Food and Agriculture Organization of the United Nations

GLOBAL SYMPOSIUM ON
SOIL INFORMATION AND DATA

MEASURE
MONITOR
MANAGE

From data to decisions: Transforming nitrogen management with digital agriculture

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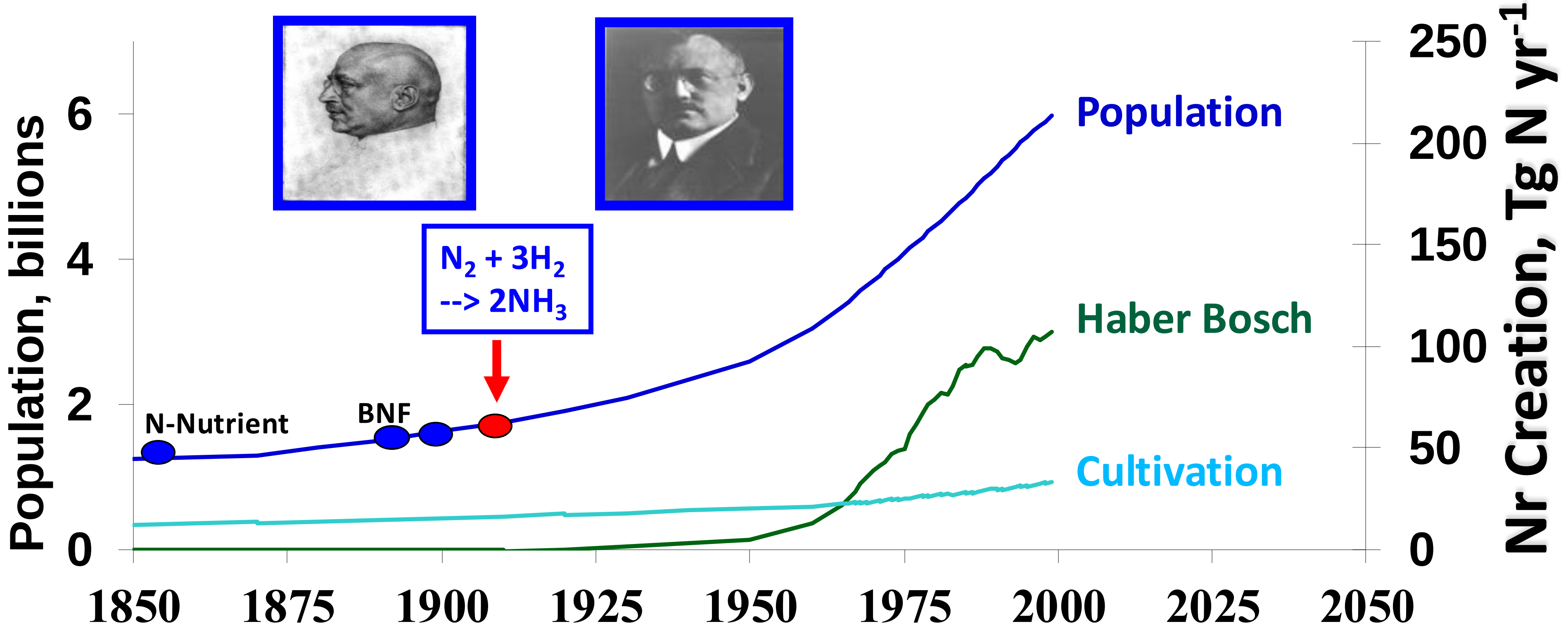
Timeline of Global Reactive N Creation by Human Activity 1850 to 2000



Galloway et al. (2003)

