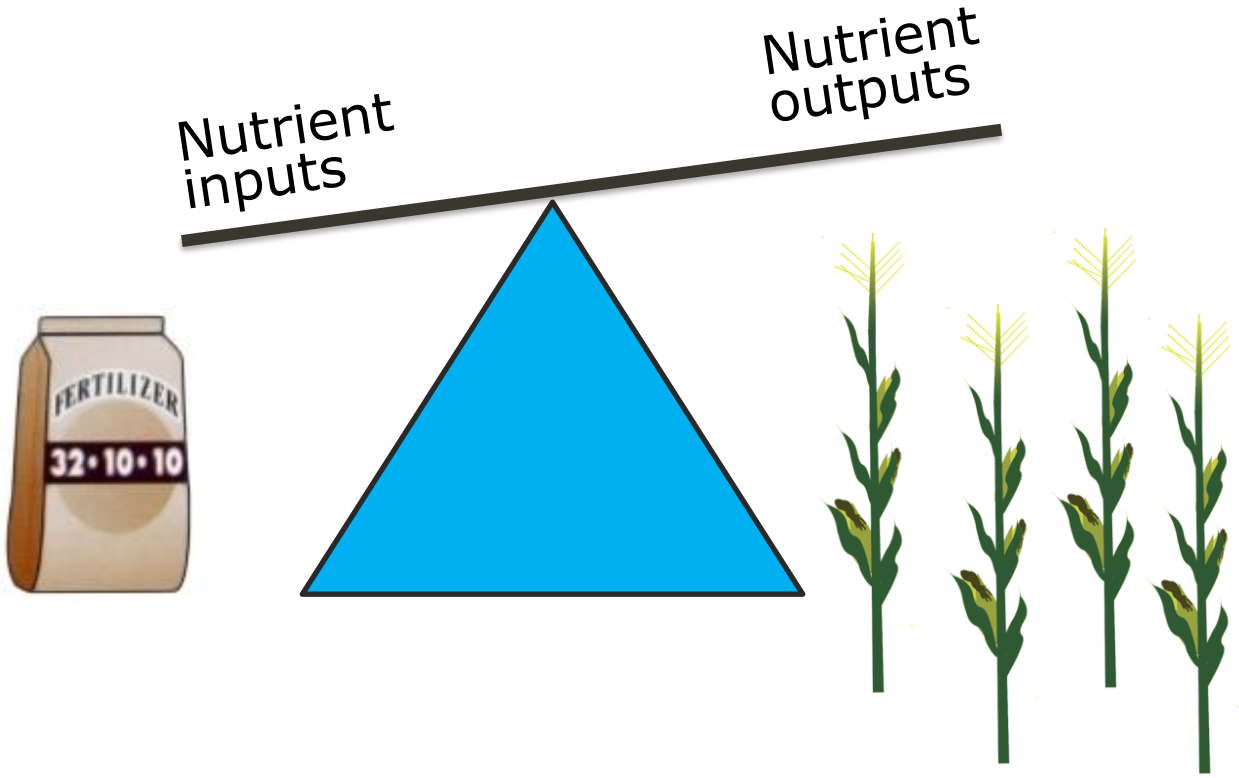
Open data for improved cropland nutrient budgets and nutrient use efficiency estimations



Dr Cameron Ludemann, Researcher

Wageningen University & Research

The Netherlands

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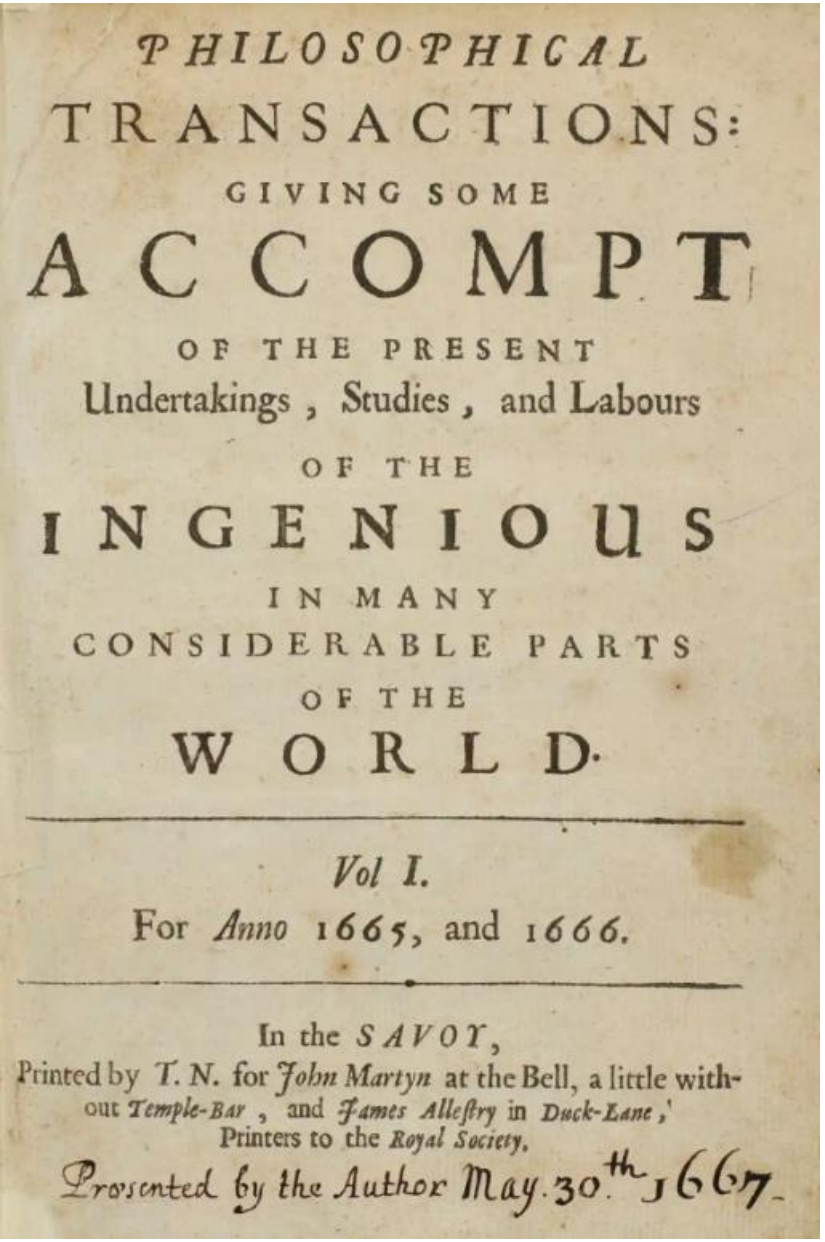
Value of open data

Open data being made available (nutrient budgets/use efficiencies)

How estimates could be improved

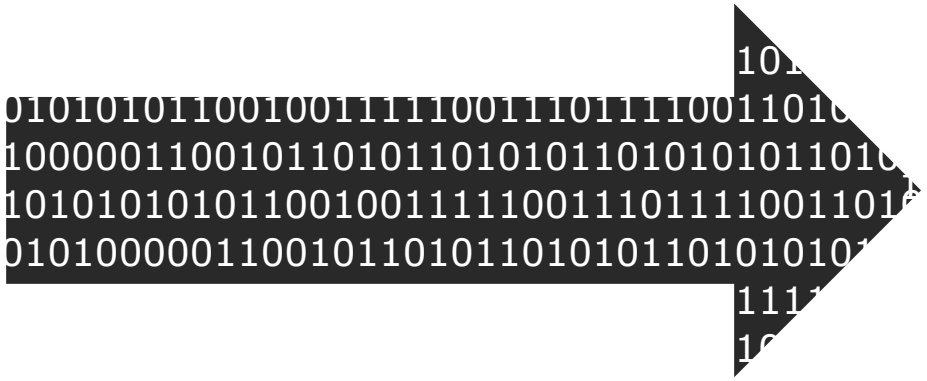
Challenges of open data projects

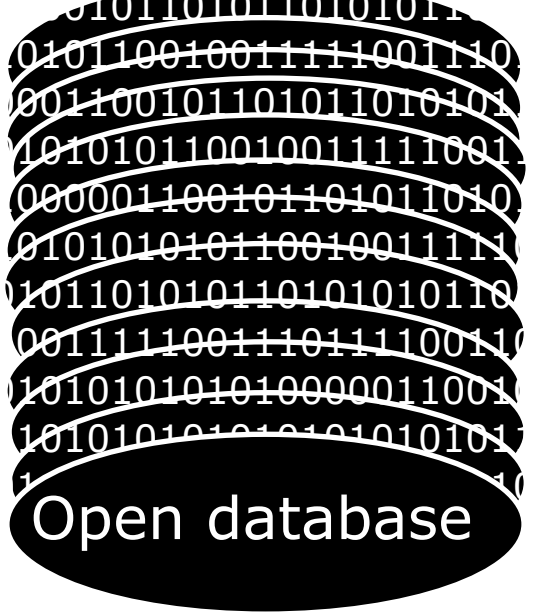


PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

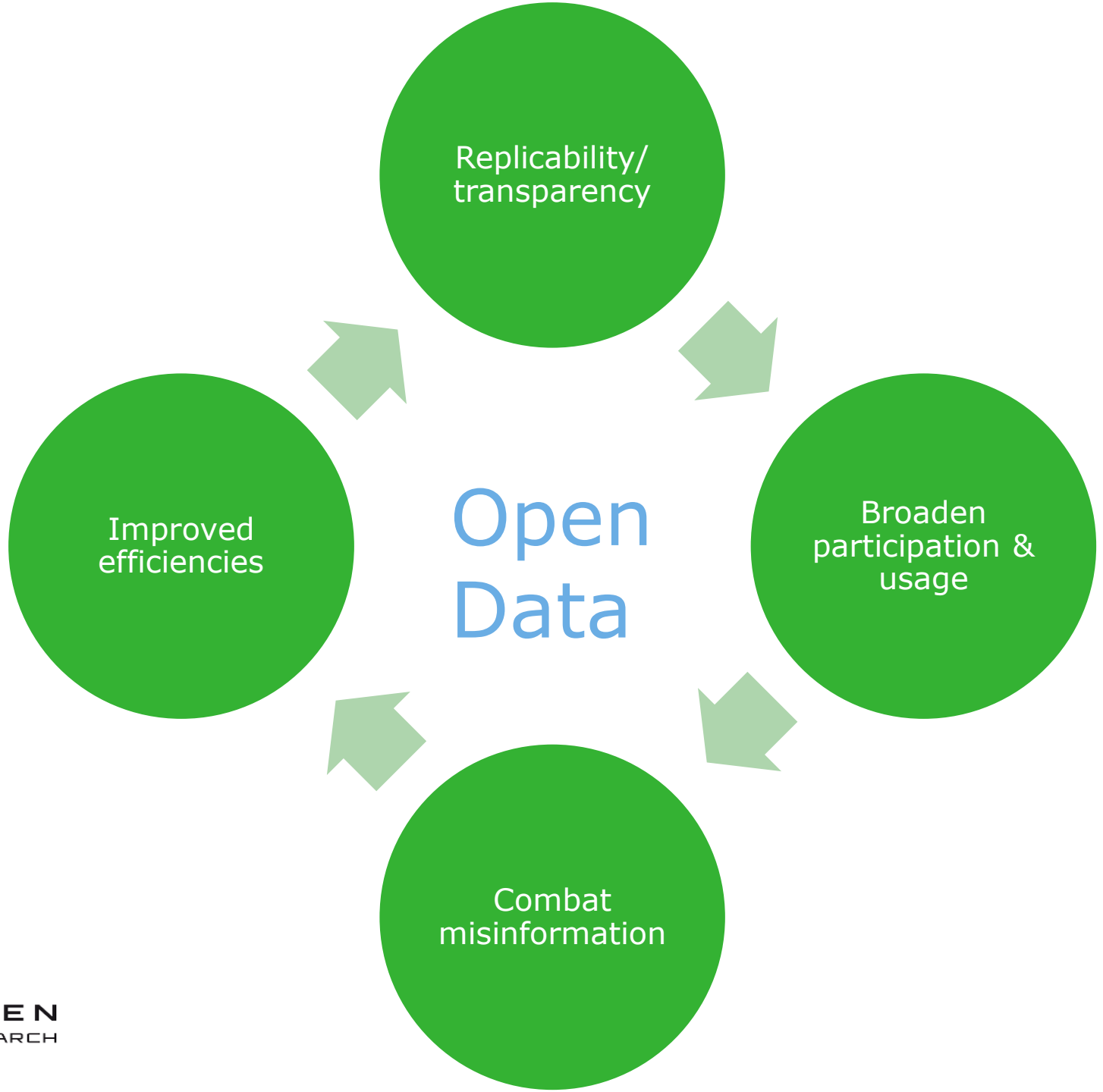
Vol I.
For Anno 1665, and 1666.

