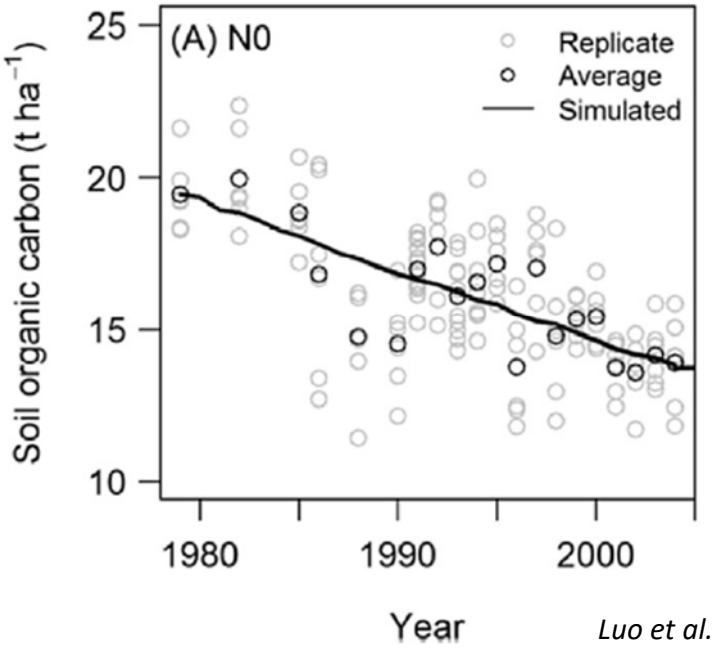
Wide range of approaches

- Guidance on default pool sizes
- Conceptual interpretation of measurements
- Adaptations based on prior history
- Spin-up approaches
- Parameter optimisation