Half of the world population fed by chemical N

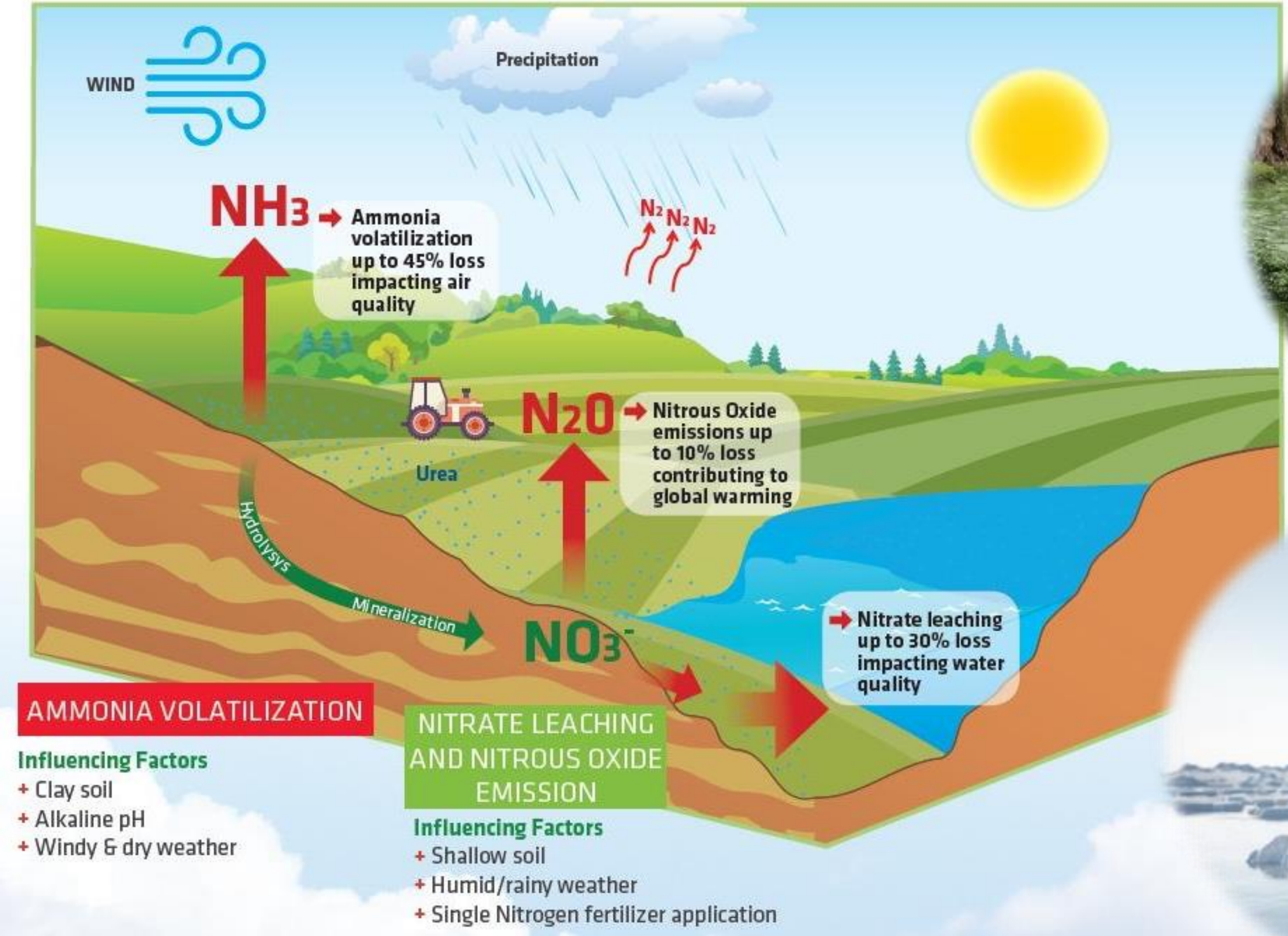
Nitrogen use efficiency matters

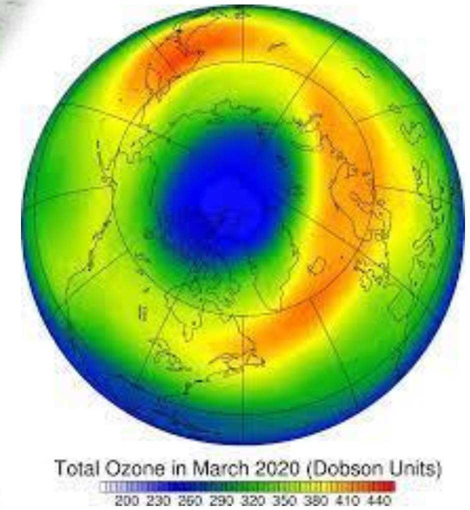
2% world energy

>$500b/year

Societal cost is a magnitude higher

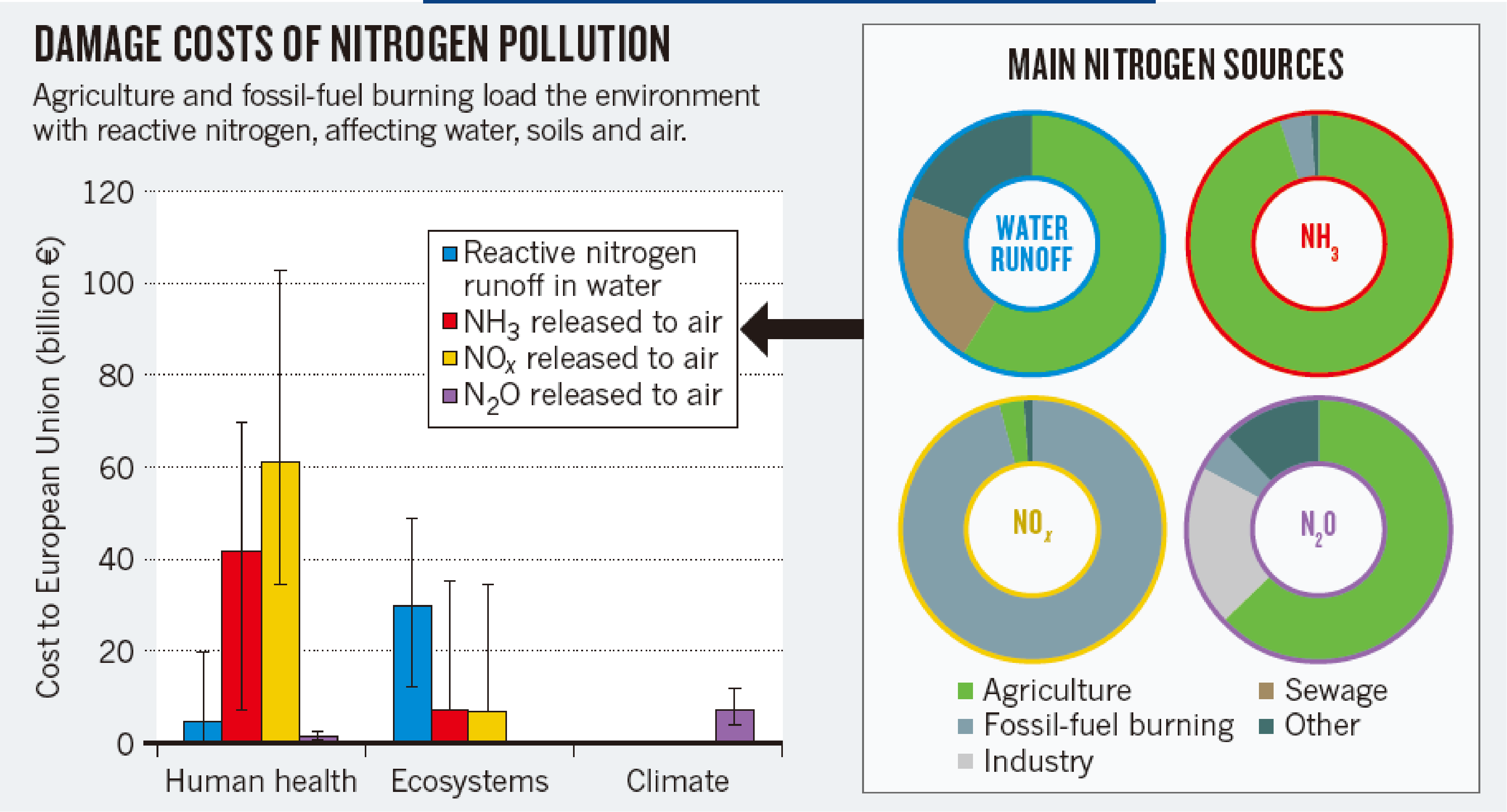
Major N loss pathways





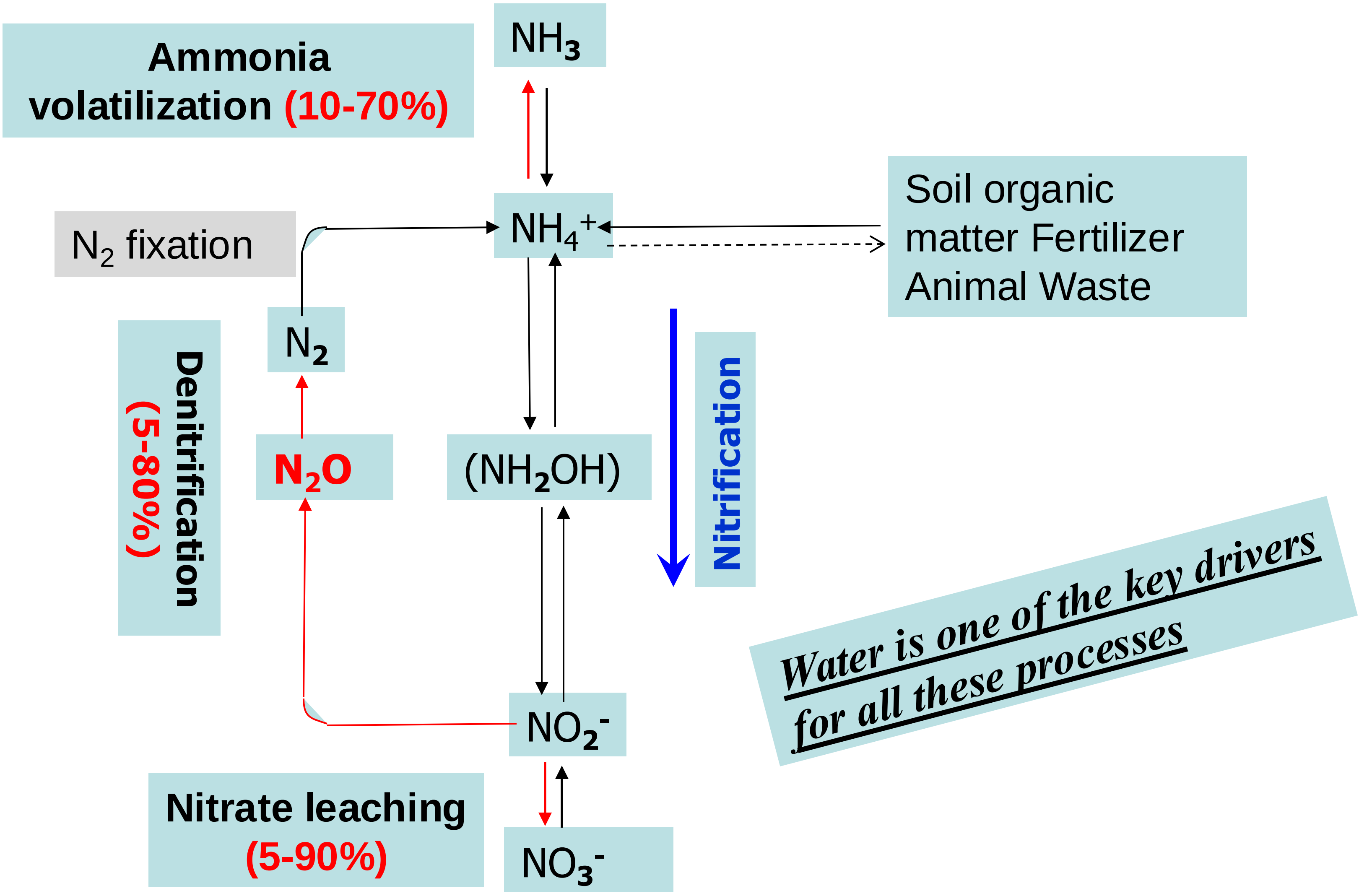
Enormous damage costs of N pollution (Societal cost)

€70-320B per year in EU

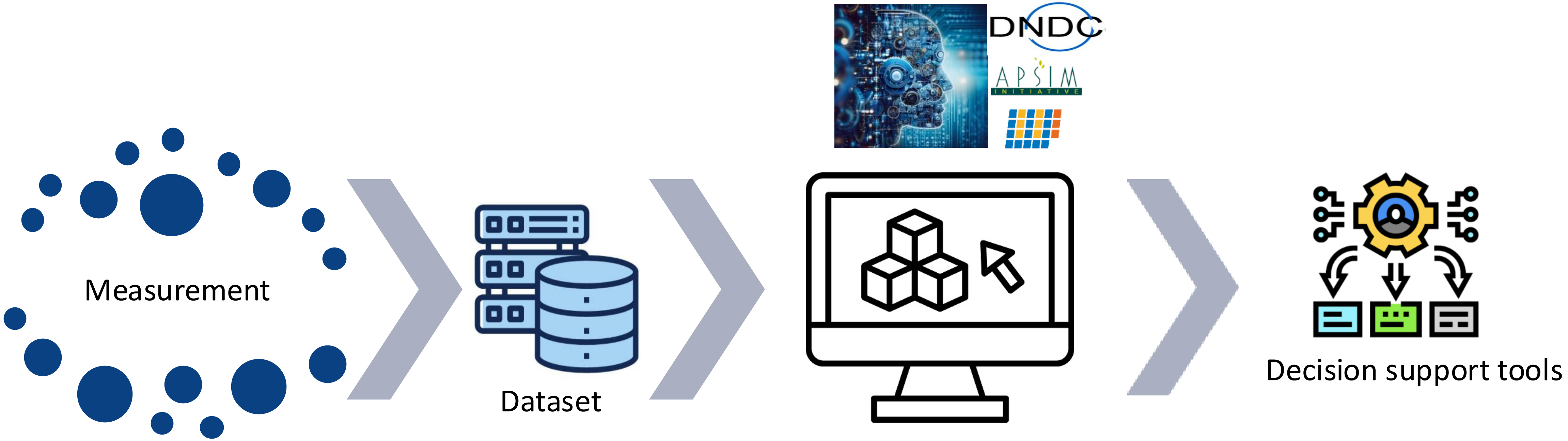


Sutton et al. 2011

How N is lost in soil?



From data to decision



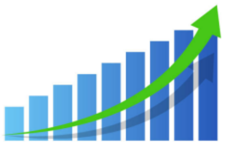
- Difficult to measure,
- costly,
- time-consuming,
- limited scales.

- Empirical model,
- Process-based models (APSIM, DNDC, WNMM, etc.),
- Scaling models (EF),
- Machine learning.