In the SAVOY,
Printed by T. N. for John Martyn at the Bell, a little without Temple-Bar, and James Allestry in Duck-Lane,
Printers to the Royal Society.
Presented by the Author May. 30th 1667.





https://royalsocietypublishing.org/loi/rsta/group/c1600.d1690.y1699



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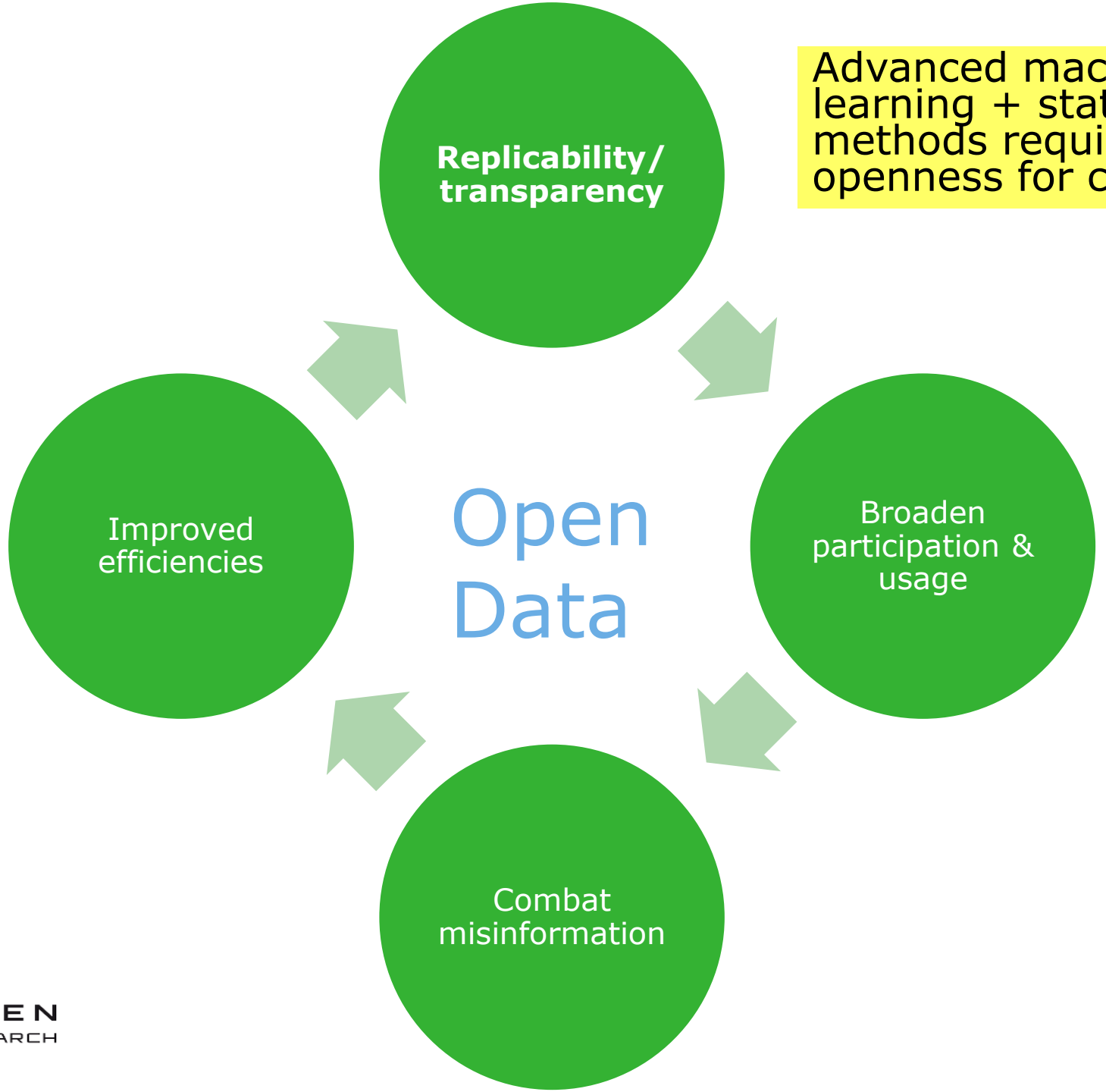
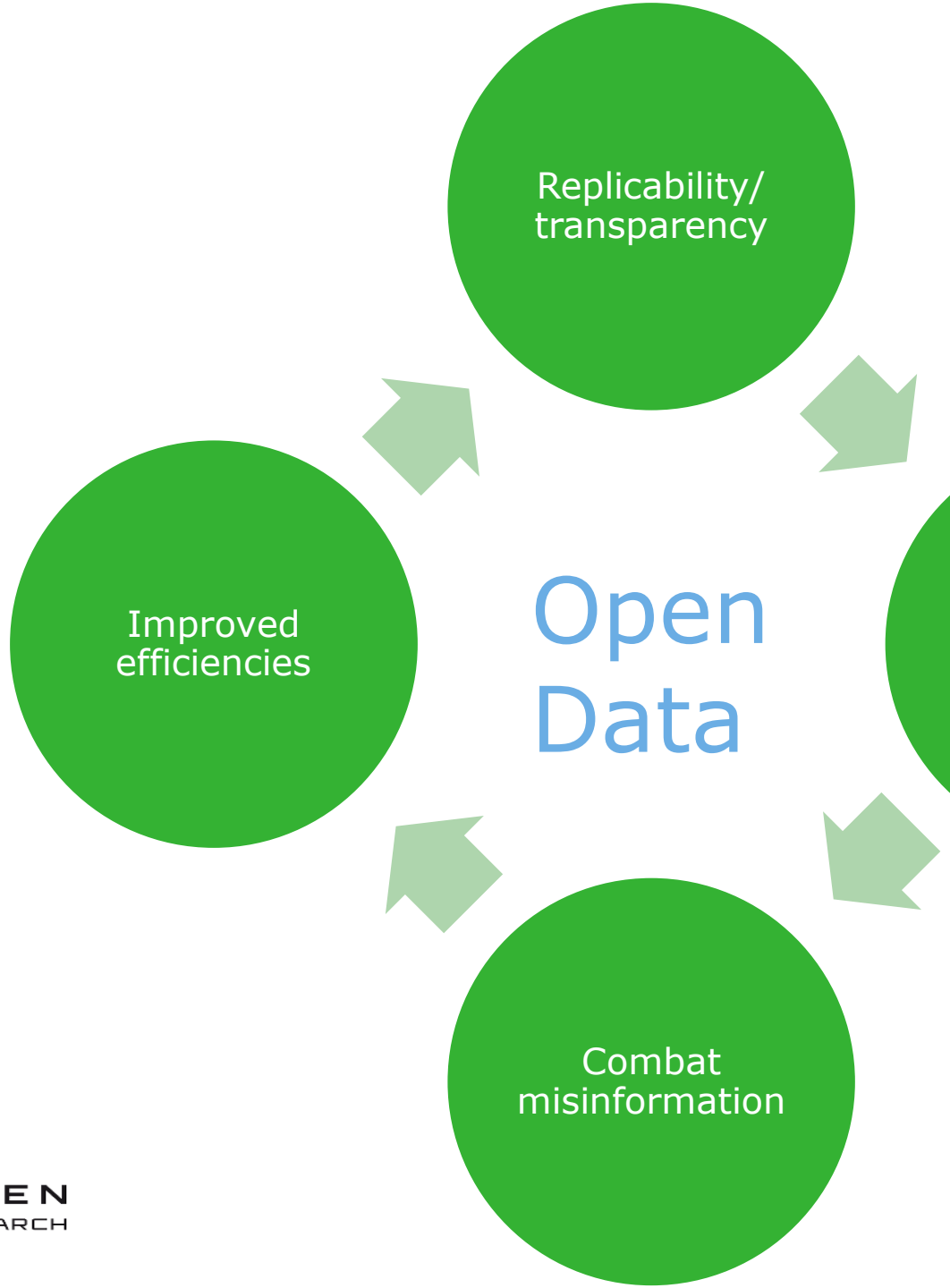


Advanced machine learning + statistical methods require greater openness for code/data



Analysis from different sectors

Credit: NASA, ESA, and D. Coe (NASA JPL/Caltech and STScI)

https://pixabay.com/photos/valais-alps-mountains-glacier-3562988/

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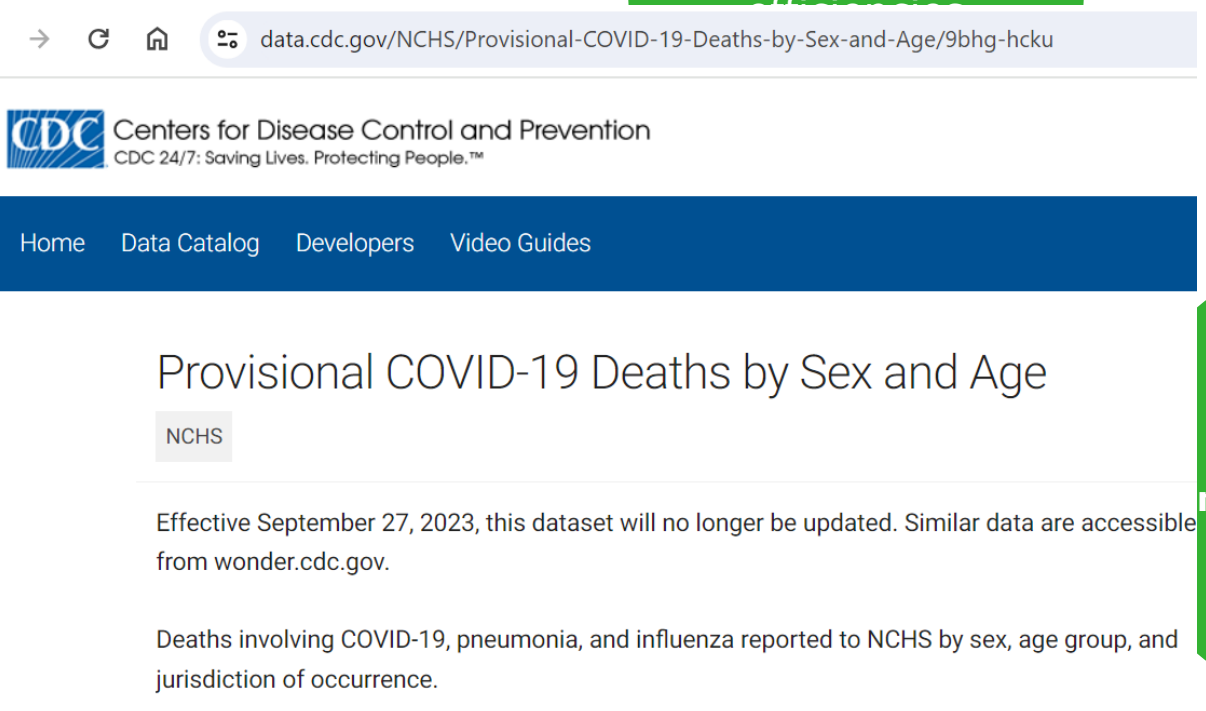
Replicability/ transparency

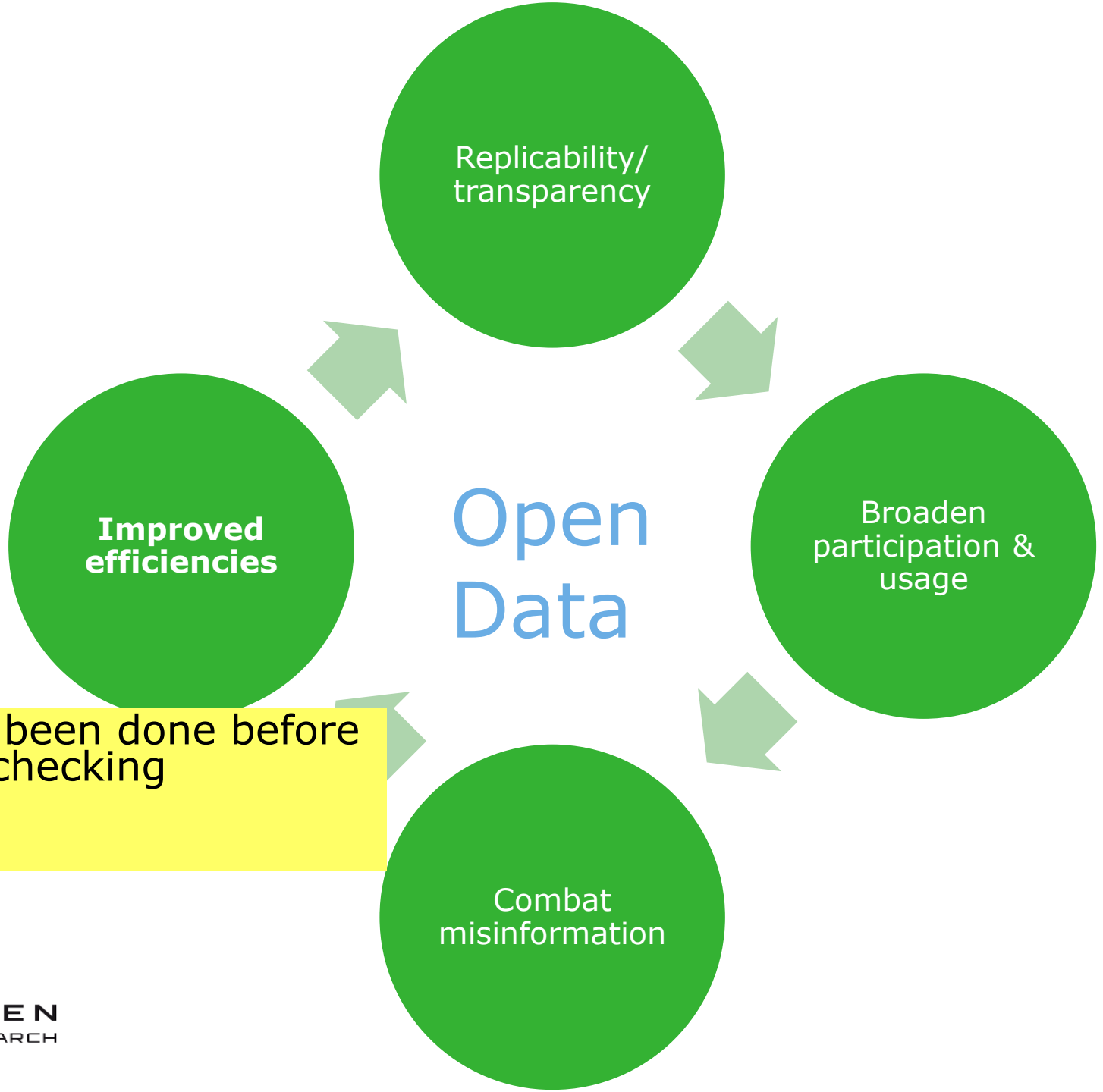
Broaden participation & usage

Combat misinformation

Improved

Open Data





Easier to know what's been done before
Crowd sourcing error checking
Meta-analysis easier

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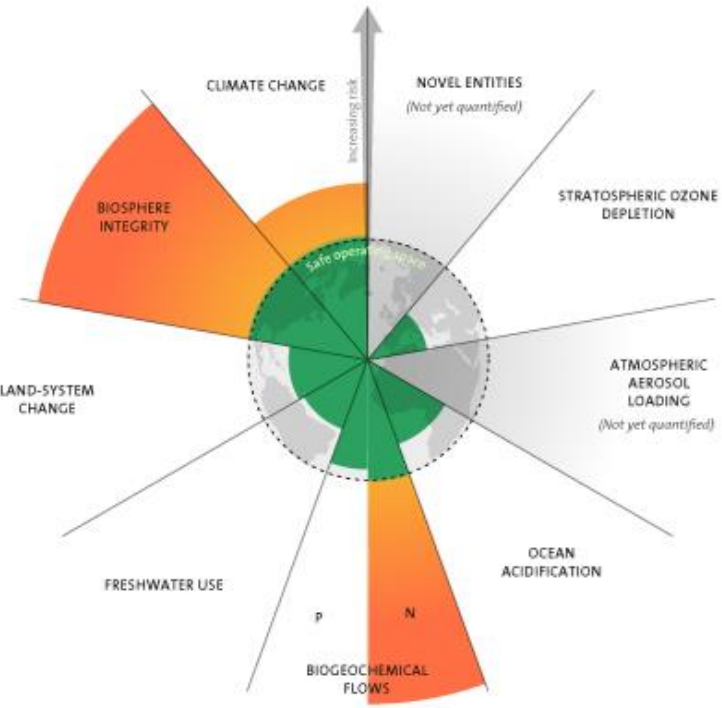
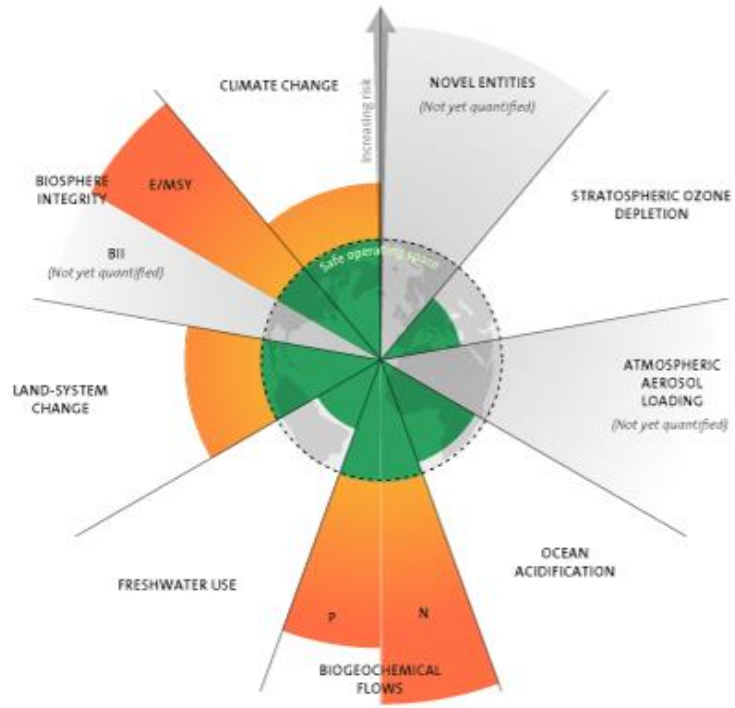
2009