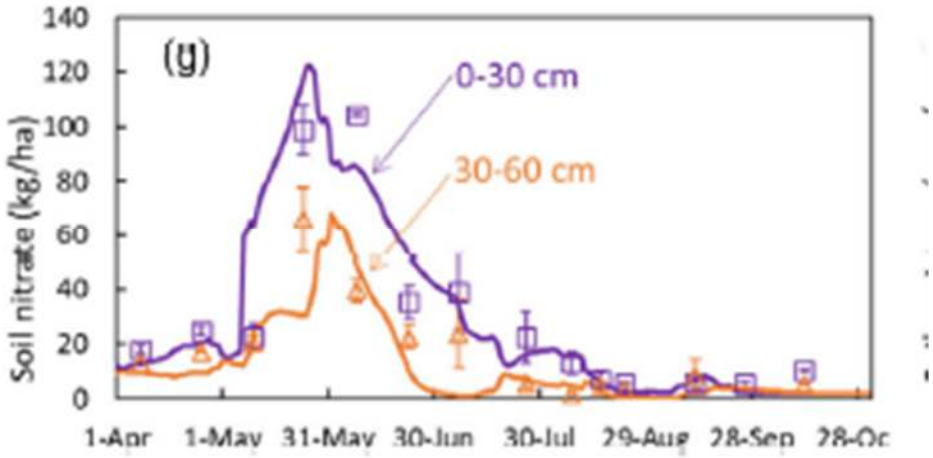
Model Challenges

Sensitivity to initialisation approach

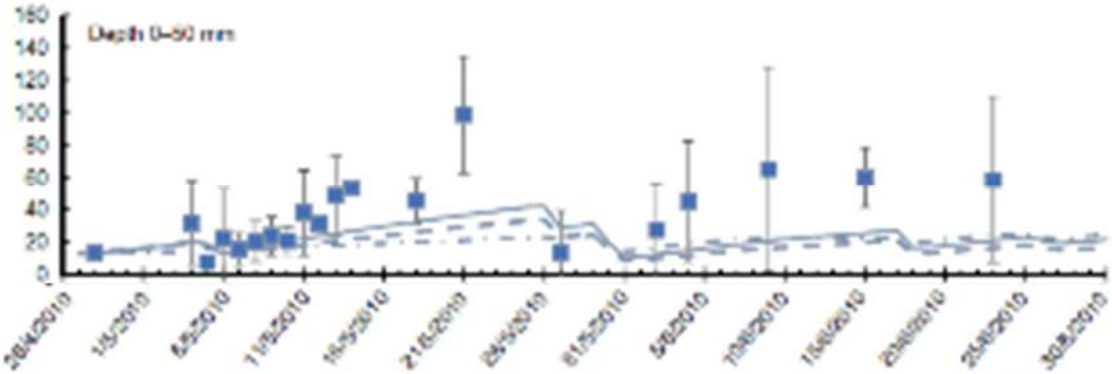
Uncertainty in measured data



Luo et al. 2016



Archontoulis et al 2020



Smith et al 2020

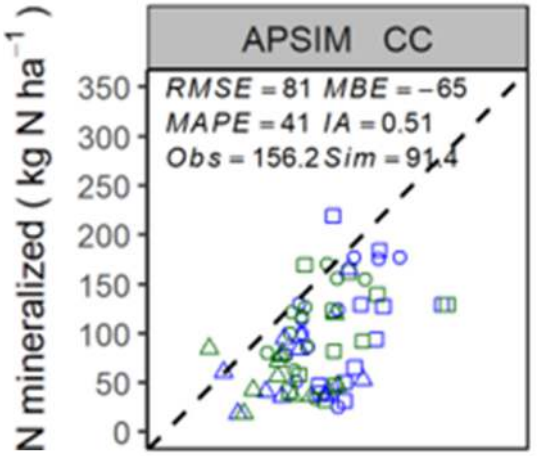
Better performance where dynamics is clear and understood

Model Challenges

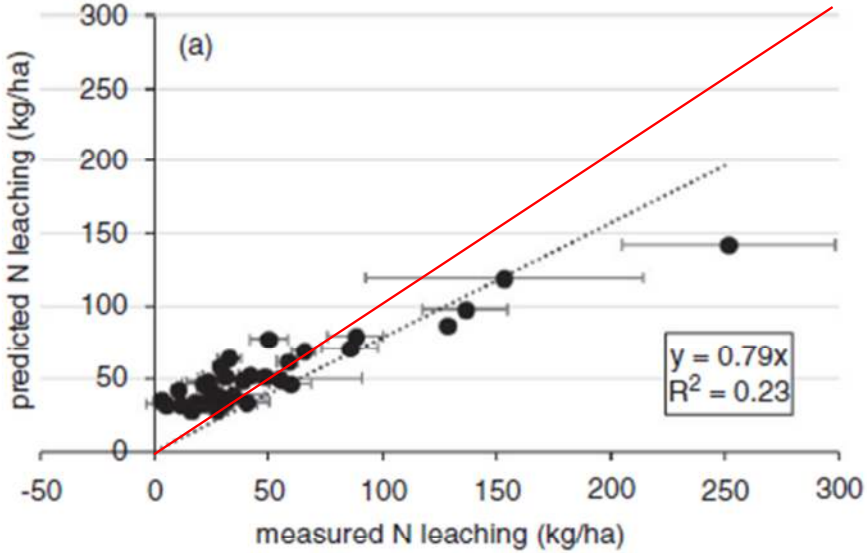
Sensitivity to initialisation approach

Uncertainty in measured data

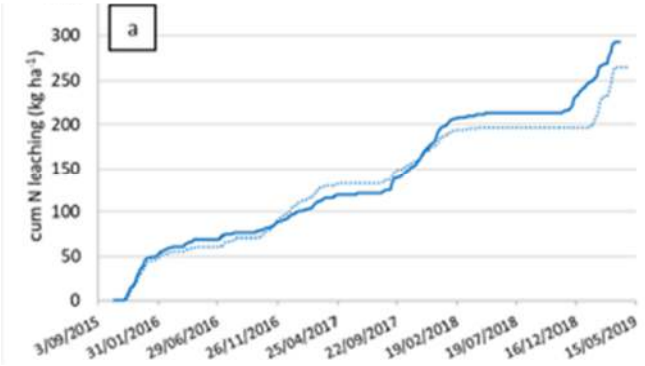
Value of time-series above obs-pred plots!