Measurement: The foundation of big data

diverse sources

extensive measurements



measurement accuracy

provide inputs

Better measurements lead to more accurate predictions

Modelling and Prediction






Airborne Research Australia
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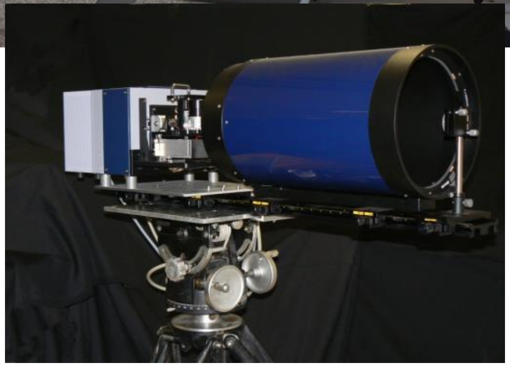
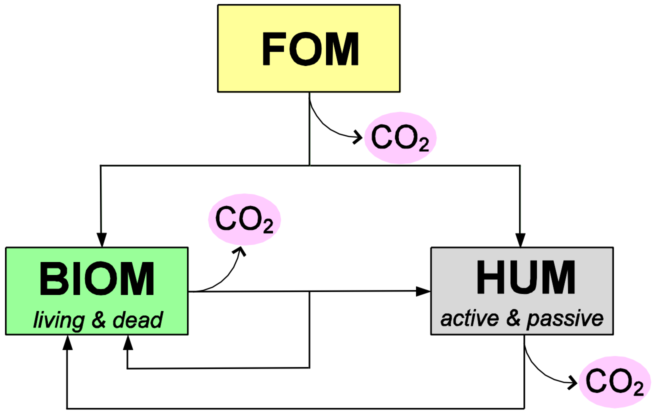
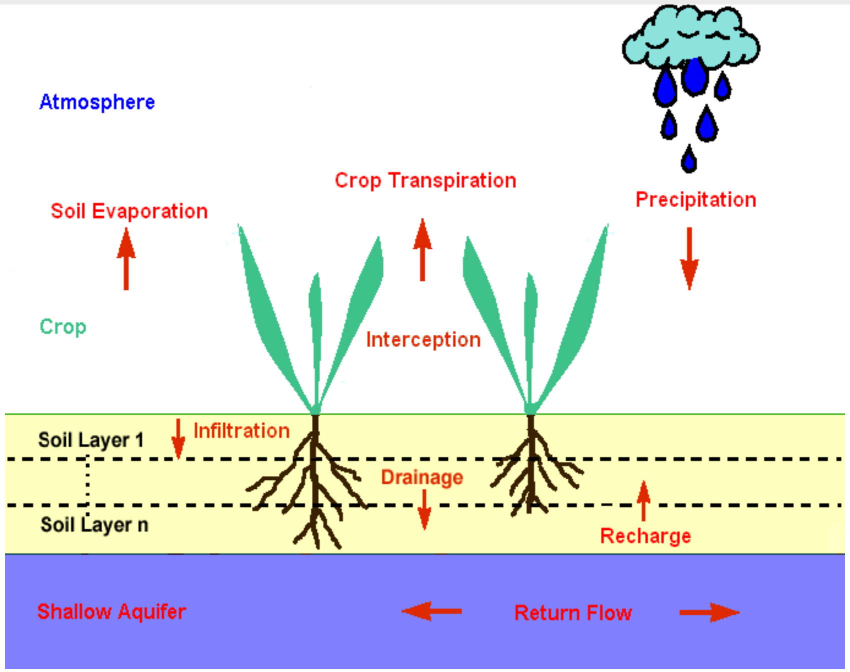
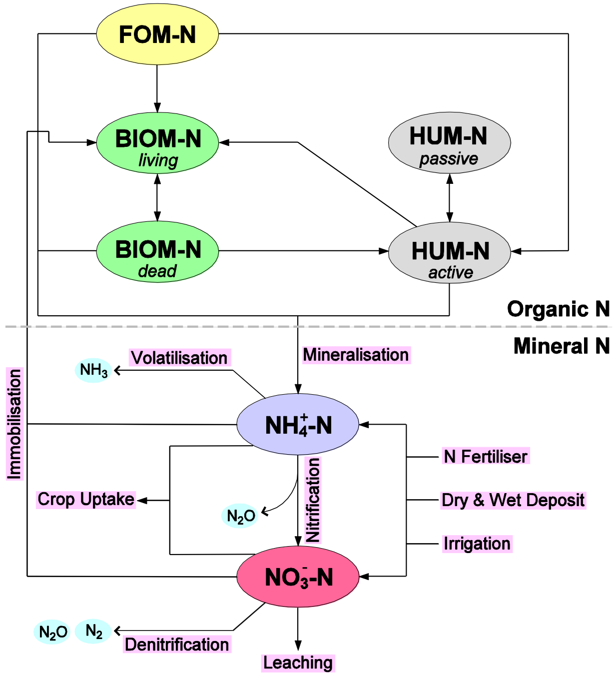


WNMM—spatially referenced water and nutrients management mode , it simulates:

- Soil water dynamics
- Plant growth
- Comprehensive C and N cycling, including N_2O emissions

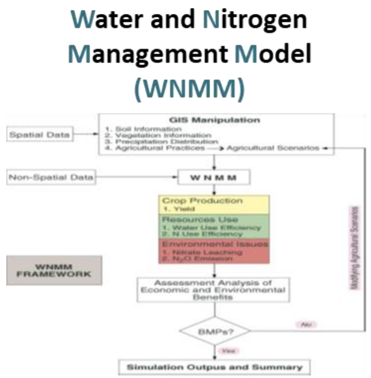






(Li et al, 2005, 2007, 2008, 2009; Chen et al 2010)

Modelling



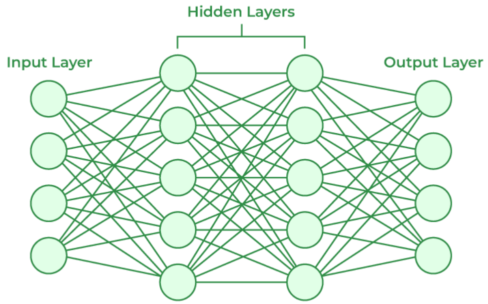
Process-based modelling

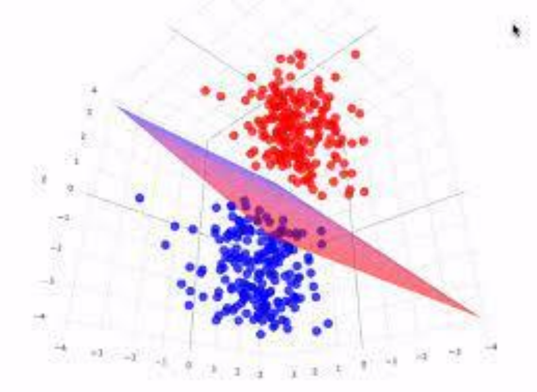
- Mechanistic understanding
- Complex equations
- Parameter-driven: high-quality empirical data
- High interpretability and transparency

Machine learning

- Data-Driven
- Algorithms and Training
- Large datasets
- Lower interpretability

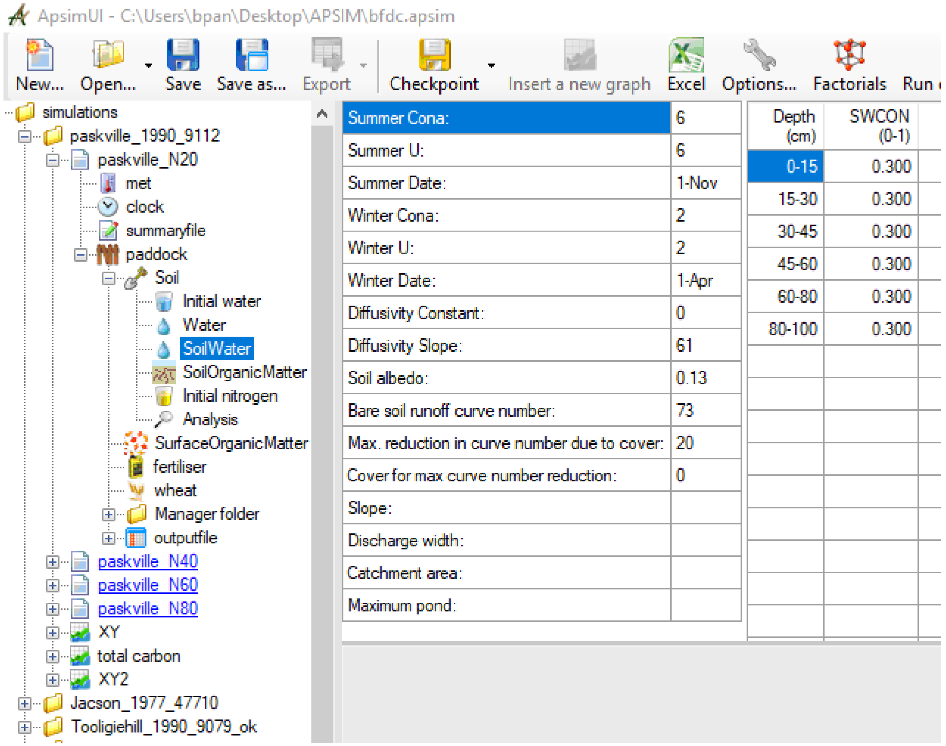
- Random Forest (RF), Support Vector Machines (SVM), Neural Networks (NNs)