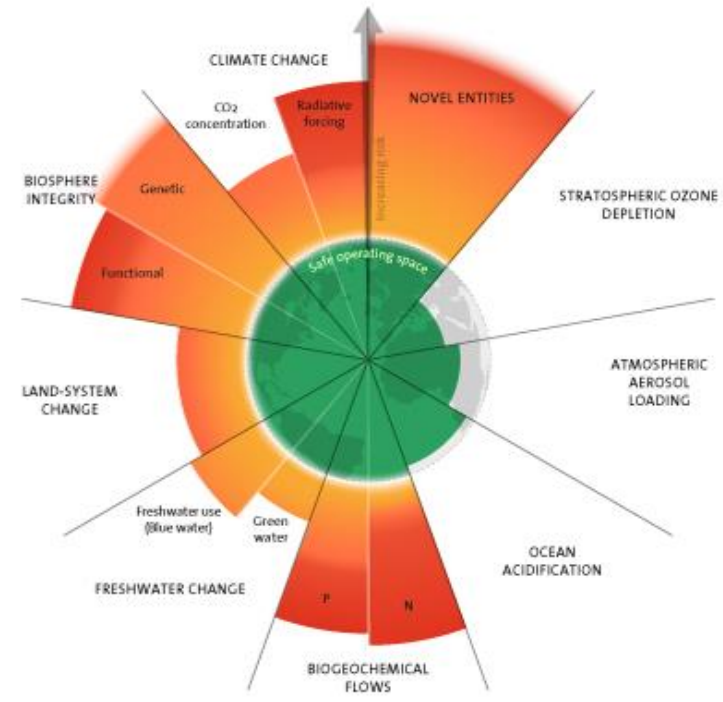
3 boundaries crossed

2015



4 boundaries crossed

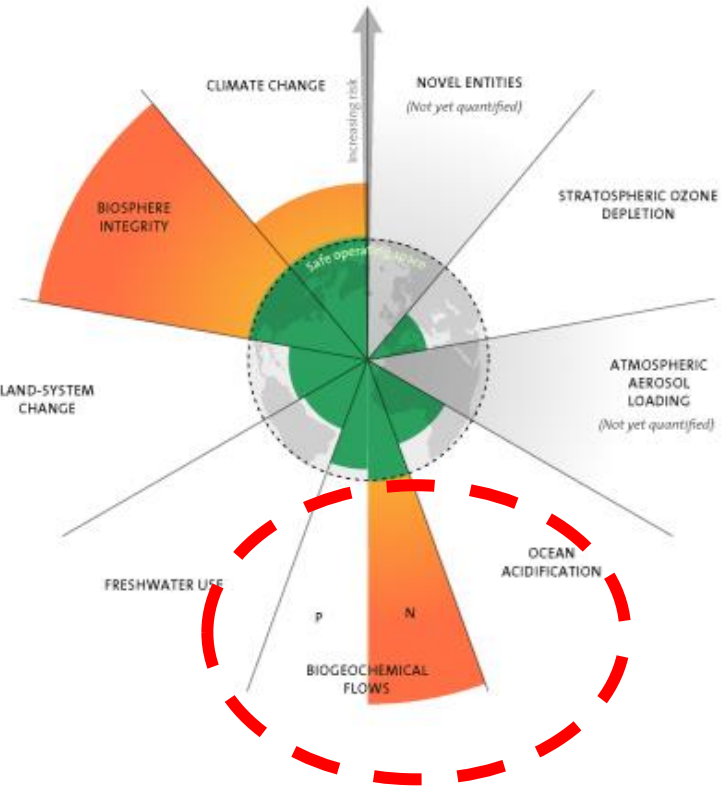
2023



6 boundaries crossed

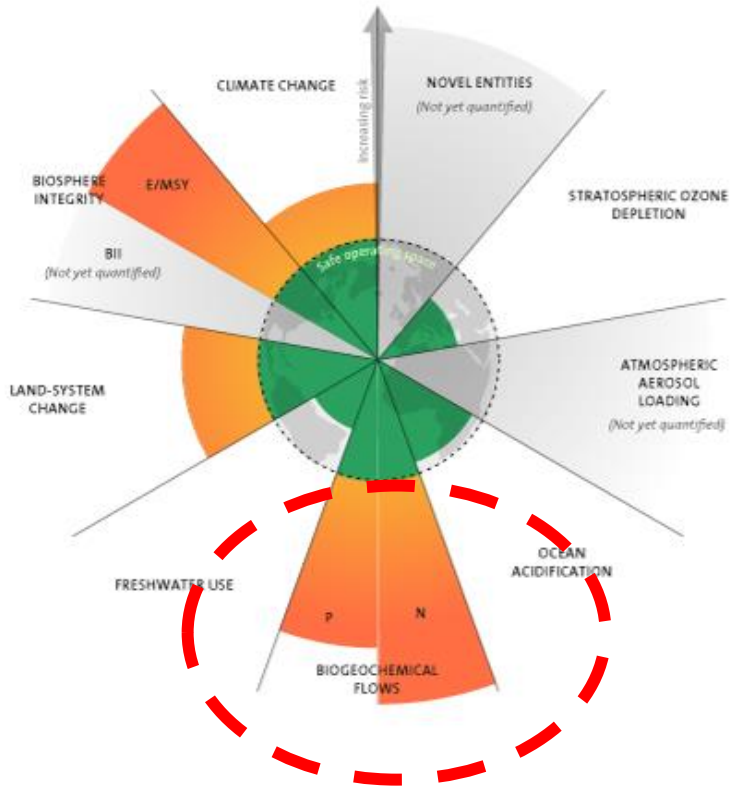
Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023
https://www.stockholmresilience.org/research/planetary-boundaries.html

2009



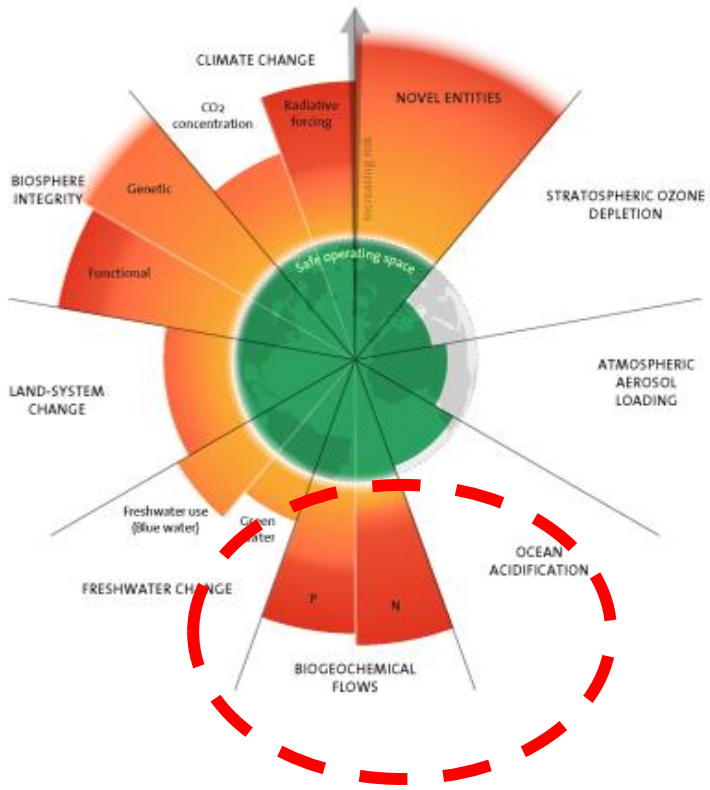
3 boundaries crossed

2015



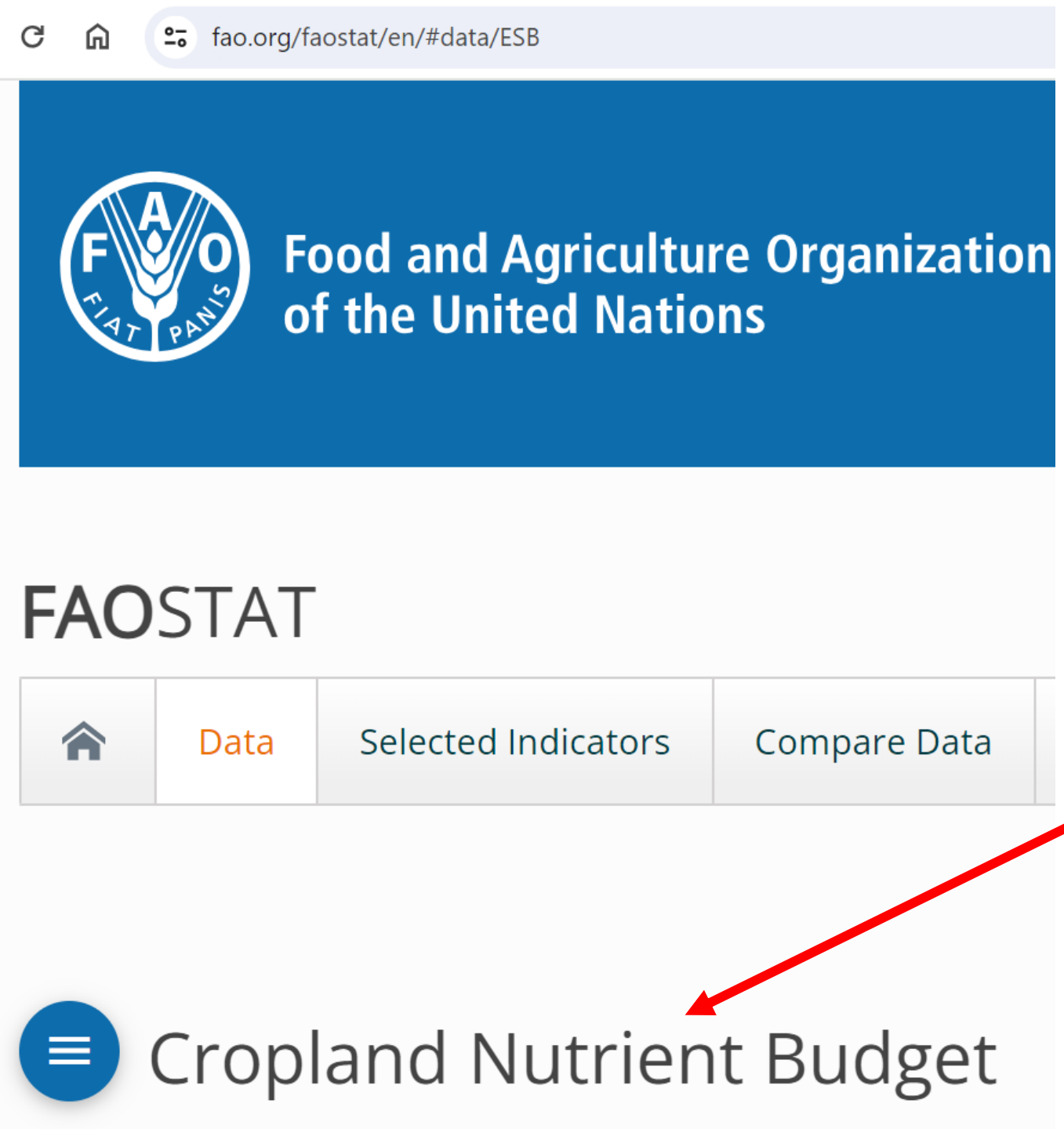
4 boundaries crossed

2023



6 boundaries crossed

Nutrients becoming an increasingly important issue in terms of planetary boundaries...



Open data for all budget components, balances & use efficiencies by country.

2020 is latest data.

New data will come out ~December 2023.

FAO Cropland Nutrient Balance =

Nutrient Inputs

Synthetic Fertilizers (SF) × Fraction SF applied to cropland (CF)

+

Manure Applied to Soils (MAS)

+

Atmospheric N deposition (AD)

+

Biological Fixation (BF)

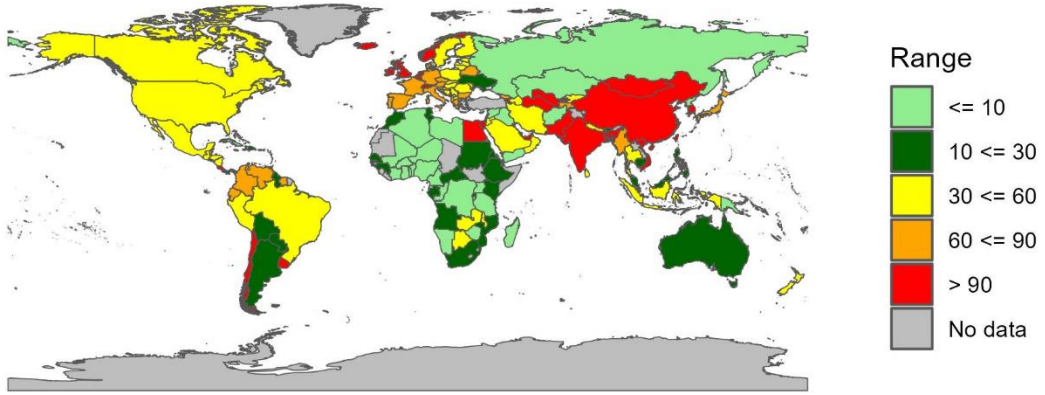
Minus

Nutrient Outputs

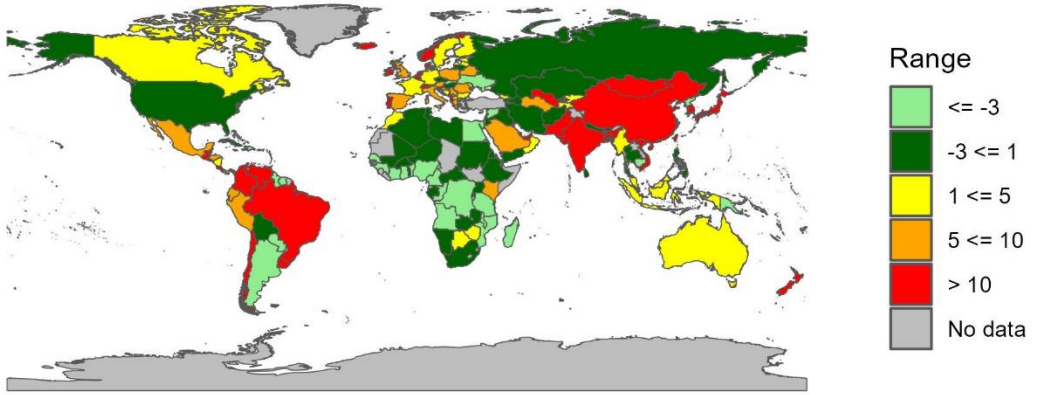
Crop Removal (CR)