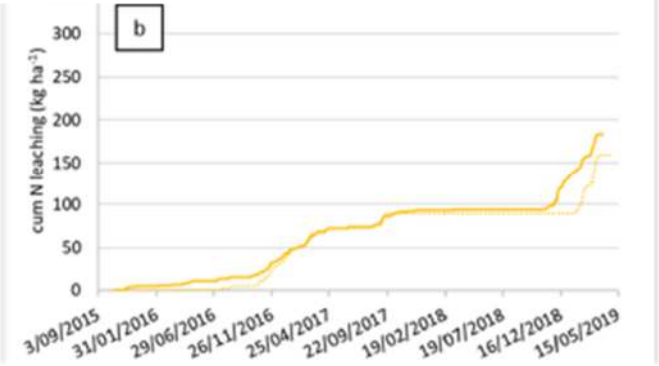


Yin et al. 2020



Vogeler et al. 2022





Vogeler et al. 2023

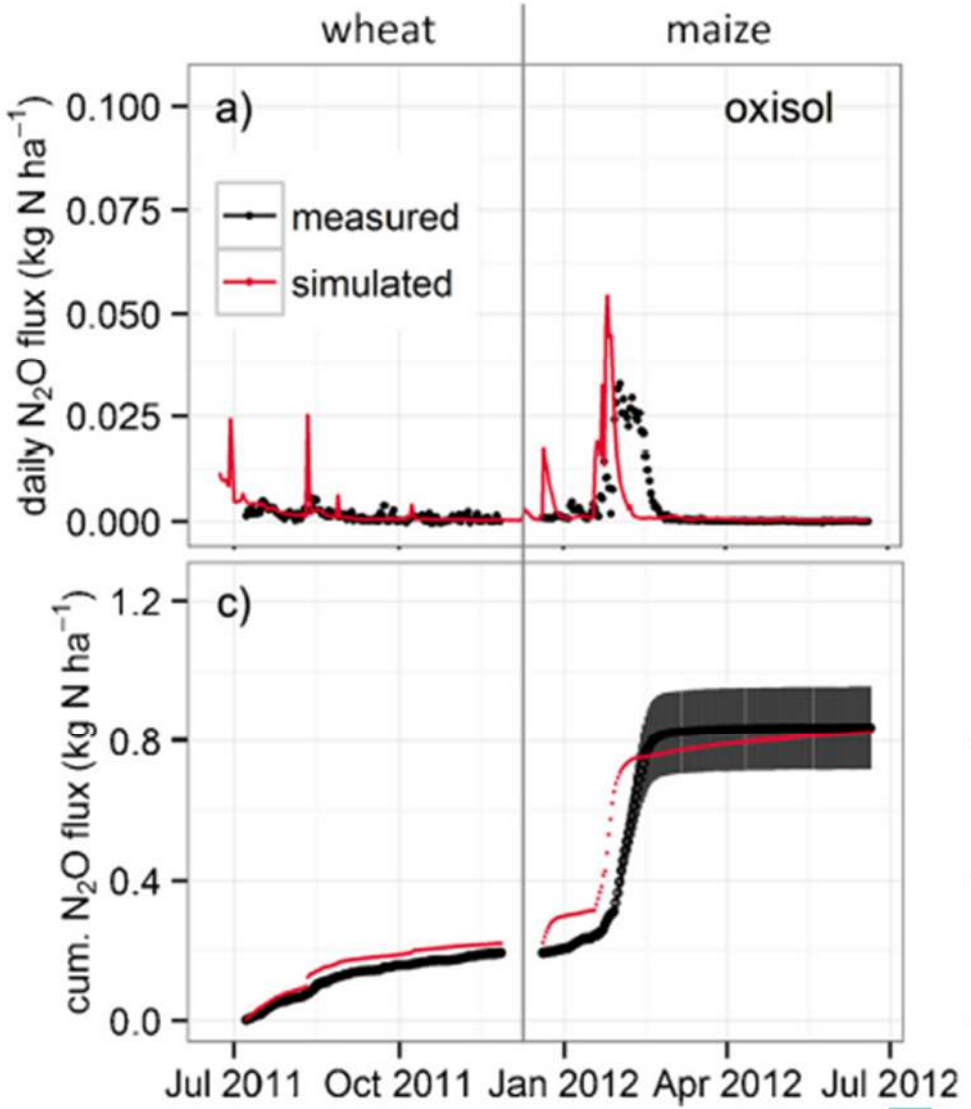
Model Challenges

Sensitivity to initialisation approach

Uncertainty in measured data

Daily timestep simulating sub-daily processes

What aspect is critical for the application?



Mielenz et al. 2016

Cautionary Tales

Parameter optimisation focused on one system

Simple measurements for complicated processes

- Getting it right for the wrong reasons
- N_2O vs denitrification
- Getting timing of crop N uptake right