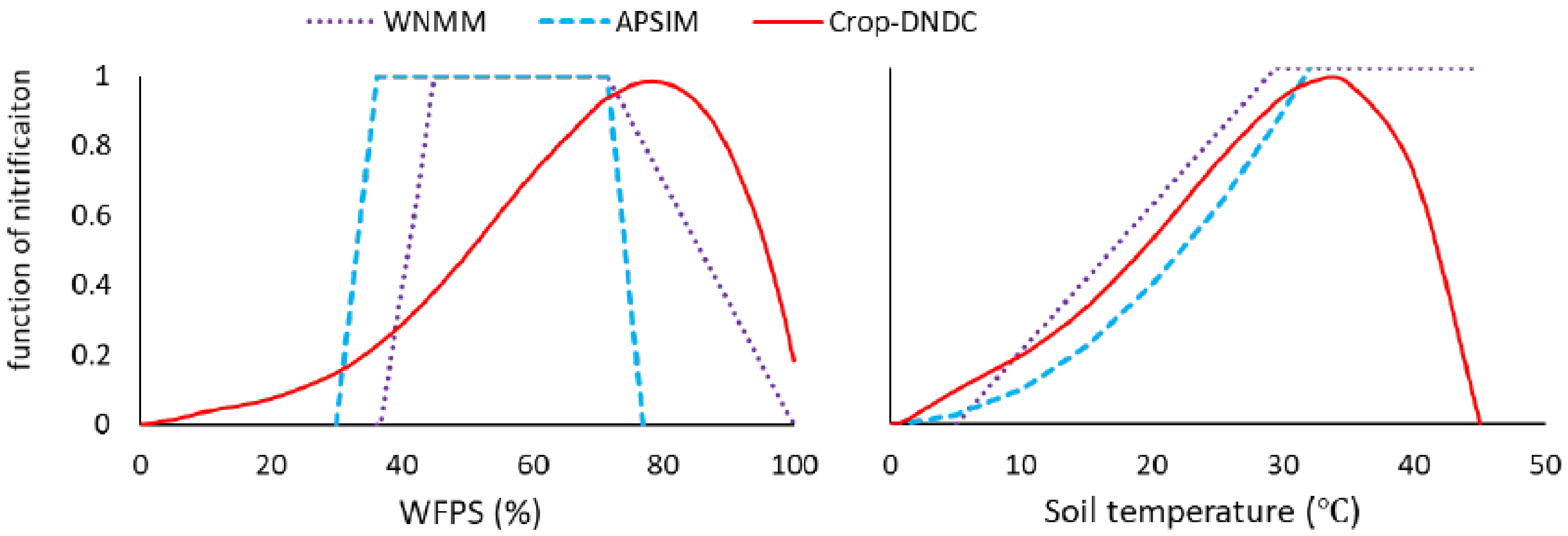




Limitations of existing process-based models

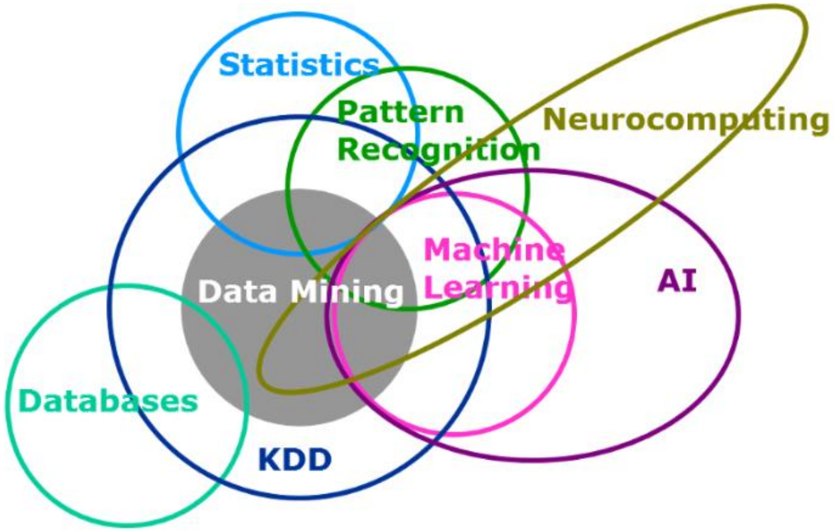
- Stringent requirement of input variables
- Parameters derived from limited data/sites
- Inconsistent responses of N loss to its key drivers
- Limited capability in regional/global simulations



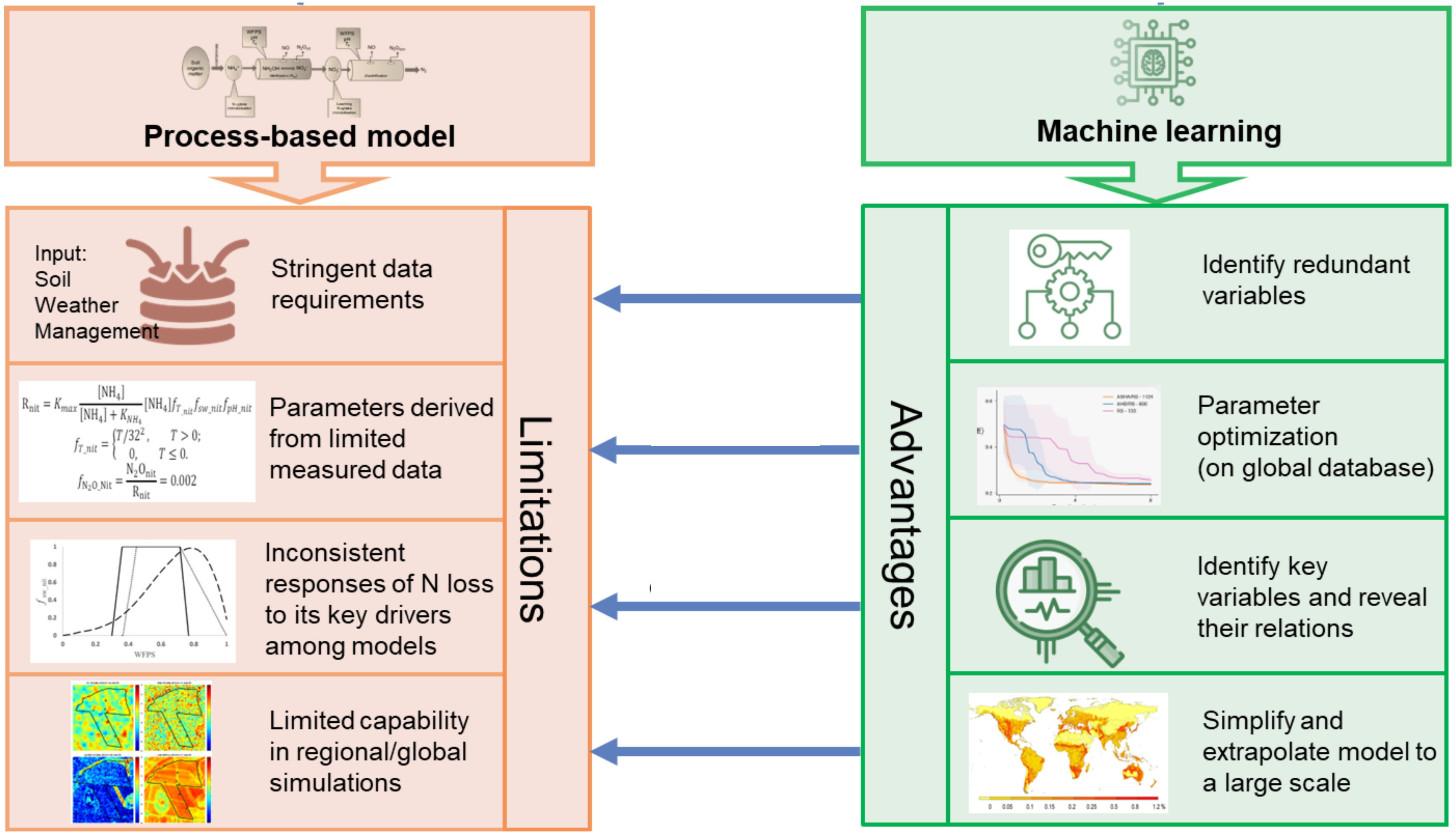


Data mining + Machine learning

- Simplify and summarize the data; uncover relevant insight and patterns by exploring and analysing large datasets.
- Machine learning uses data mining techniques to build models of what is happening behind some data so that it can predict outcomes.



Using ML to address limitations of process-based models



e.g. $f(T) = aT + b$

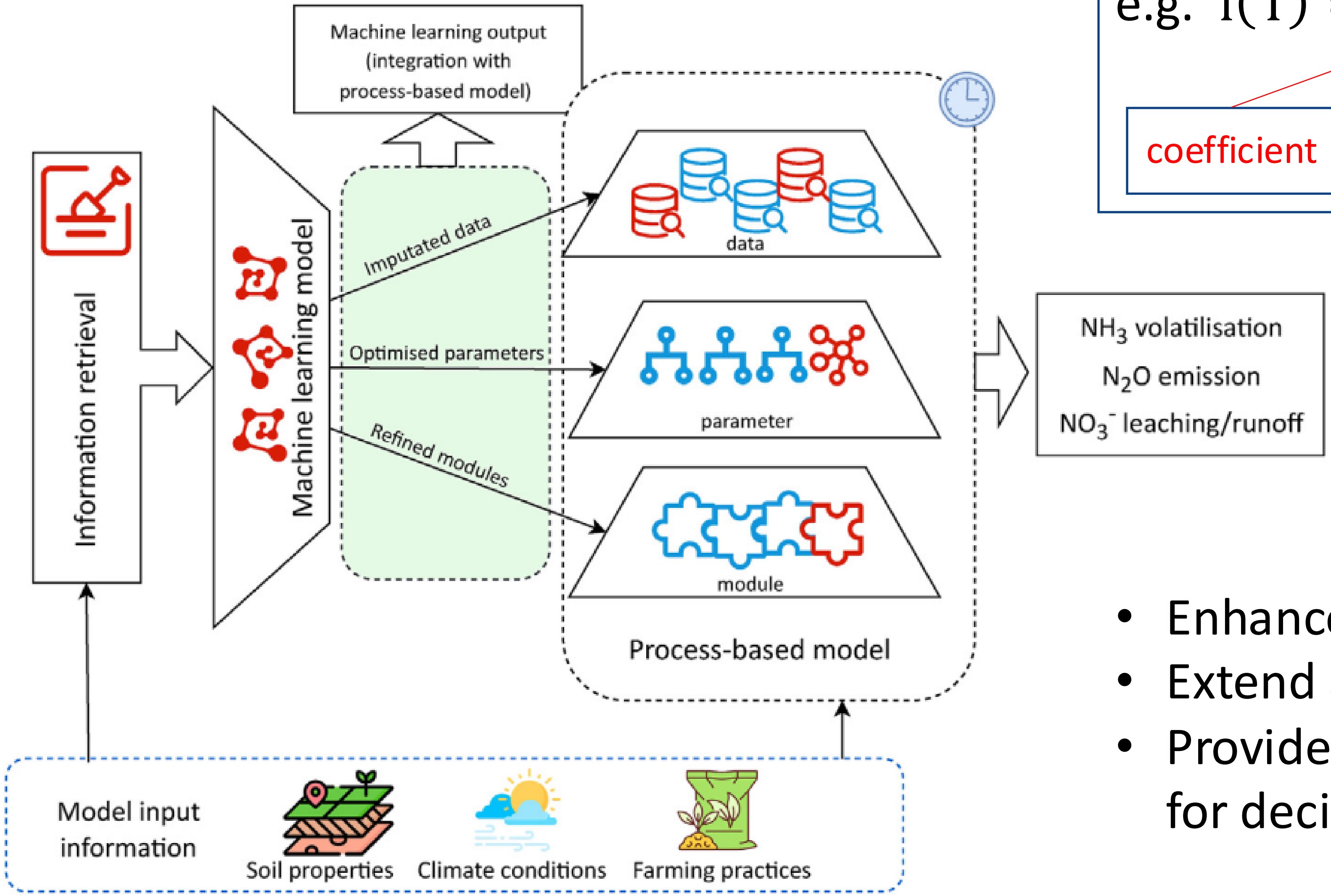
coefficient | input variable | parameter

(Lam et al., 2024 *Earth Critical Zone*)

Hybrid modelling

e.g. $f(T) = aT + b$

coefficient | input variable | parameter



- Enhance prediction capacity
- Extend applicability
- Provide data-driven insights for decision support