FAO nutrient balances (kg/ha surpluses if +ve and deficits if –ve)

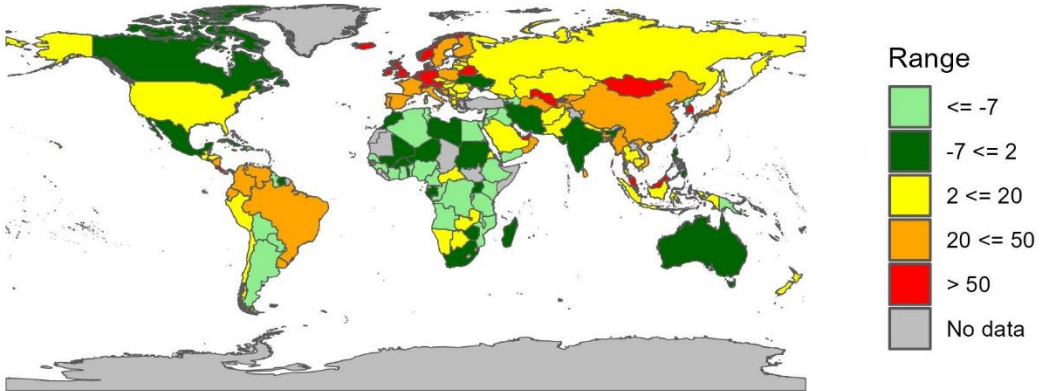
(a) N



(b) P



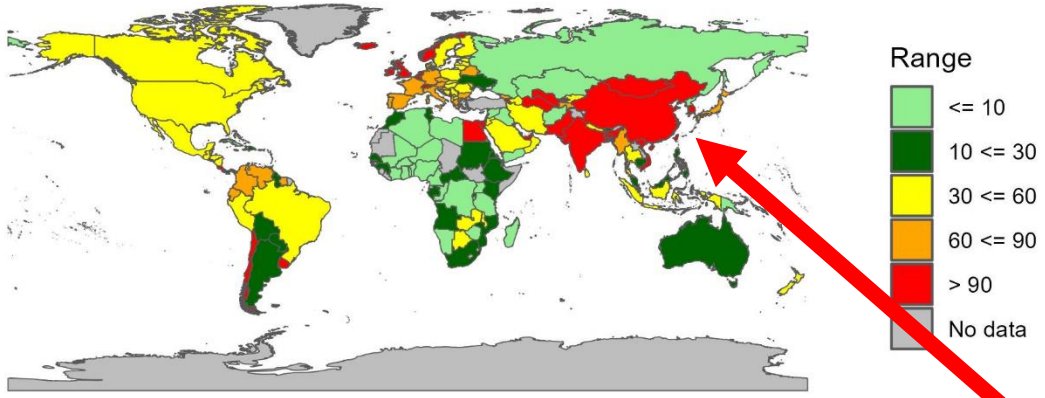
(c) K



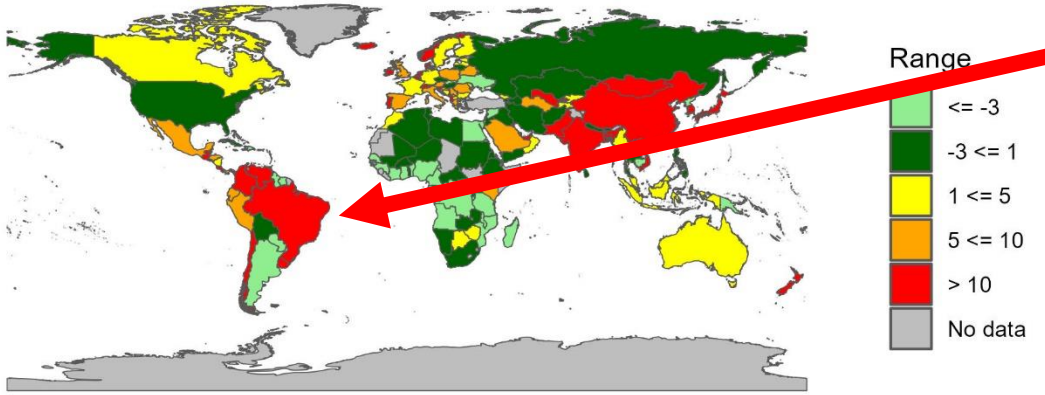
Ludemann et al (Under review)ESSD
https://essd.copernicus.org/preprints/essd-2023-206/

FAO nutrient balances (kg/ha surpluses if +ve and deficits if –ve)

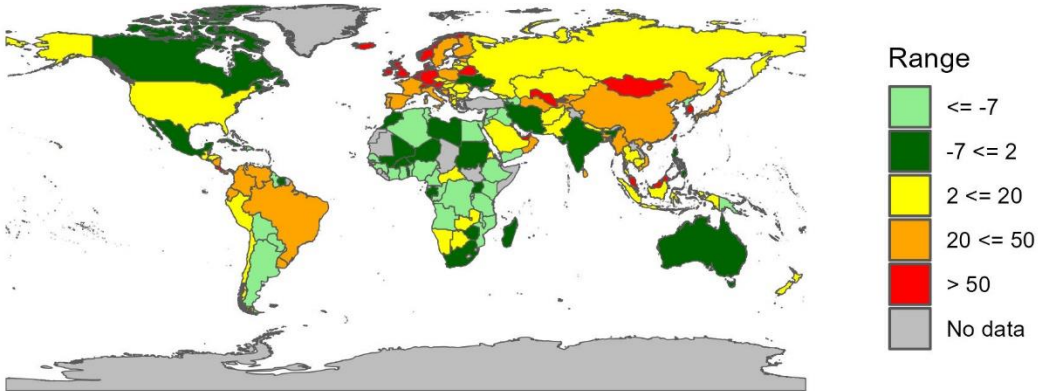
(a) N



(b) P



(c) K



Ludemann et al (Under review)ESSD
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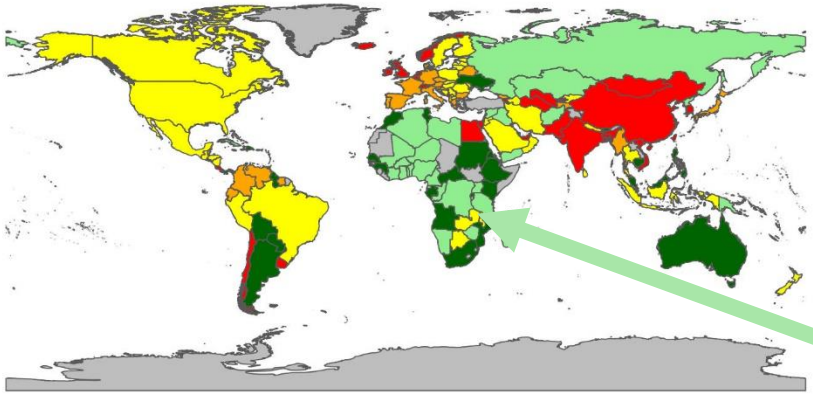
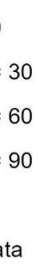
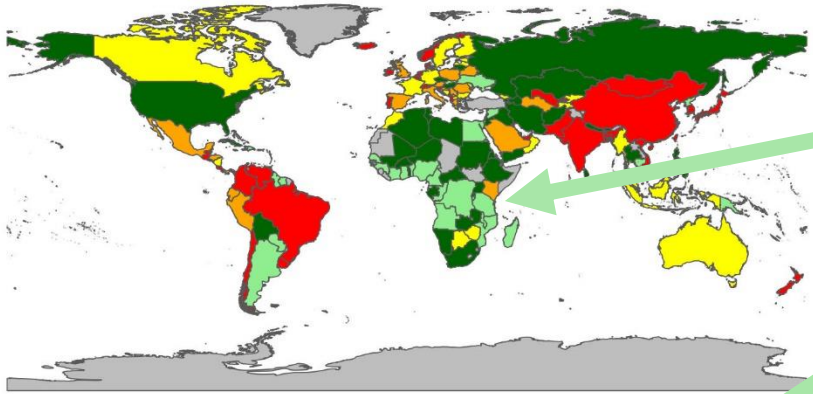
FAO nutrient balances (kg/ha surpluses if +ve and deficits if –ve)