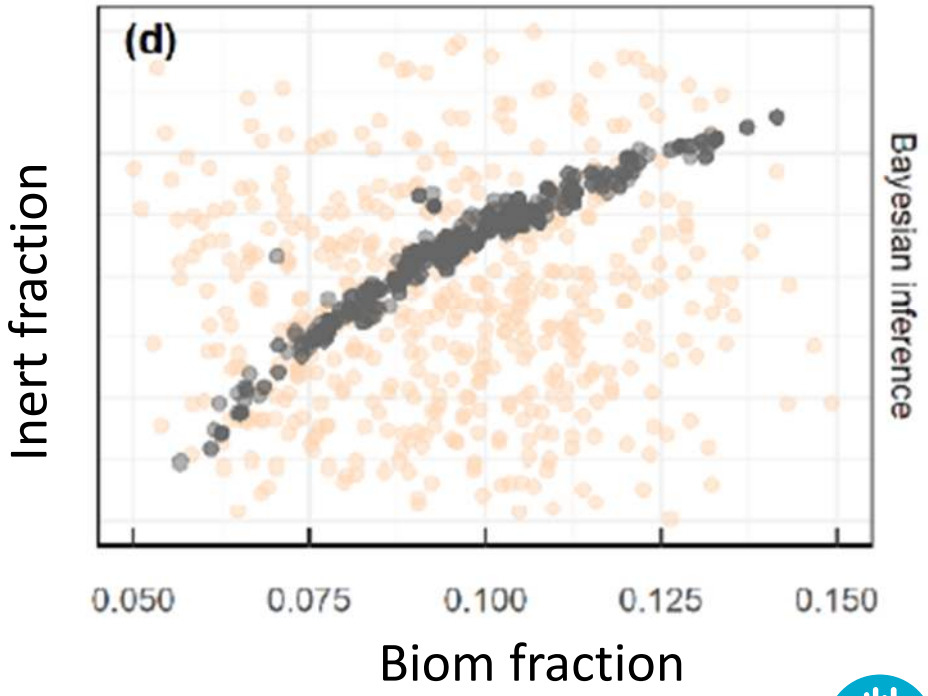
Cautionary Tales

Parameter optimisation focused on one system

Simple measurements for complicated processes

Equifinality in carbon pool parameterisation

- Pool initialisations
- Pool size vs turn-over rates



Vilas et al. 2021

Next Steps

Test prototypes

(NH_3 volatilisation and runoff)

Test proposed parameter

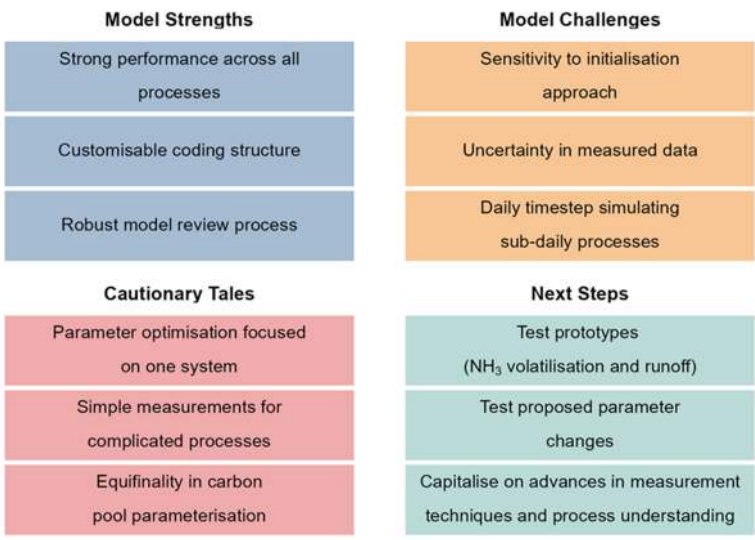
changes

Capitalise on advances in measurement

techniques and process understanding

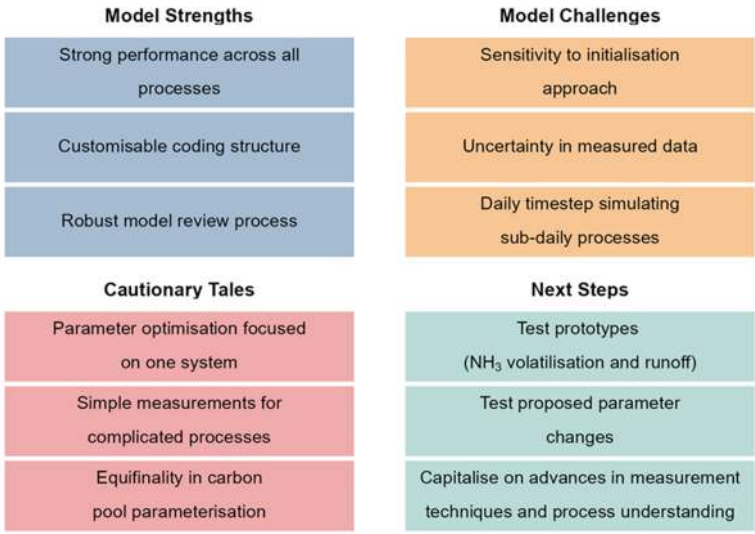
Lessons for model developers and users

- Importance of broad model evaluations across a wide range of applications to ensure their robustness
- Consider possible flow-on effects of changes
- Pay attention to environmental factors
- Quantify both N_2 and N_2O
- Use time-series and consider critical features



Implications for use of model output

- Understand the strengths and weaknesses and any constraints
- Focus on parameters and time frames that matter / are validated
- The biggest strength of ag systems models is to represent the consequences of system interactions



Thank you

on behalf of the author team

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Australia's National Science Agency

Want to know more?

https://github.com/APSIMInitiative

APSIM Initiative
53 followers Dean.Holzworth@csiro.au

Review of APSIM's soil nitrogen modelling capability for agricultural systems analyses

(in review at Agricultural Systems)