A hybrid modelling framework for enhancing process-based models using machine learning

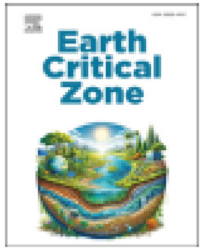
(Lam et al., 2024 *Earth Critical Zone*)

Earth Critical Zone 1 (2024) 100006

Contents lists available at ScienceDirect

Earth Critical Zone

journal homepage: www.sciencedirect.com/journal/earth-critical-zone



Advancing agroecosystem modelling of nitrogen losses with machine learning

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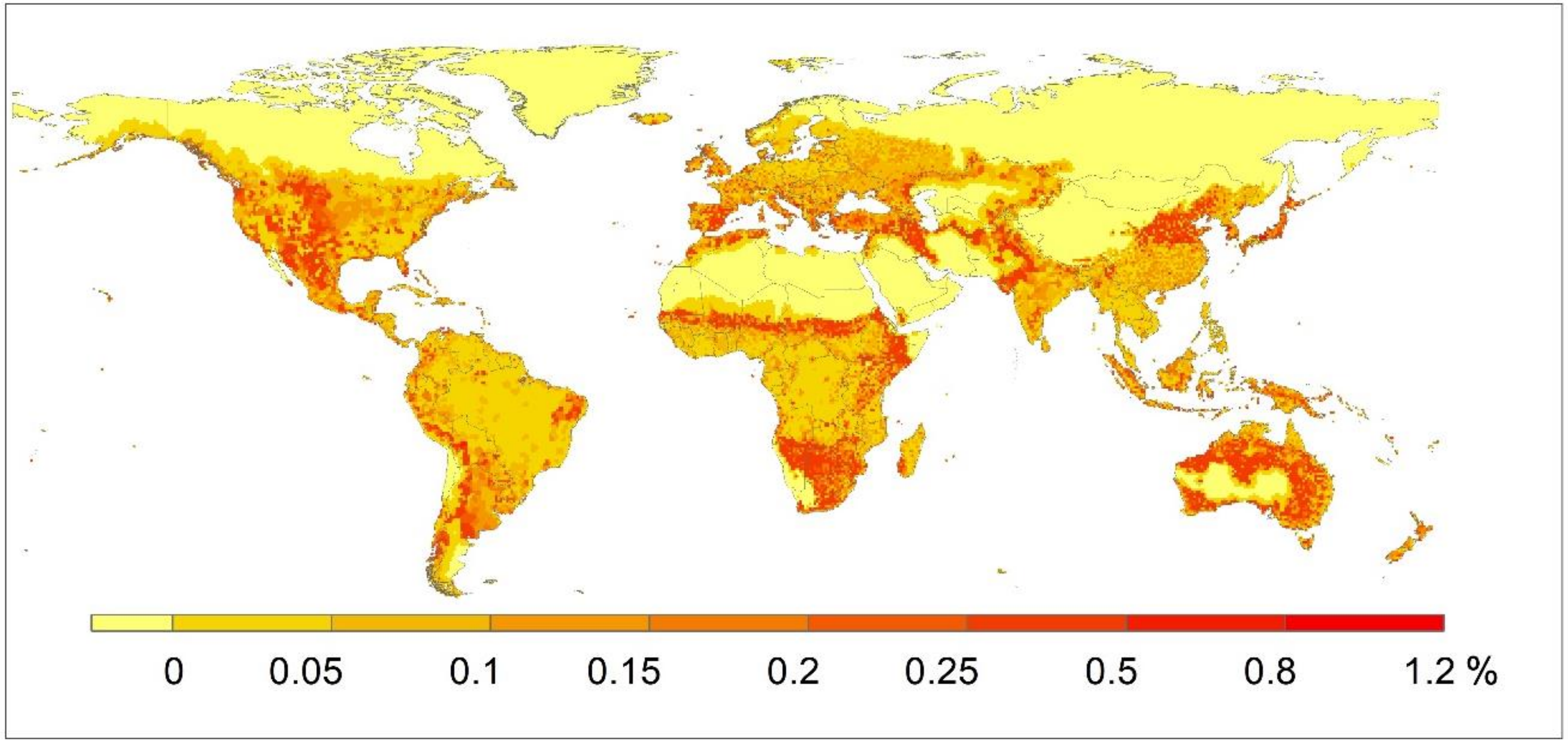
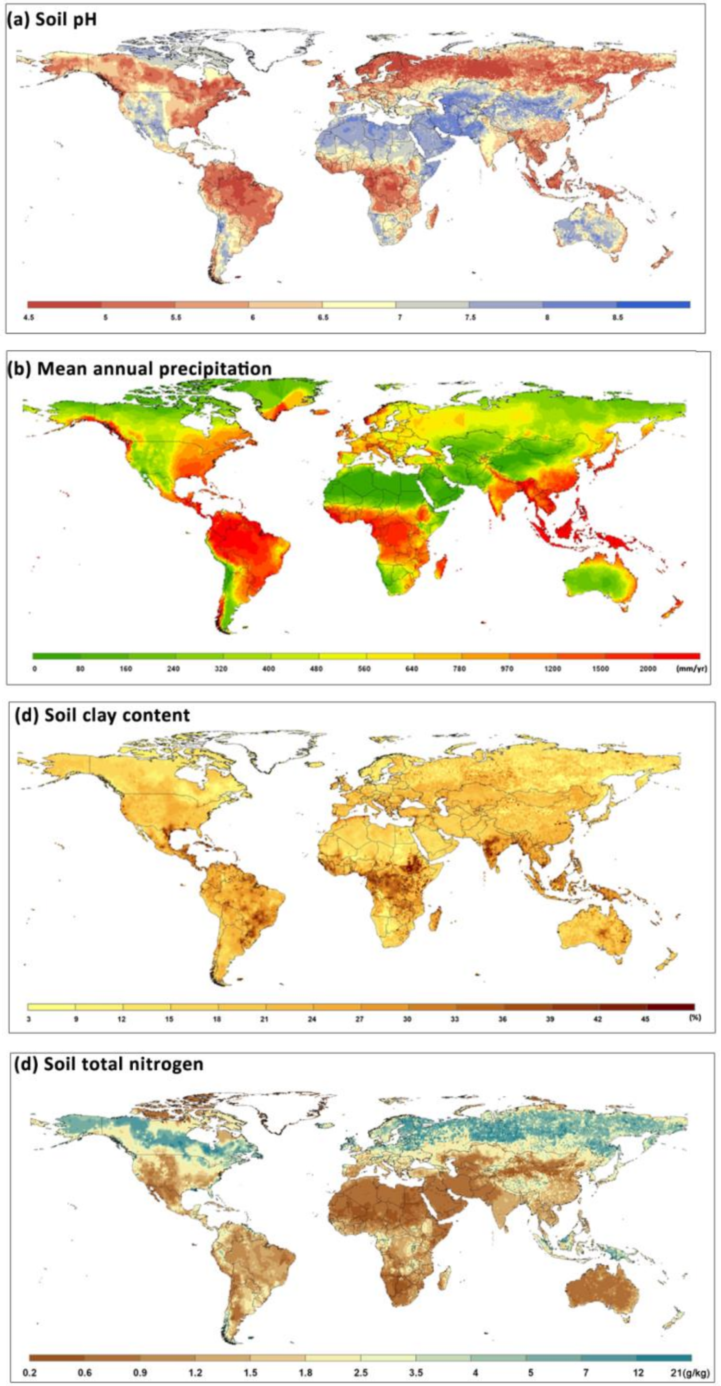
[a] School of Agriculture, Food and Ecosystem Sciences, The University of Melbourne, Parkville, Victoria, Australia
[b] Department of Computing Technologies, Swinburne University of Technology, Hawthorn, Victoria, Australia

Lam, S.K., Pan, B., Qin, A.K. and Chen, D., 2024. Advancing agroecosystem modelling of nitrogen losses with machine learning. *Earth Critical Zone*, *1*(1), p.100006.