(a) N

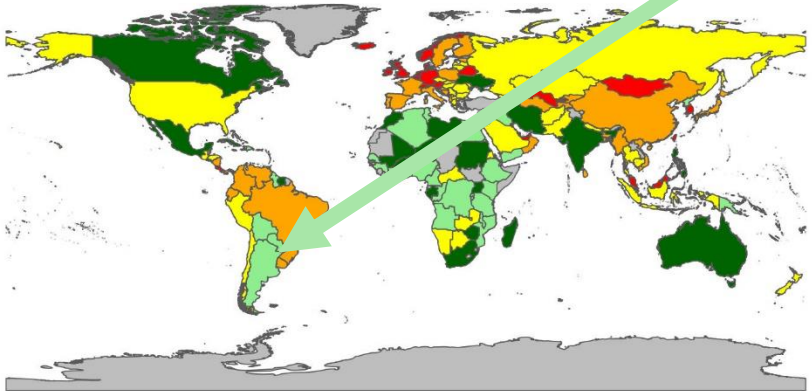


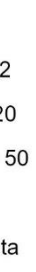


(b) P



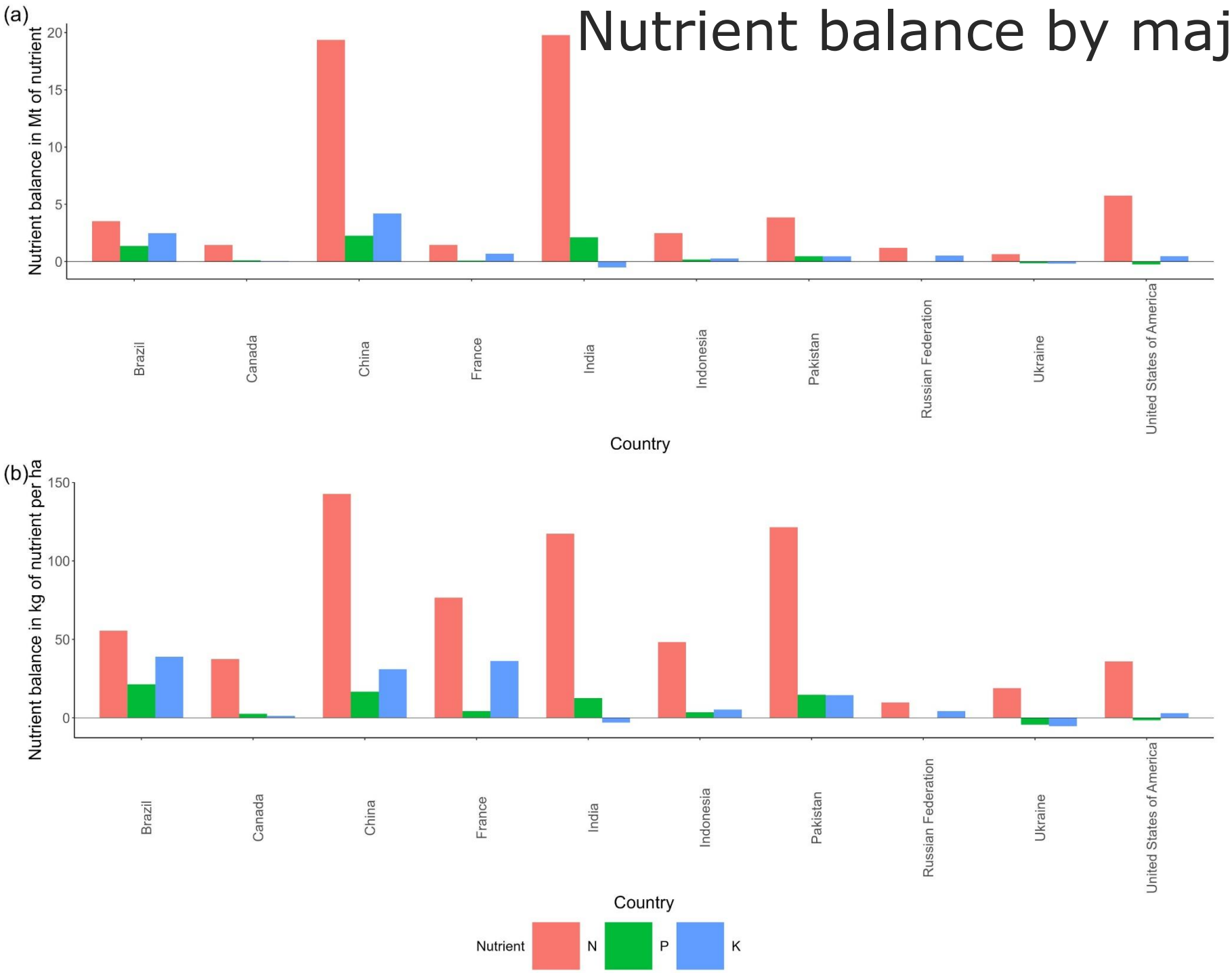
(c) K

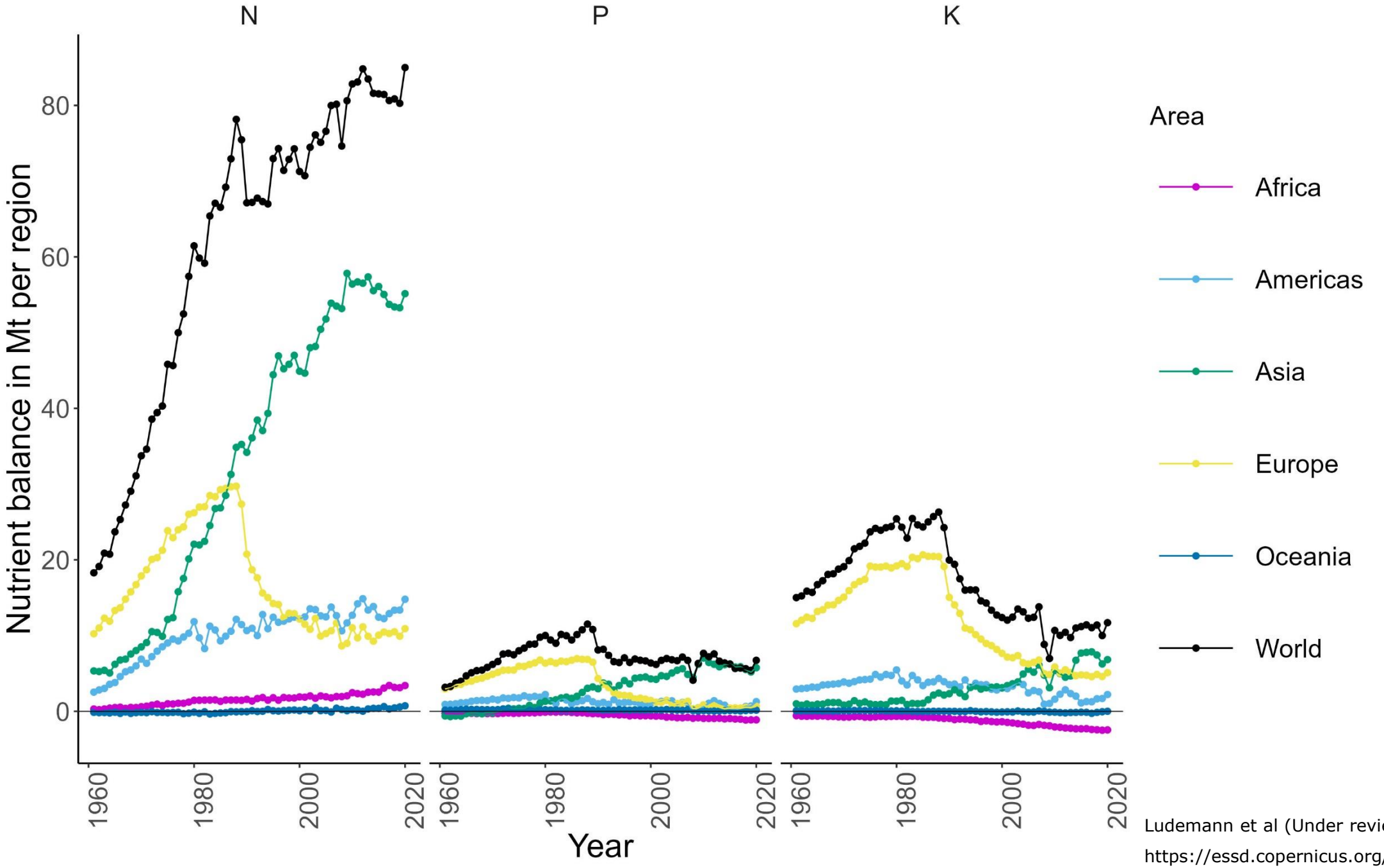




Ludemann et al (Under review)ESSD
https://essd.copernicus.org/preprints/essd-2023-206/

Nutrient balance by major country





Ludemann et al (Under review)ESSD

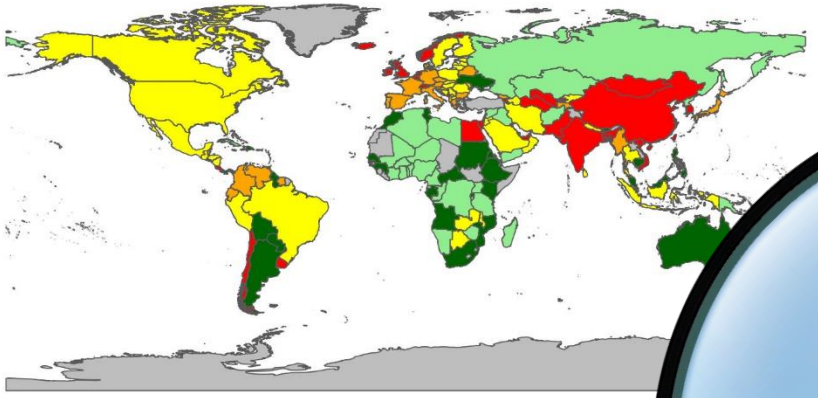
https://essd.copernicus.org/preprints/essd-2023-206/

Data not always available for every region/country

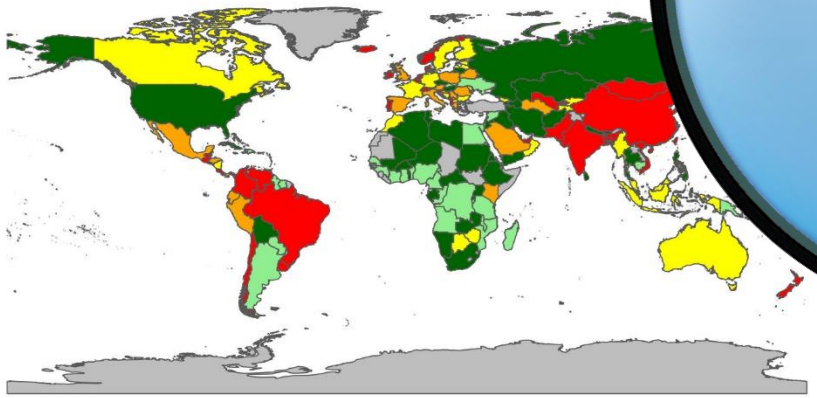
Therefore use Tiers of data:

- If no data available use world averages (Tier 1-Current FAO cropland budget)
- If region/country specific values available use these (Tier 2)
- If field experiment data available use these (Tier 3)

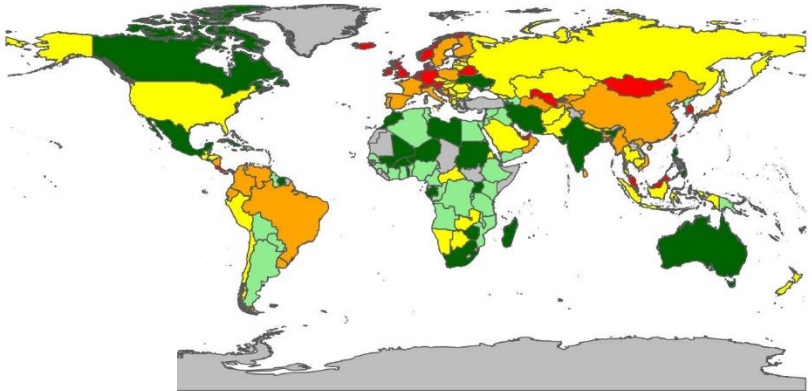
(a) N



(b) P



(c) K



Range

No data

Enable researchers to use more locally relevant estimates.

Range

<= -7

-7 <= 2

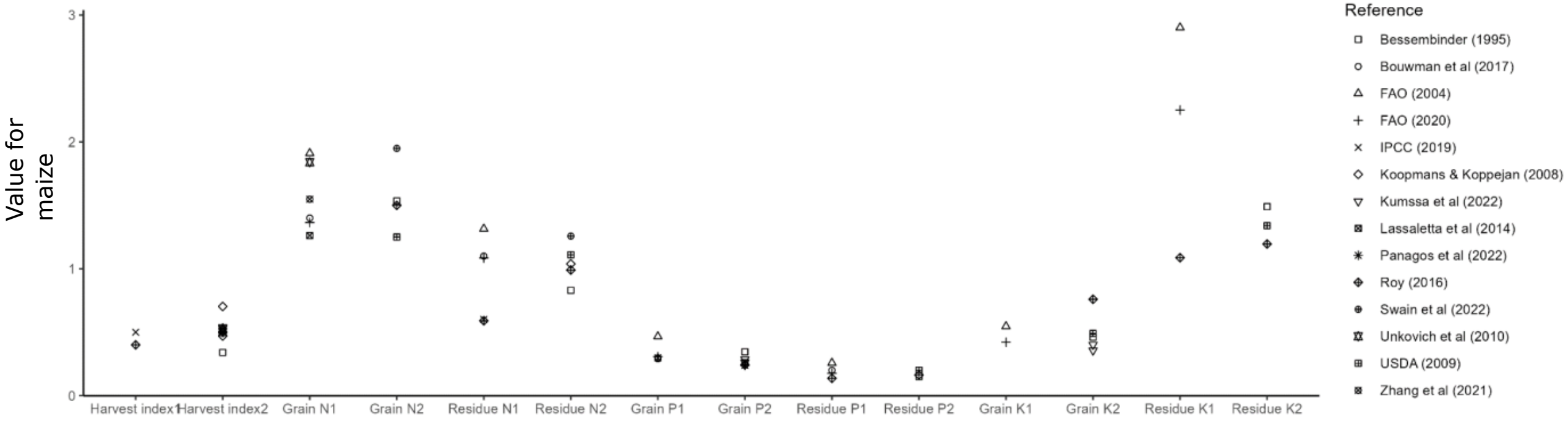
2 <= 20

20 <= 50

> 50

No data

Choice of data sources could more than double some estimates of nutrients taken off cropland as maize grain or residue



Ludemann et al. Under review. *Nutrient Cycling in Agroecosystems*

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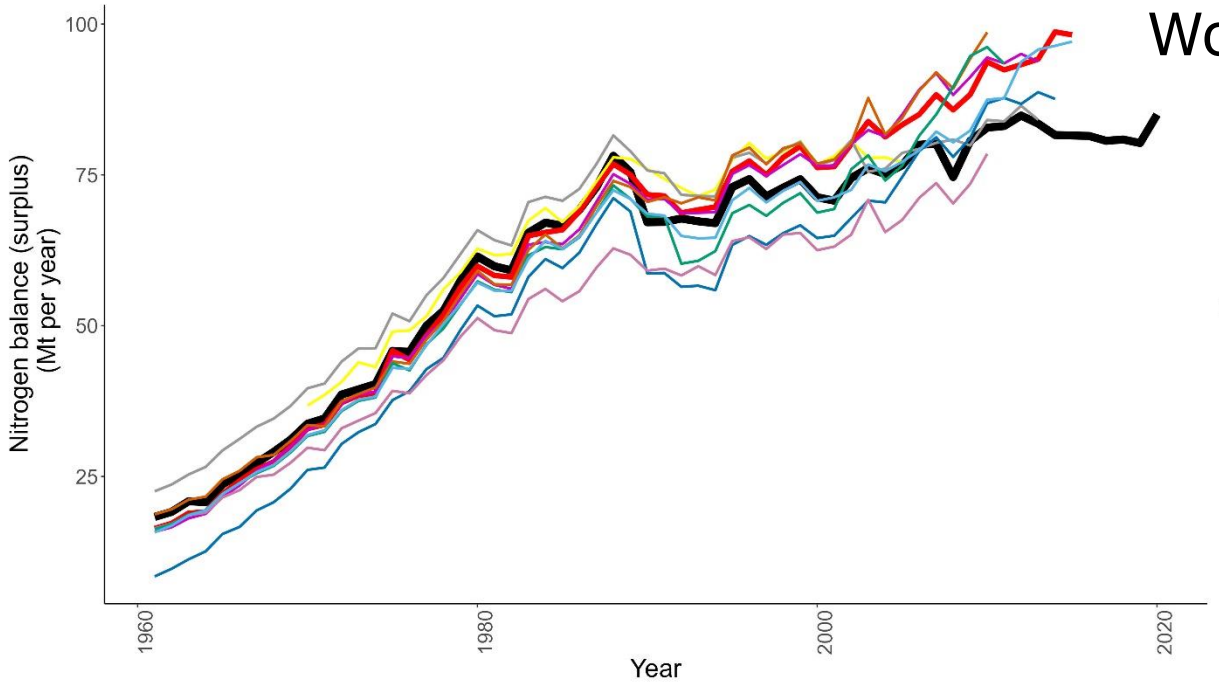
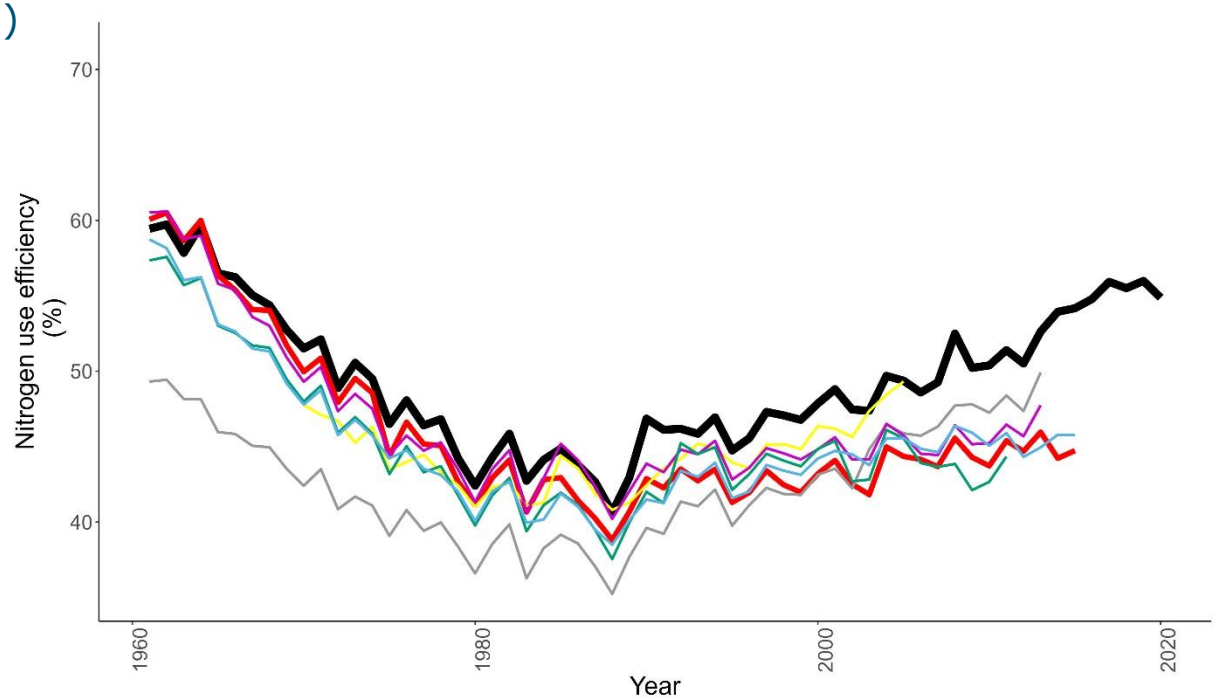
World cropland N balance and use efficiencies

a)



b)



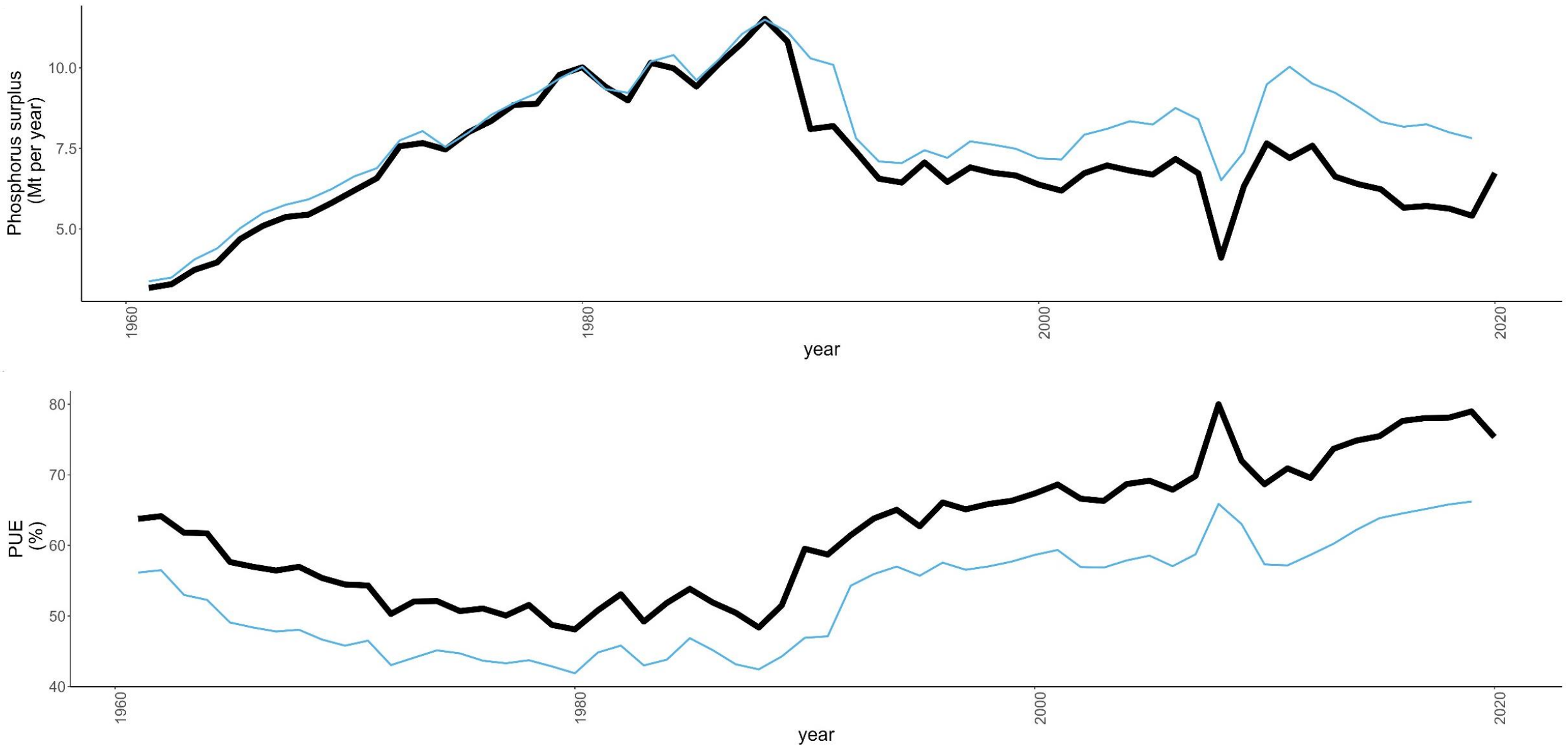
Reference

- FAO (2022) Cropland Nutrient Budget (current study)
- FAO (2021)
- Bouwman et al (2013)
- Bodirsky et al (2012) no forage
- Bodirsky (2012) with forage
- Chang et al (2014)
- Conant et al (2013)
- Gerber & Mueller (2012)
- Lassaletta et al (2014;2016)
- Lu & Tian (2017)
- Nishina et al (2017) no double crop
- Nishina et al (2017) with double crop
- Zhang et al (2015)
- Zhang et al (2015) reorganized

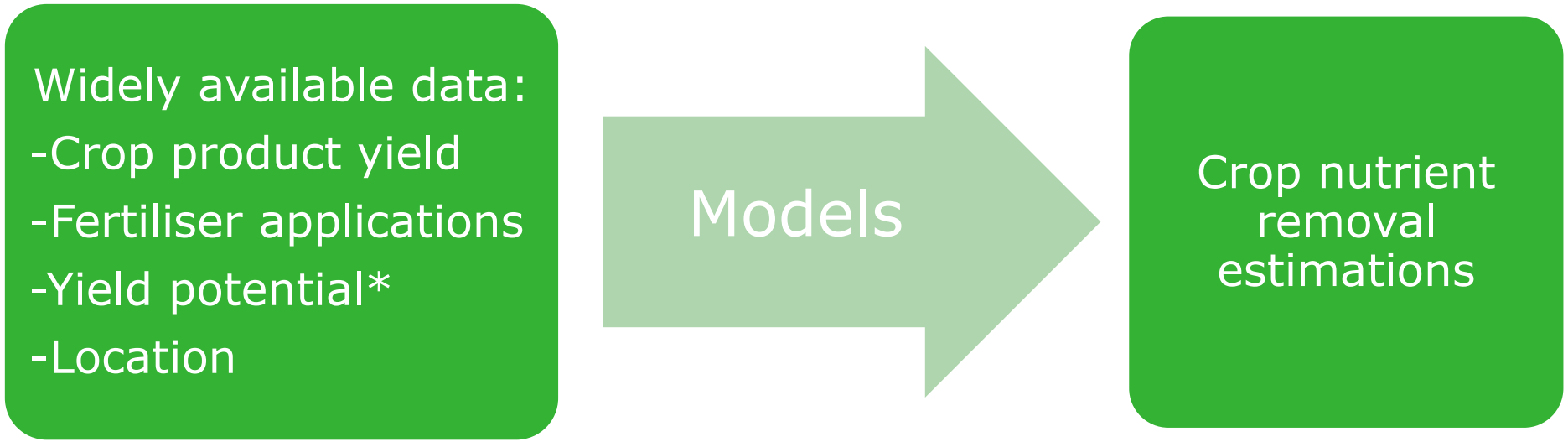
Ludemann et al (Under review)ESSD

https://essd.copernicus.org/preprints/essd-2023-206/

World cropland P balance and use efficiencies



We developed models to improve estimates of maize nutrient removal based on widely available data (Tier 3)



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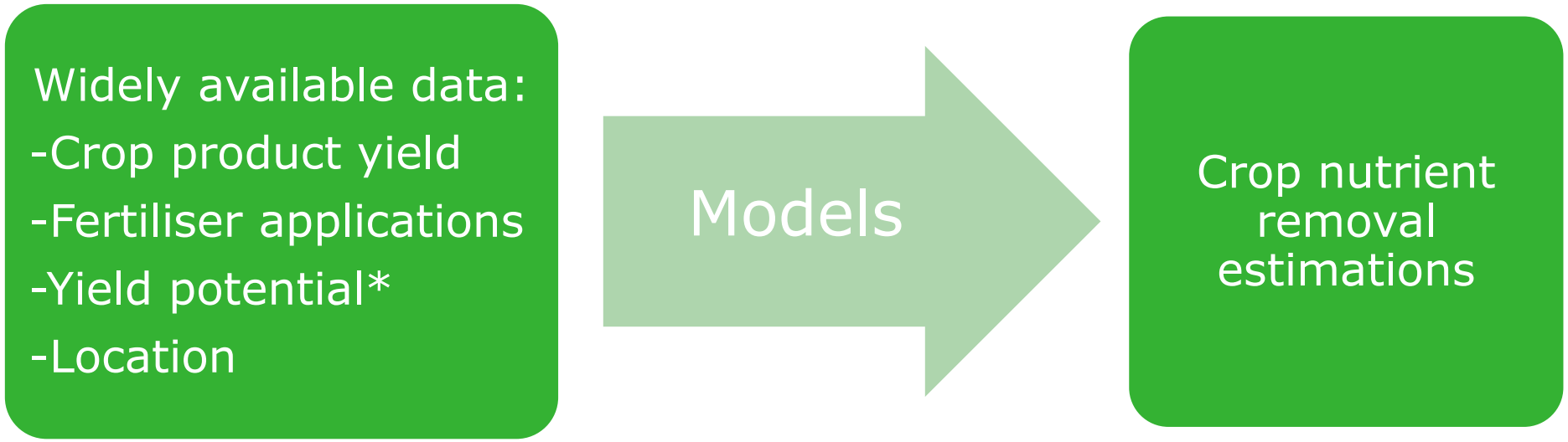
*Global Yield Gap Atlas: www.yieldgap.org

Use Tier 3 estimates of crop nutrient removal in maize nutrient budgets to compare with current Tier 1 estimates



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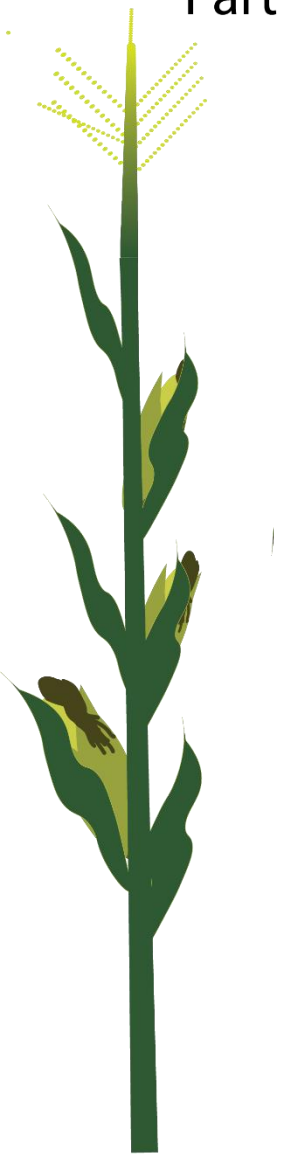
*Global Yield Gap Atlas: www.yieldgap.org

Partial nutrient budget



=Nutrient inputs – Nutrient outputs

<u>Partial</u> as we only include:

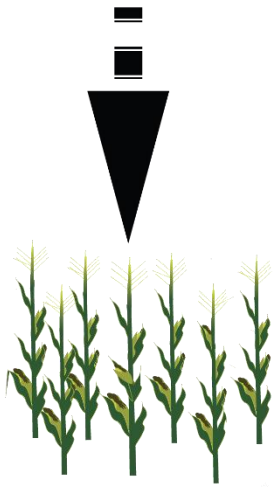
Inputs=Fertilizer applied

Outputs= Nutrients in crop removed

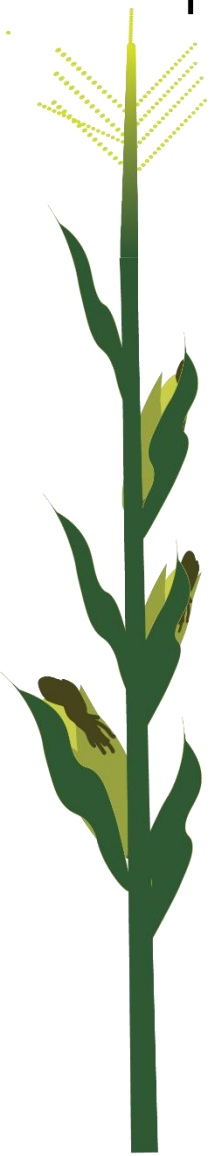
(assume other components remain constant)