Prediction of $f_{N_2O\_Nit}$ at the global scale

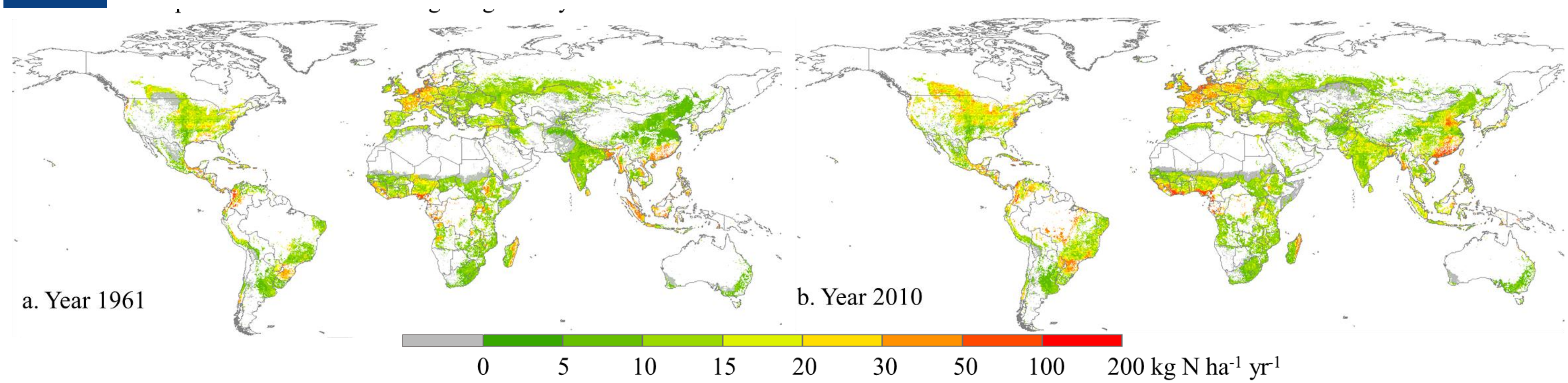


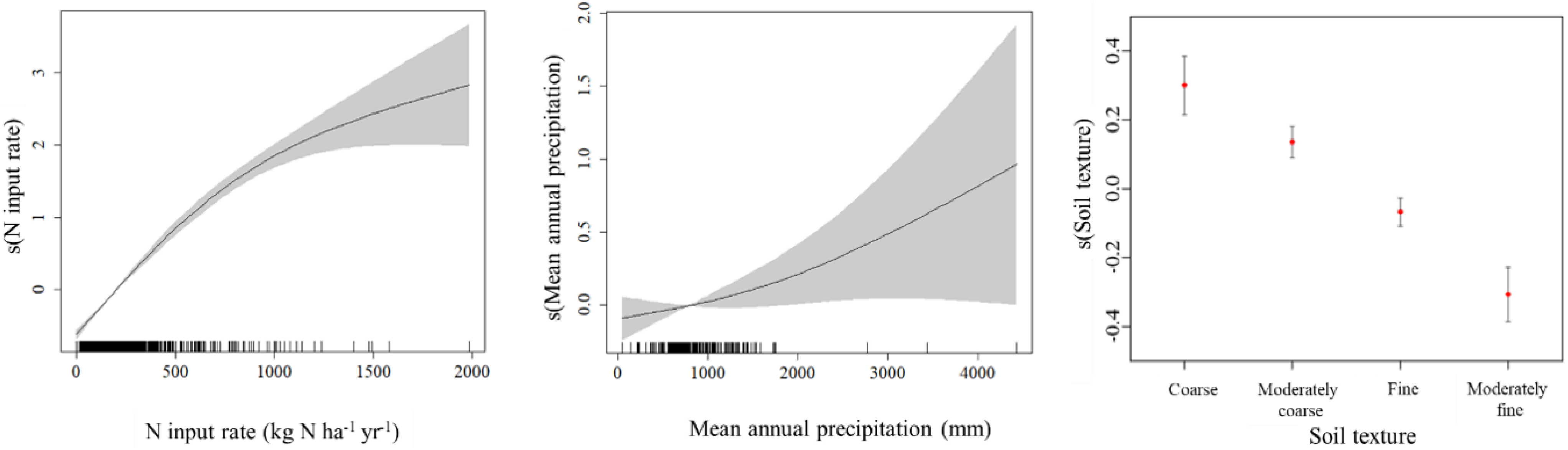
Global distribution of $f_{N_2O\_Nit}$ predicted by SGB model (R^2 =0.55, RMSE=0.4)



- A constant $f_{N_2O\_Nit}$ to estimate the N_2O emission from nitrification by process-based models is unsuitable

Global pattern of NO_3-N leaching in agroecosystems in year 1961 and 2010 based on NL_{NO3} model

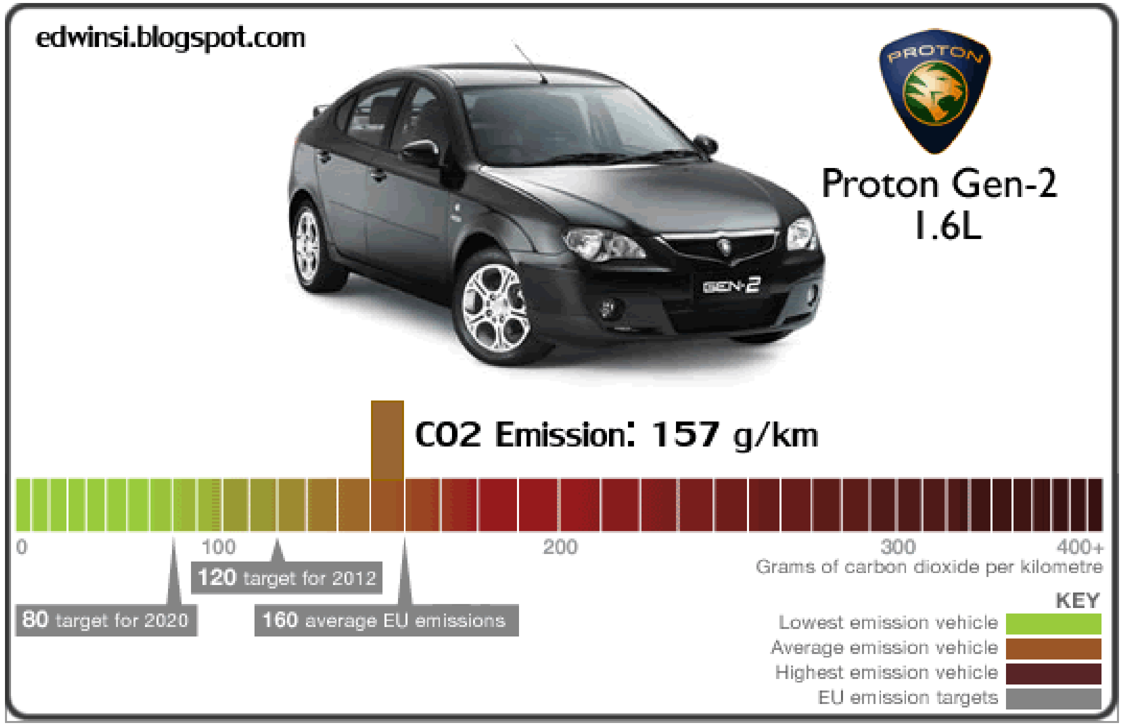




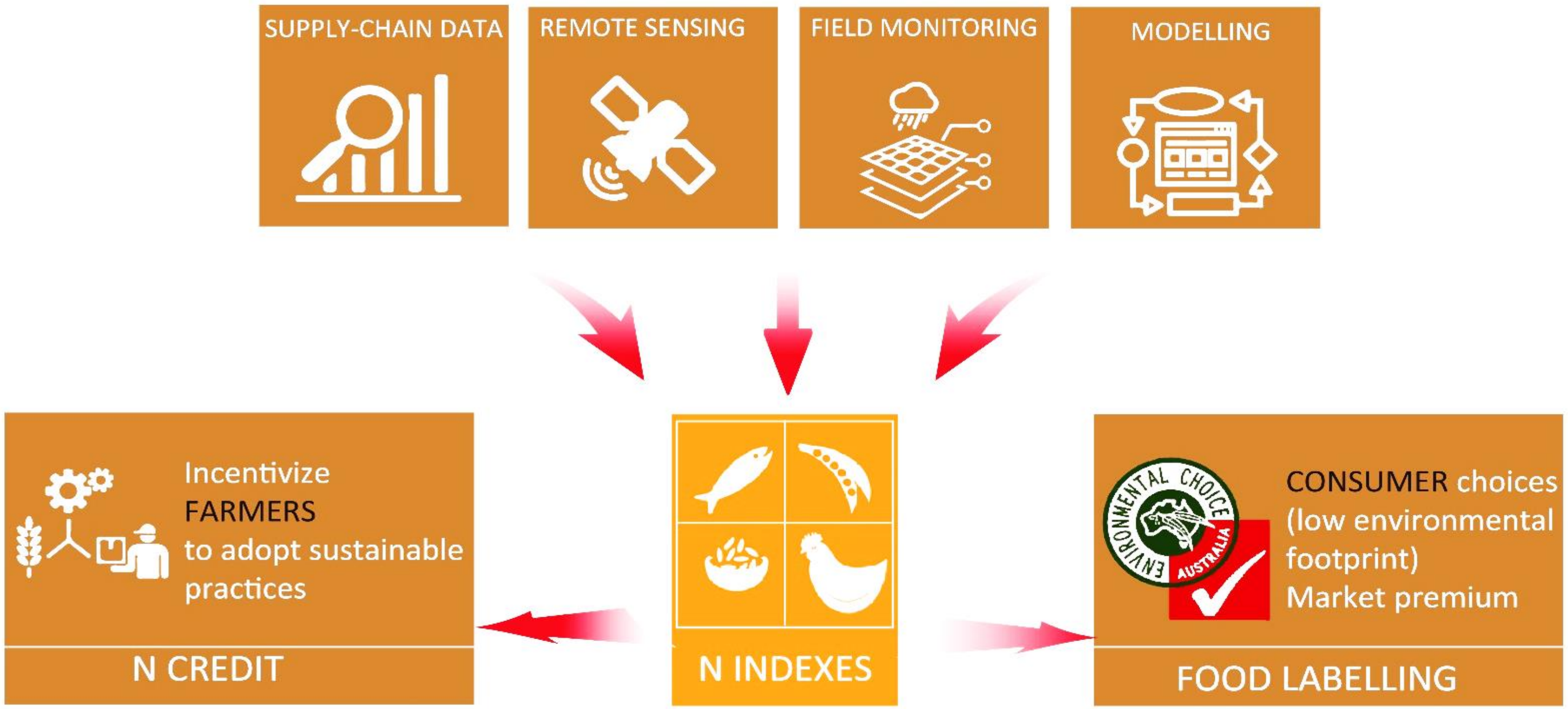
Big data, N footprint (green index) ----Benchmarking & Food credentials

- So far, societal (sustainability) cost of Nr is considered when farmers make fertiliser decision
- no evidenced based index for "**Green**"/sustainable agriculture products
- Can we develop Environmental Footprint → True Environmental cost, N footprint.
- to encourage and reward the more sustainable practices?
- To develop real environmental cost of agriculture products, leading to the payment/trading (*Environmental Offset)*, Environmental Credit