Partial nutrient budget

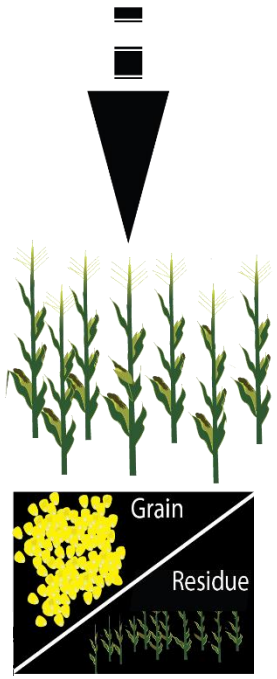
Inputs:
Nutrients in fertilizer



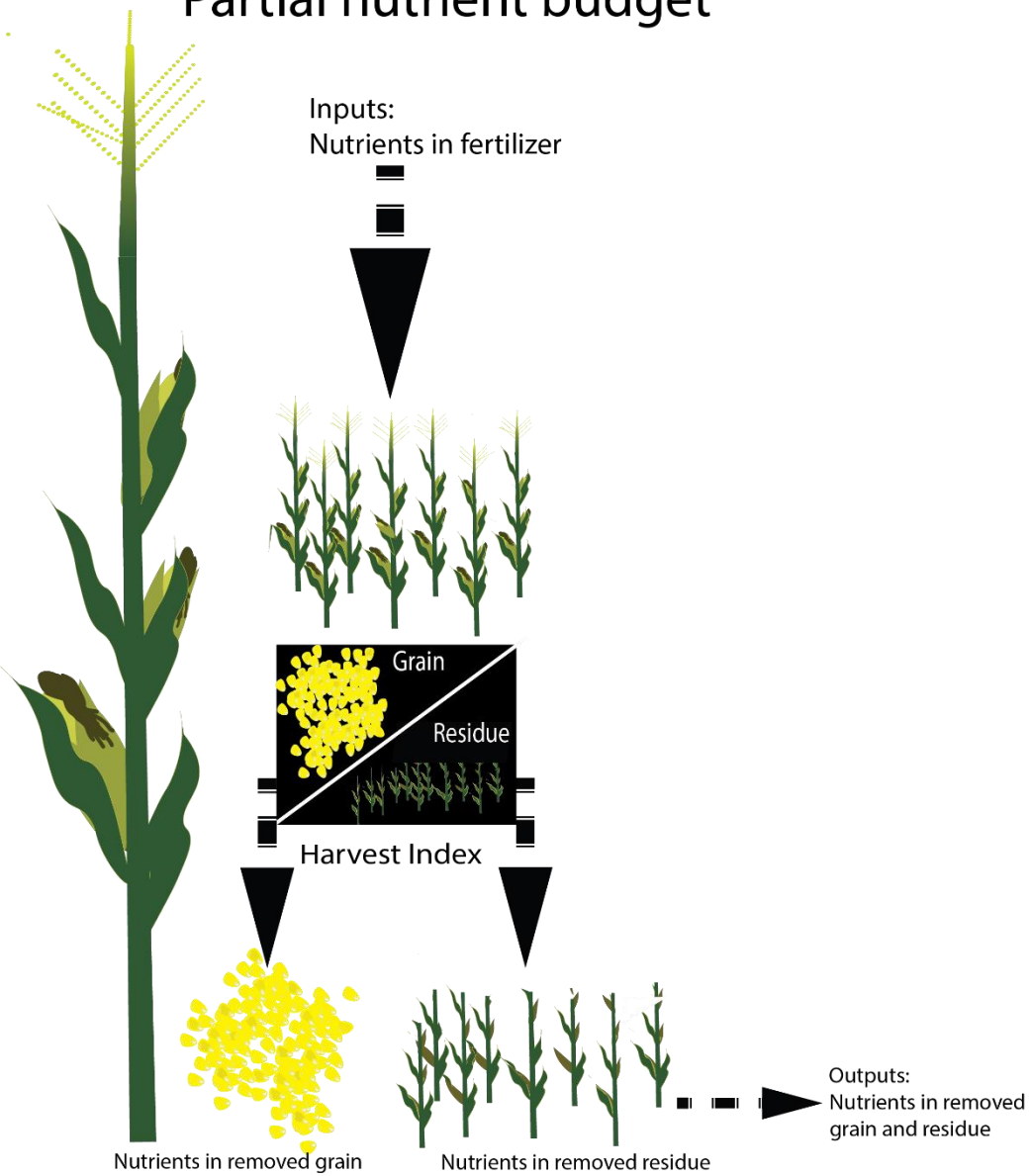
Partial nutrient budget



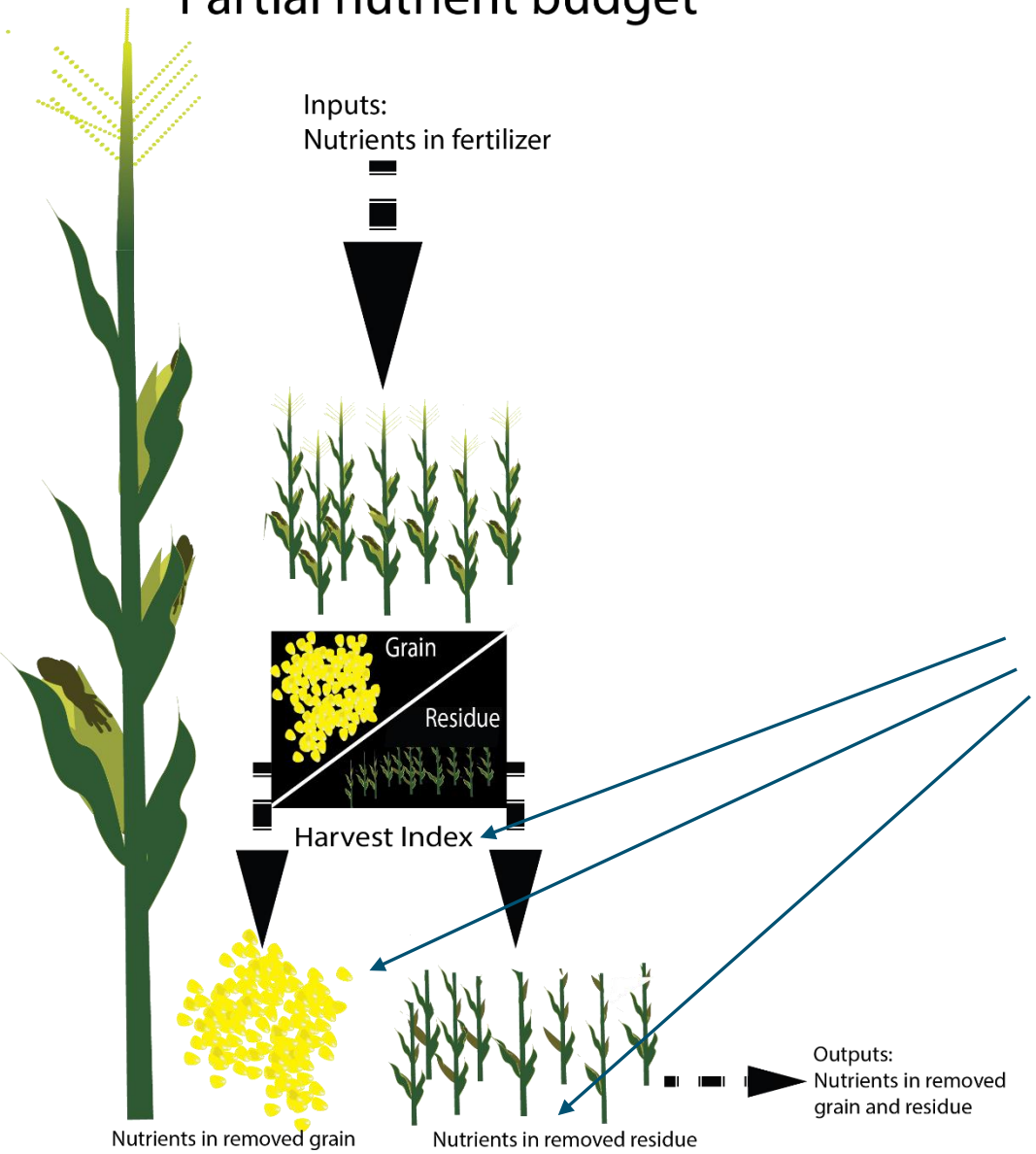
Inputs:
Nutrients in fertilizer



Partial nutrient budget

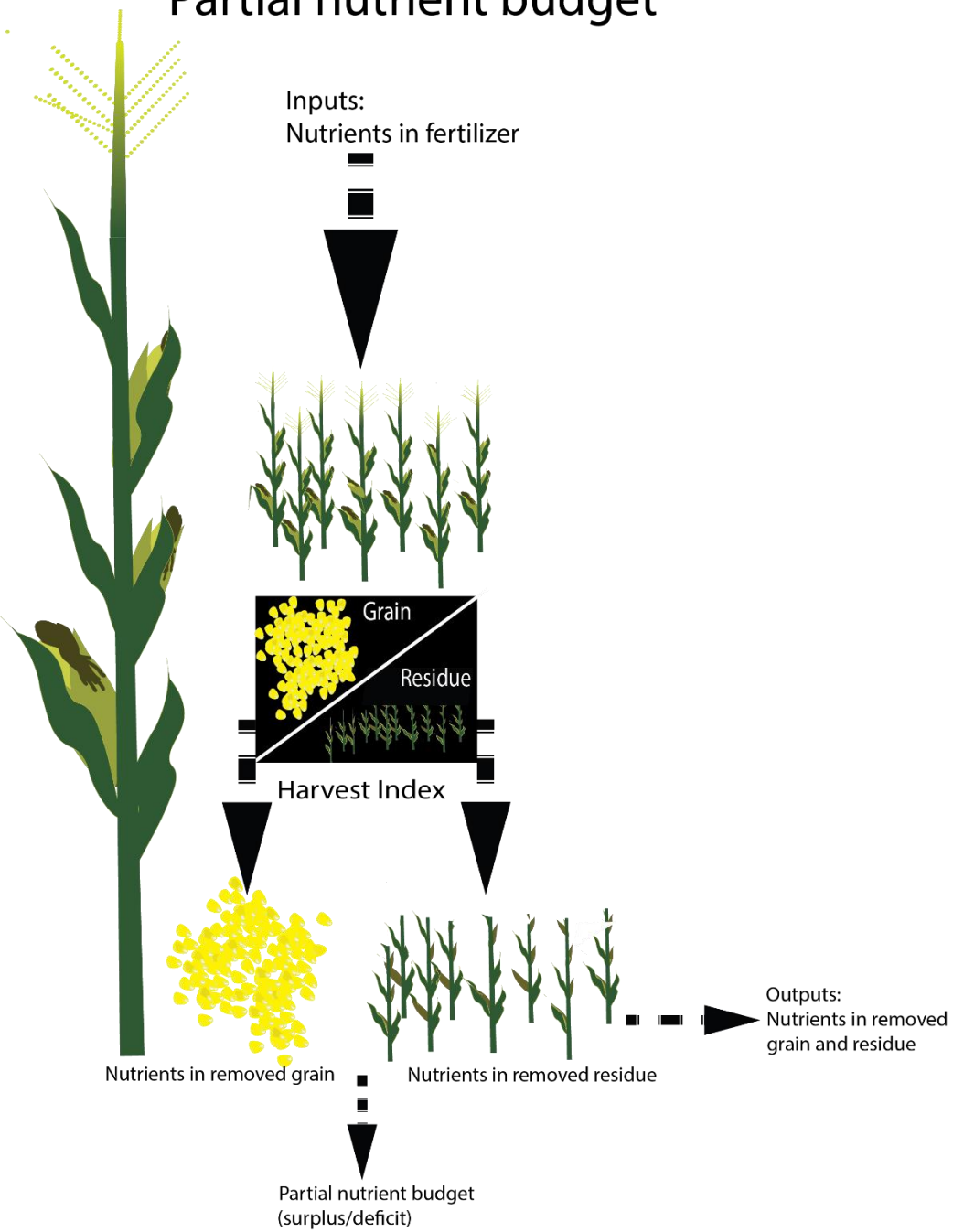


Partial nutrient budget



Using maize field experiment data we created models for predicting:
-Harvest index
-Nutrient concentrations of grain
-Nutrient concentrations of residue

Partial nutrient budget



Nutrients included in database are N, P and K

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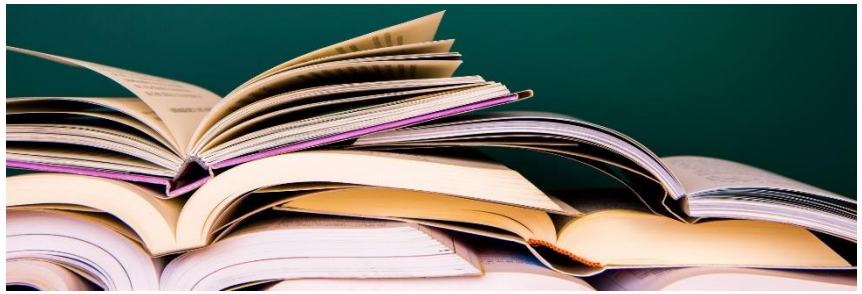
www.freepik.com/free-vector/workers-farm-activity-illustration_5551358.htm

Our models used Tier 3 data from

Literature



Requests from individuals/organisations

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Tier 1 and 2 estimates from literature collated in DRYAD (search for “Ludemann” datasets)

datadryad.org/stash/dataset/doi:10.5061/dryad.n2z34tn0x

DRYAD

Explore data | Search

Who we are | What we do | Join us | Help

Global data on crop nutrient concentration and harvest indices

Ludemann, Cameron I., Wageningen University & Research, https://orcid.org/0000-0002-8902-7052

Hijbeek, Renske, Wageningen University & Research

van Loon, Marloes, Wageningen University & Research

Murrell, T. Scott, African Plant Nutrition Institute

Dobermann, Achim, International Fertilizer Association

van Ittersum, Martin, Wageningen University & Research

cameron.ludemann@wur.nl, renske.hijbeek@wur.nl, marloes.vanloon@wur.nl, s.murrell@apni.net, adobermann@fertilizer.org, martin.vanittersum@wur.nl

Publication date: March 7, 2023

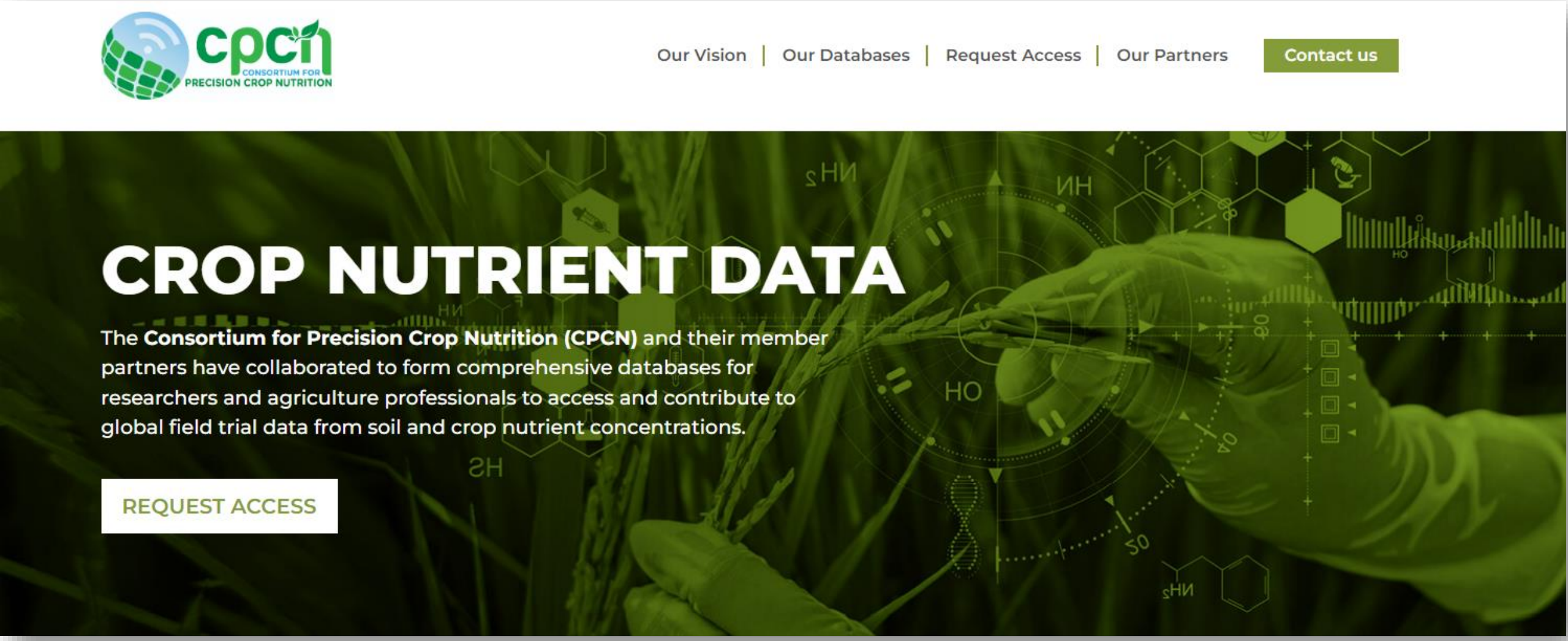
Publisher: Dryad

https://doi.org/10.5061/dryad.n2z34tn0x

Citation

Ludemann, Cameron I. et al. (2023), Global data on crop nutrient concentration and harvest indices, Dryad, Dataset, https://doi.org/10.5061/dryad.n2z34tn0x

www.cropnutrientdata.net (raw replicated data from requests)



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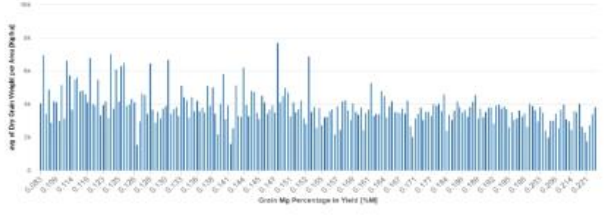
Search

Created

Create New Workspace

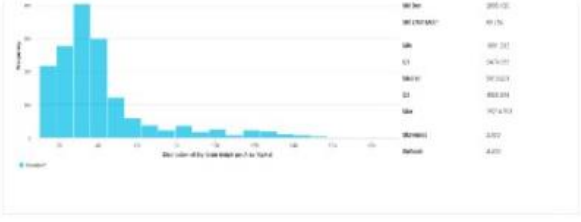
Yield and Mg concentration



1 widget

23.10.2023

Cameron's column plot dry grain yield per hectare filtered above...



1 widget

17.11.2022

Cameron's scatterplot nitrogen uptake in grain vs dry grain weig...