Factual index V.S. Marketing slogans



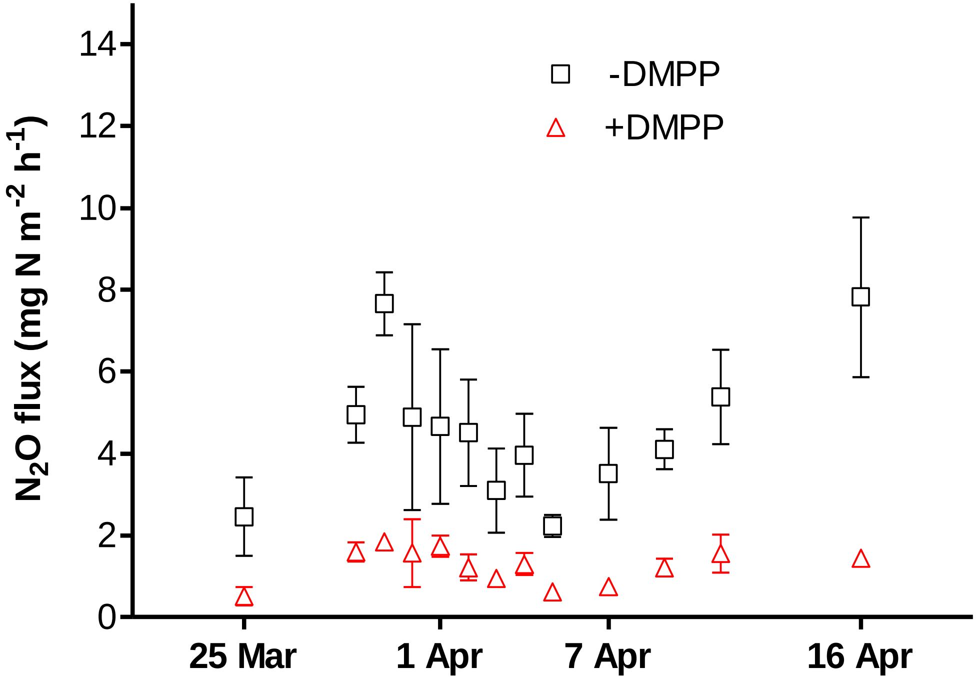
Data and evidence provision: N index Framework



- Build new evidence-based N indexes for agricultural products that account for the environmental impacts of Nr use/loss across the food supply chain.
- Cost-benefit analysis of Nr use/loss in agriculture.
- Incentivize farmers to adopt more sustainable N management practices, influence consumers choice and market premium

Greener products due to the use of NIs

↓ 73% N_2O emission

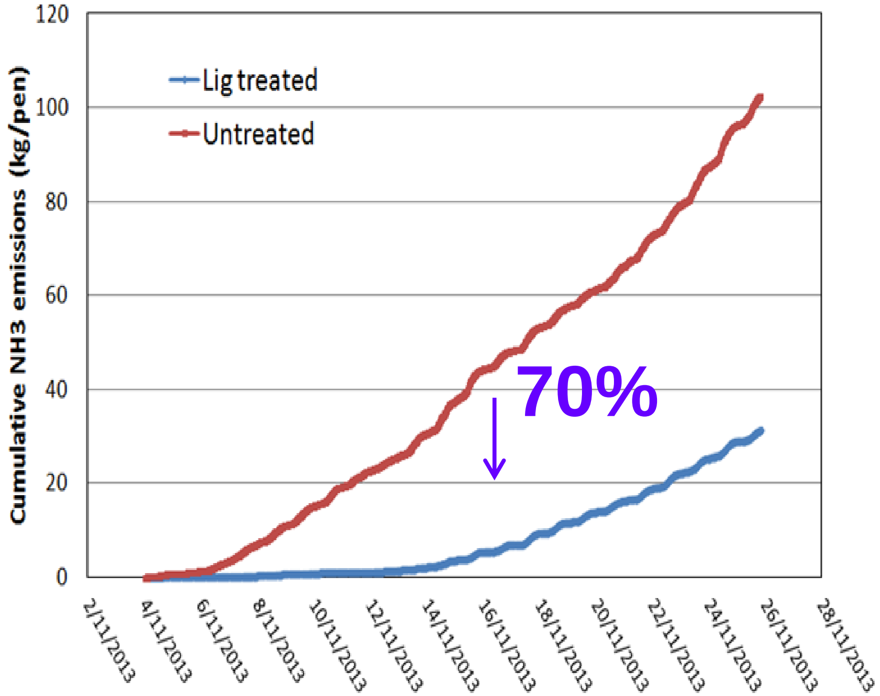


A celery farm in Australia

Control	DMPP
	
20 mg N_2O-N loss per kg celery	**6 mg N_2O-N loss per kg celery**
	

Farmers – Sustainable practice

Lignite for mitigating NH_3 volatilization



Before

160 g NH_3-N loss per kg beef

After

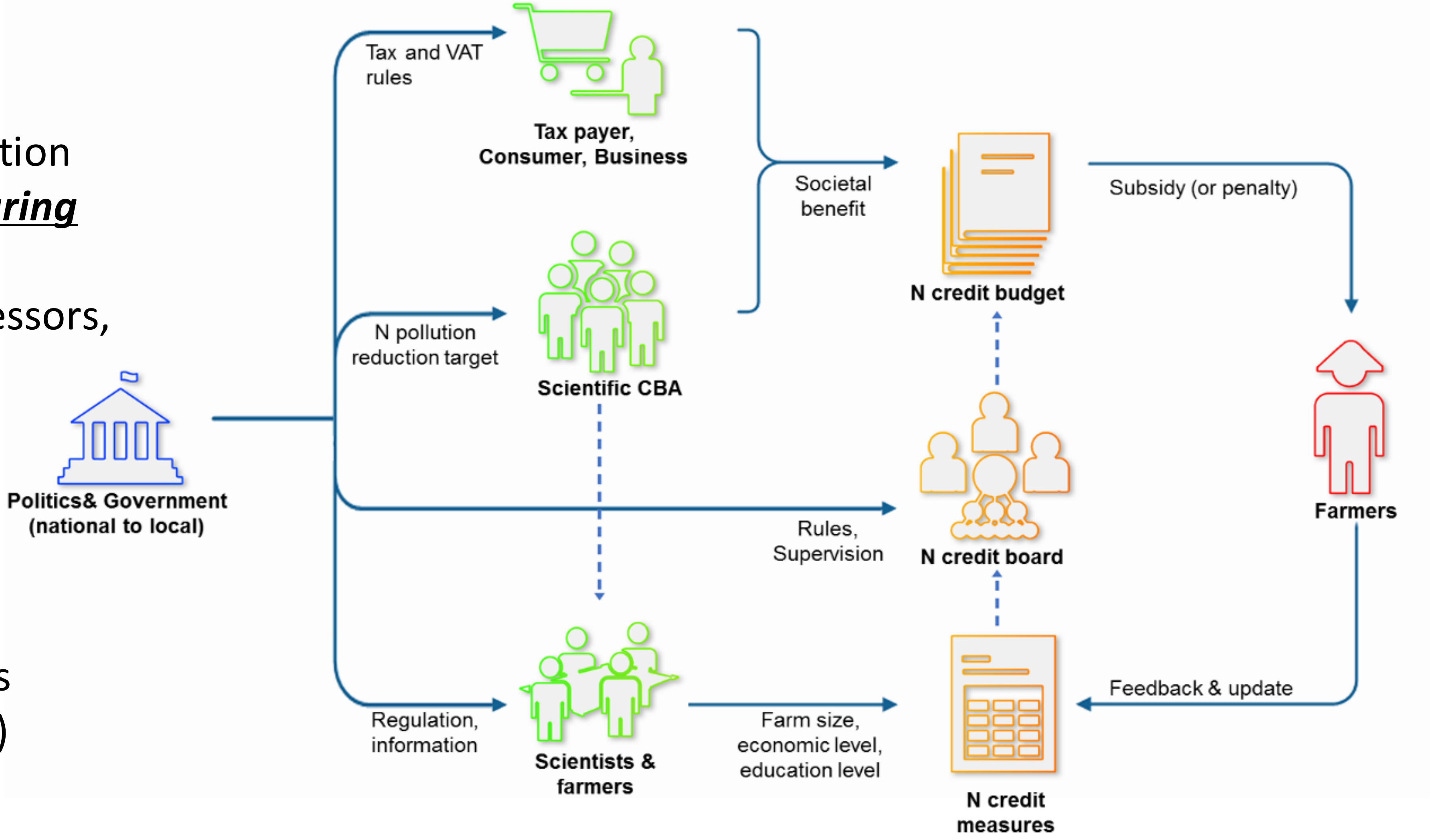
48 g NH_3-N loss per kg beef

Nitrogen Credit System (NCS)

Establishment of NCS to reduce agricultural pollution and improve NUE by ***sharing responsibilities*** among farmers, suppliers, processors, retailers, consumers and governments.

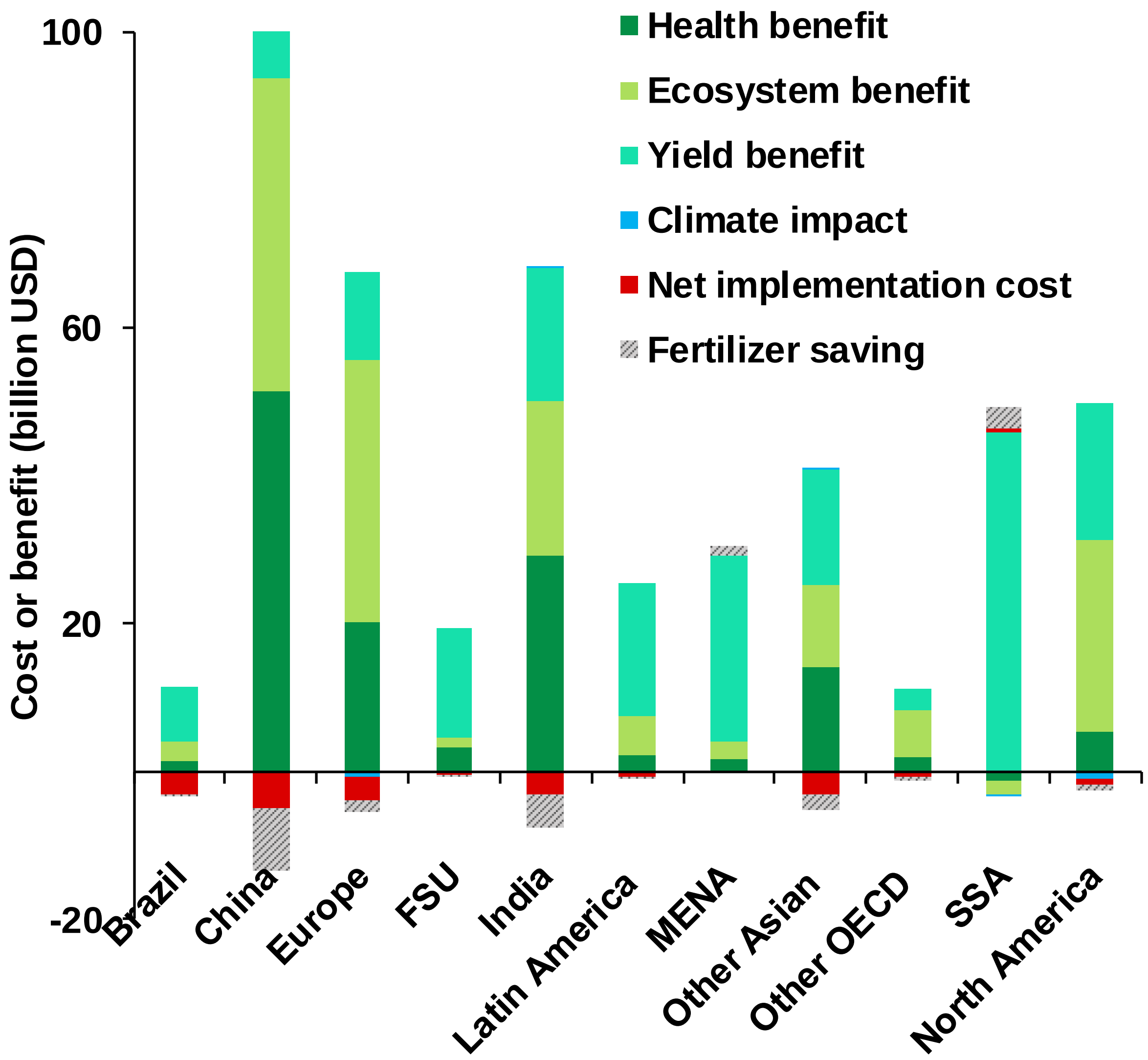
To provide financial

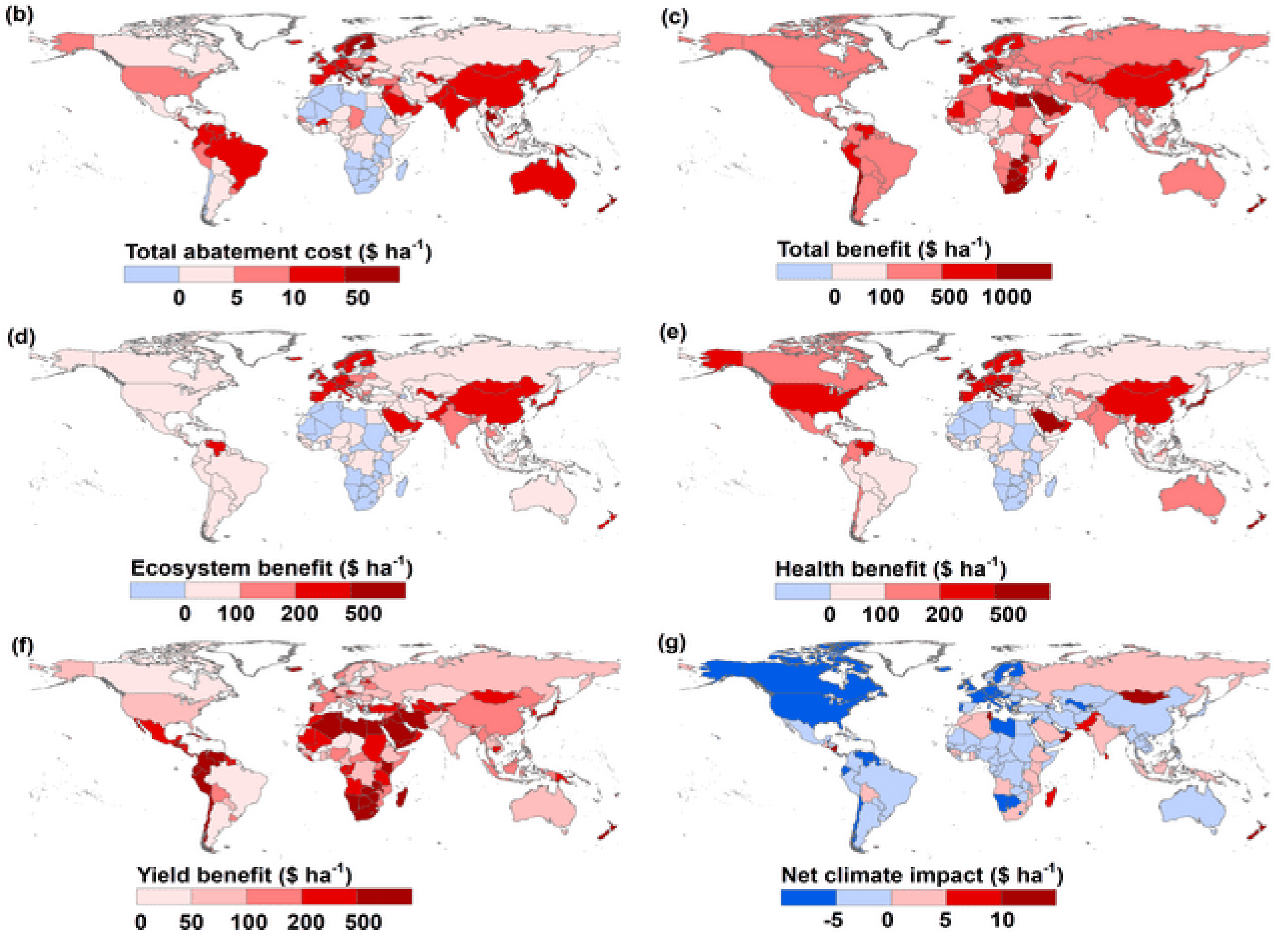
Incentives for lower environmental footprints products (including EEFs)



Gu et al. 2021, *The Innovation*; Gu et al, 2022, *Nature*

Mitigating Nr pollution from global croplands





Global overall benefits to cost ratio is 25 !

Gu etal, 2022, Nature

Management of nutrients for improved profitability and sustainability of crop production in Lao PDR

Australian Government
Australian Centre for International Agricultural Research

Research Design Brief

ACIAR Program(s) area	SLAM
Project Title	Quantifying the impacts of nitrogen use and developing sustainable agricultural N management strategies in Laos rice-based farming systems
Project Number	SLAM/2022/102
ACIAR Research Program Manager	James Quilty

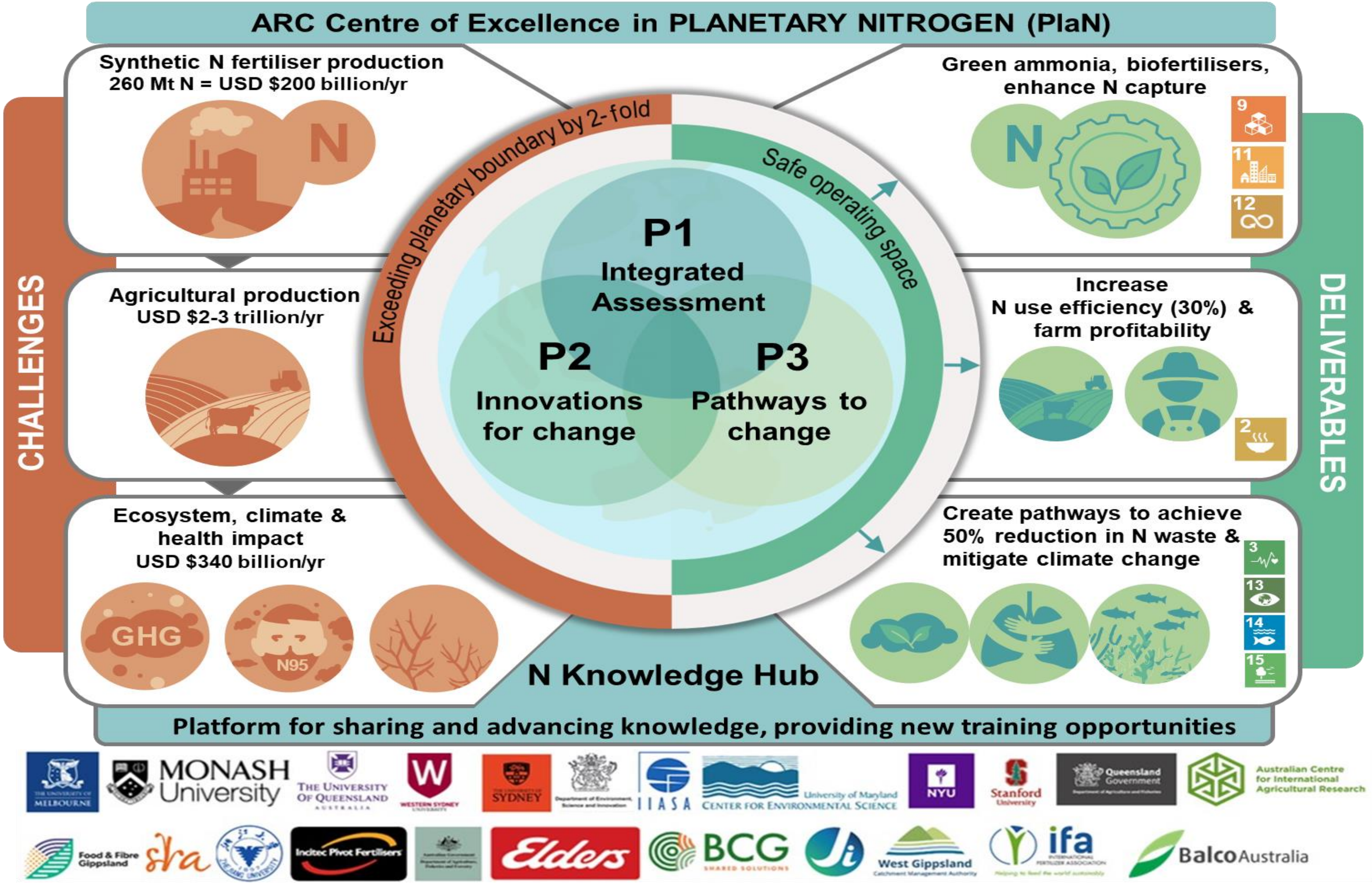


Fig 1. ARC Centre of Excellence in PLANETARY NITROGEN challenges, deliverables & 23-organisation team

Food and Agriculture Organization of the United Nations

THANK YOU

GLOBAL SOIL PARTNERSHIP