Cameron's scatter plot N uptake in grain vs dry grain weight

Cameron's map of all data with yield grouped by agroeco zones

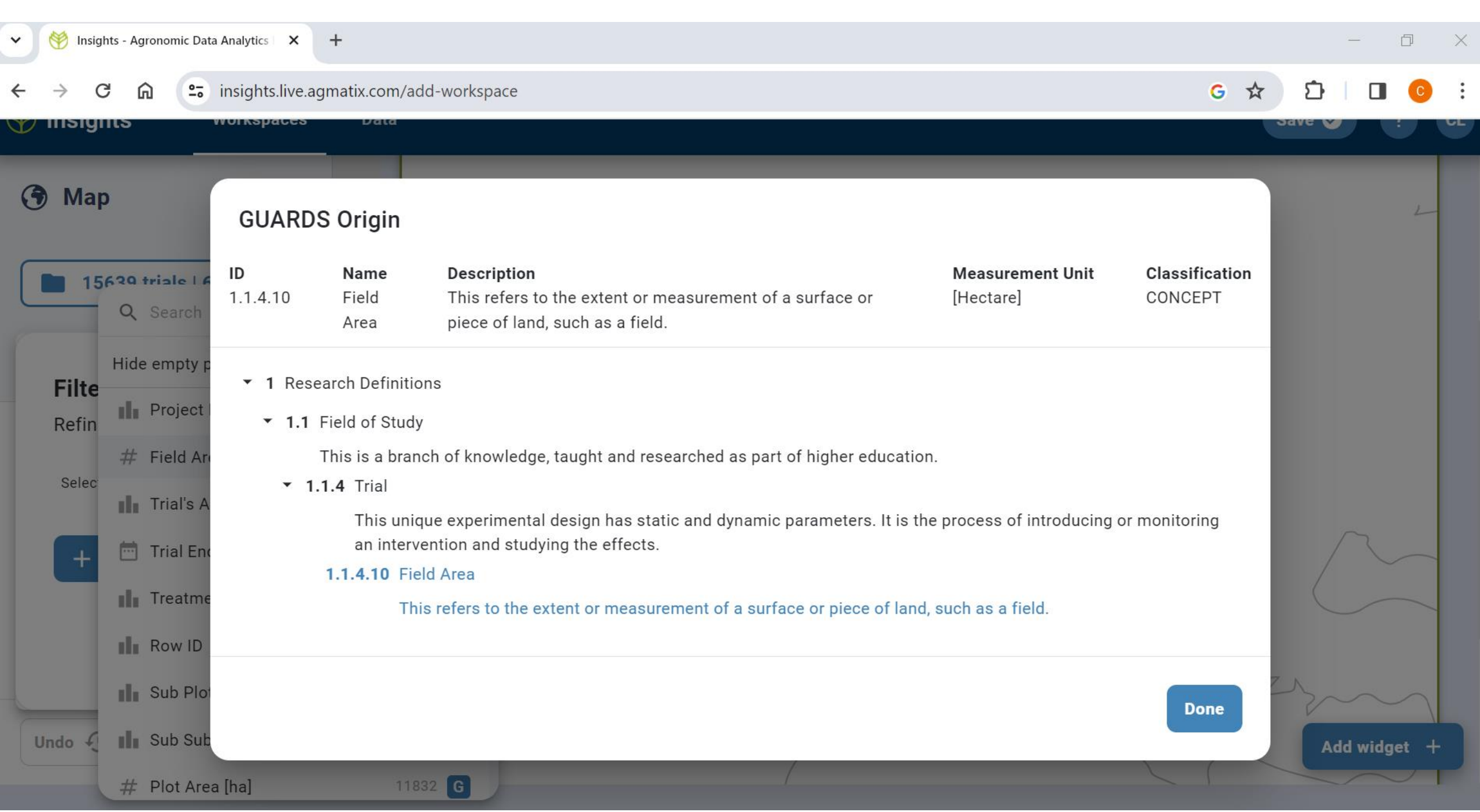
All projects

Project list

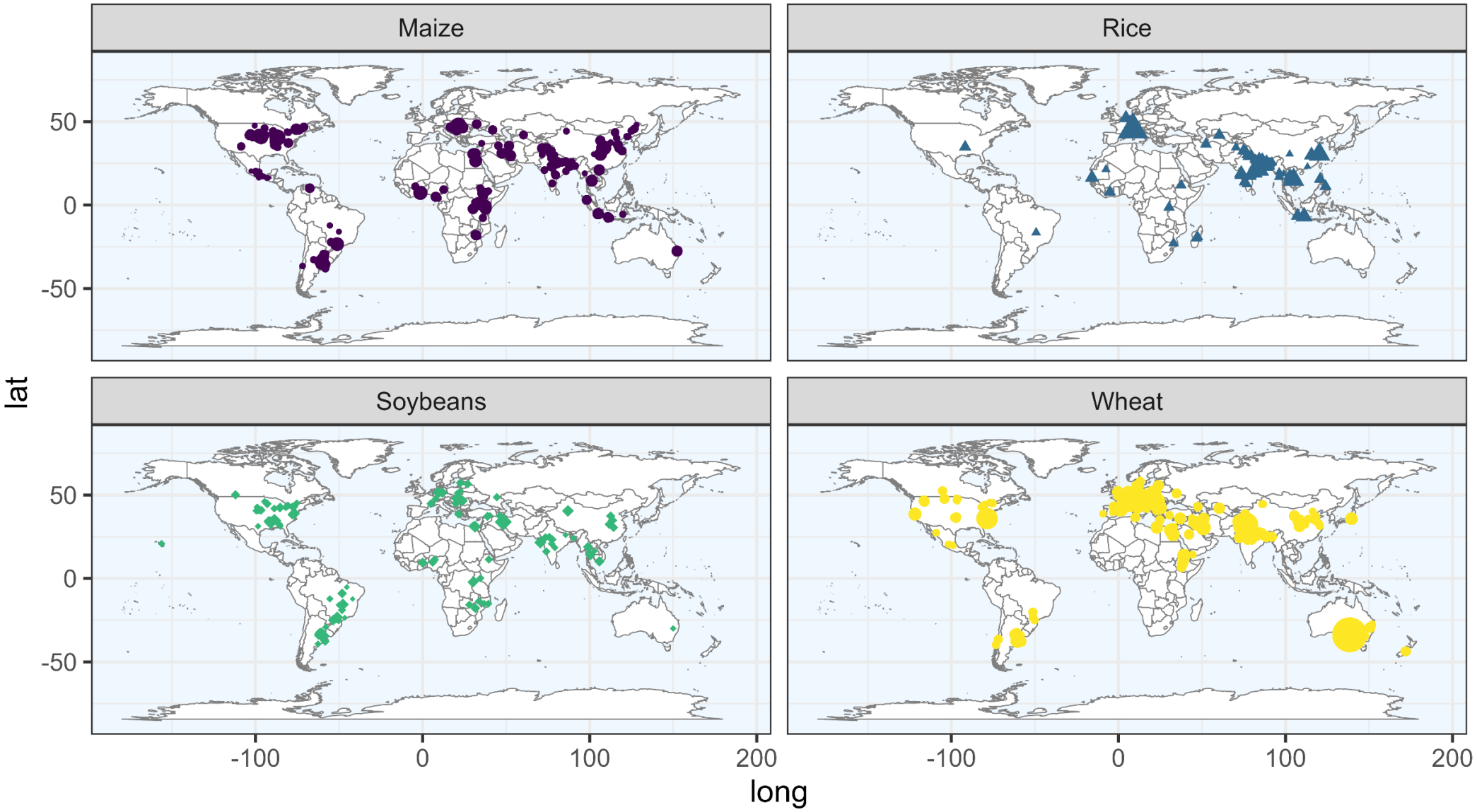
This list contains all your organization's projects and layout information. Each project consists of trials and their data.

Search

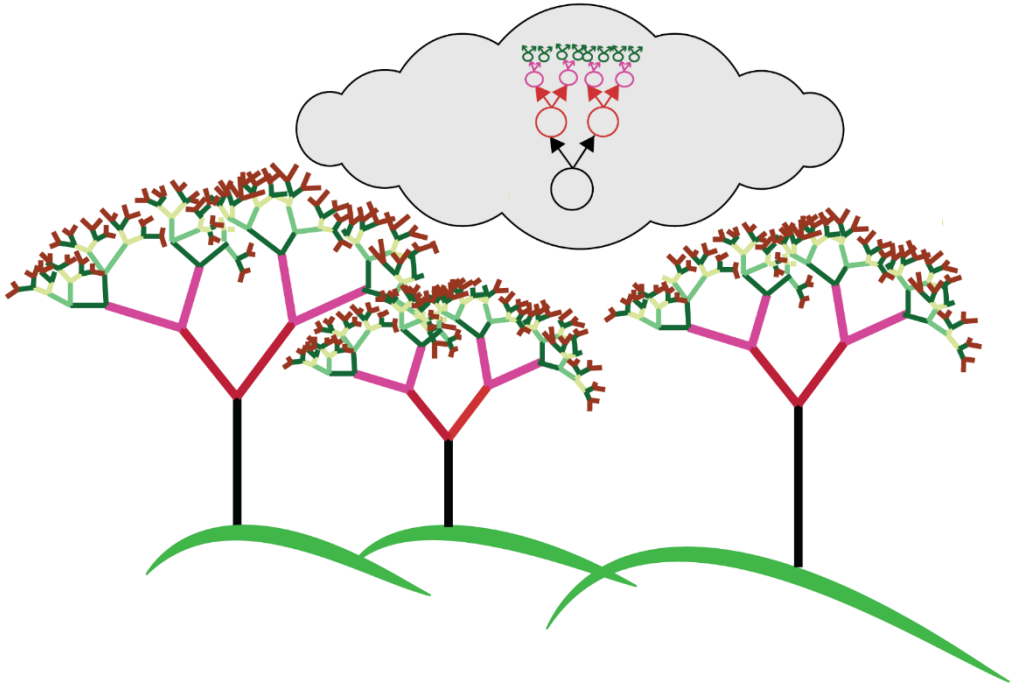
Project ID	Project name	Company	Trials
GCNRD002	Does the combined application of organic and mineral nutrient sources influence maize productivity? A me...	CPCN	361
GCNRD004-1	Fertilizer inputs, nutrient balance and soil nutrient-supplying power in intensive and irrigated rice systems	CPCN	139
GCNRD004-2	Fertilizer inputs, nutrient balance and soil nutrient-supplying power in intensive and irrigated rice systems	CPCN	12
GCNRD004-3	Evaluation of yield responses to various fertilizer applications and omisions in SSNM Maize	CPCN	4753
GCNRD004-4	Evaluation of yield responses to various fertilizer applications and omisions in SSNM Rice	CPCN	332


Insights - Agronomic Data Analytics
insights.live.agmatix.com/add-workspace
Insights
Workspaces
Data
Map
Search
Hide empty p
Project
Field Ar
Trial's A
Trial En
Treatme
Row ID
Sub Plo
Sub Sub
Plot Area [ha]
11832
G
Undo
Add widget
GUARDS Origin
ID
Name
Description
Measurement Unit
Classification
1.1.4.10
Field Area
This refers to the extent or measurement of a surface or piece of land, such as a field.
[Hectare]
CONCEPT
1 Research Definitions
1.1 Field of Study
This is a branch of knowledge, taught and researched as part of higher education.
1.1.4 Trial
This unique experimental design has static and dynamic parameters. It is the process of introducing or monitoring an intervention and studying the effects.
1.1.4.10 Field Area
This refers to the extent or measurement of a surface or piece of land, such as a field.
Done

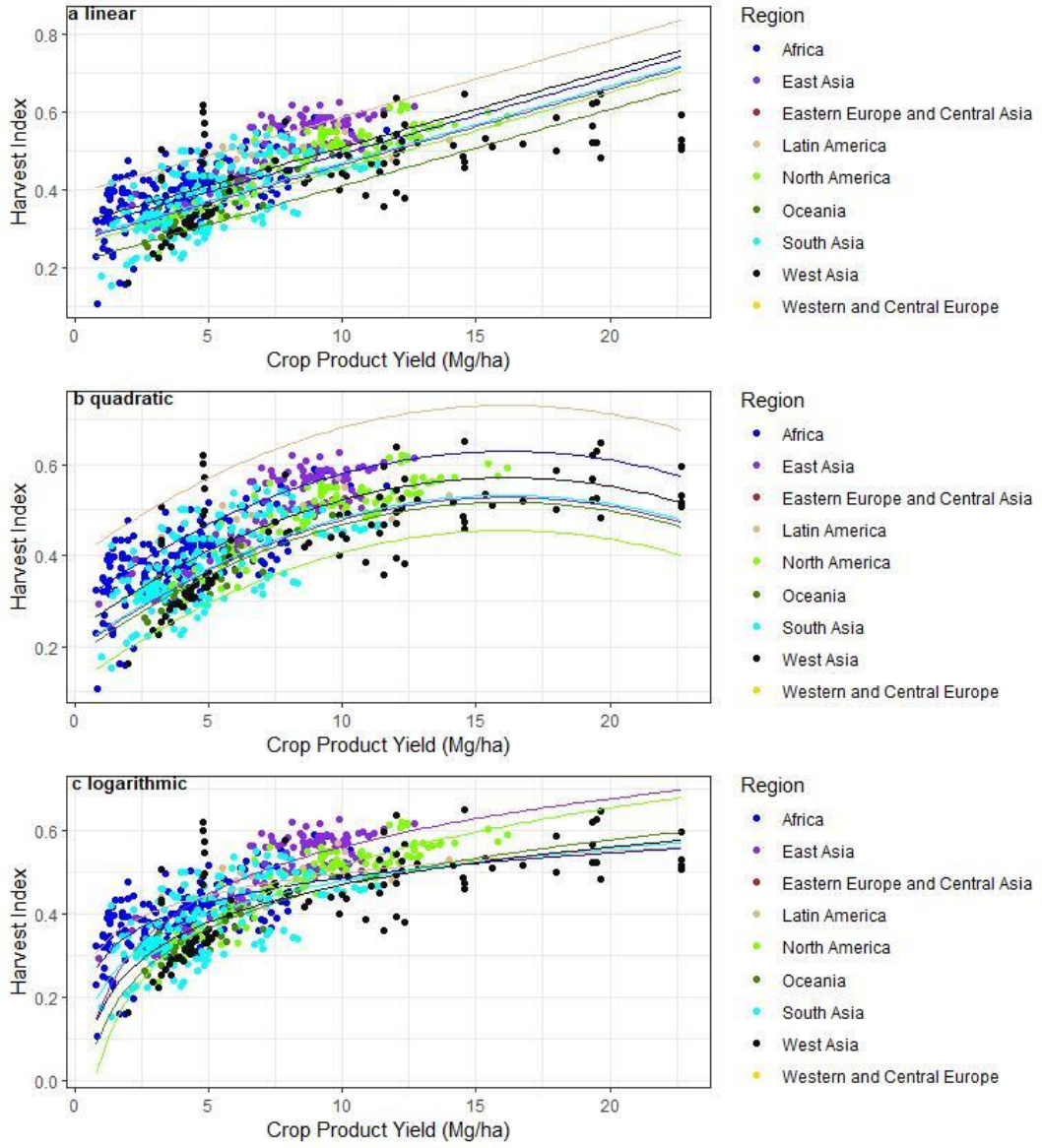
We now have data from a wide range of countries



Random forest models



Mixed-effects regression models



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We used variables that were widely available (globally) in our prediction models

-Crop product yield

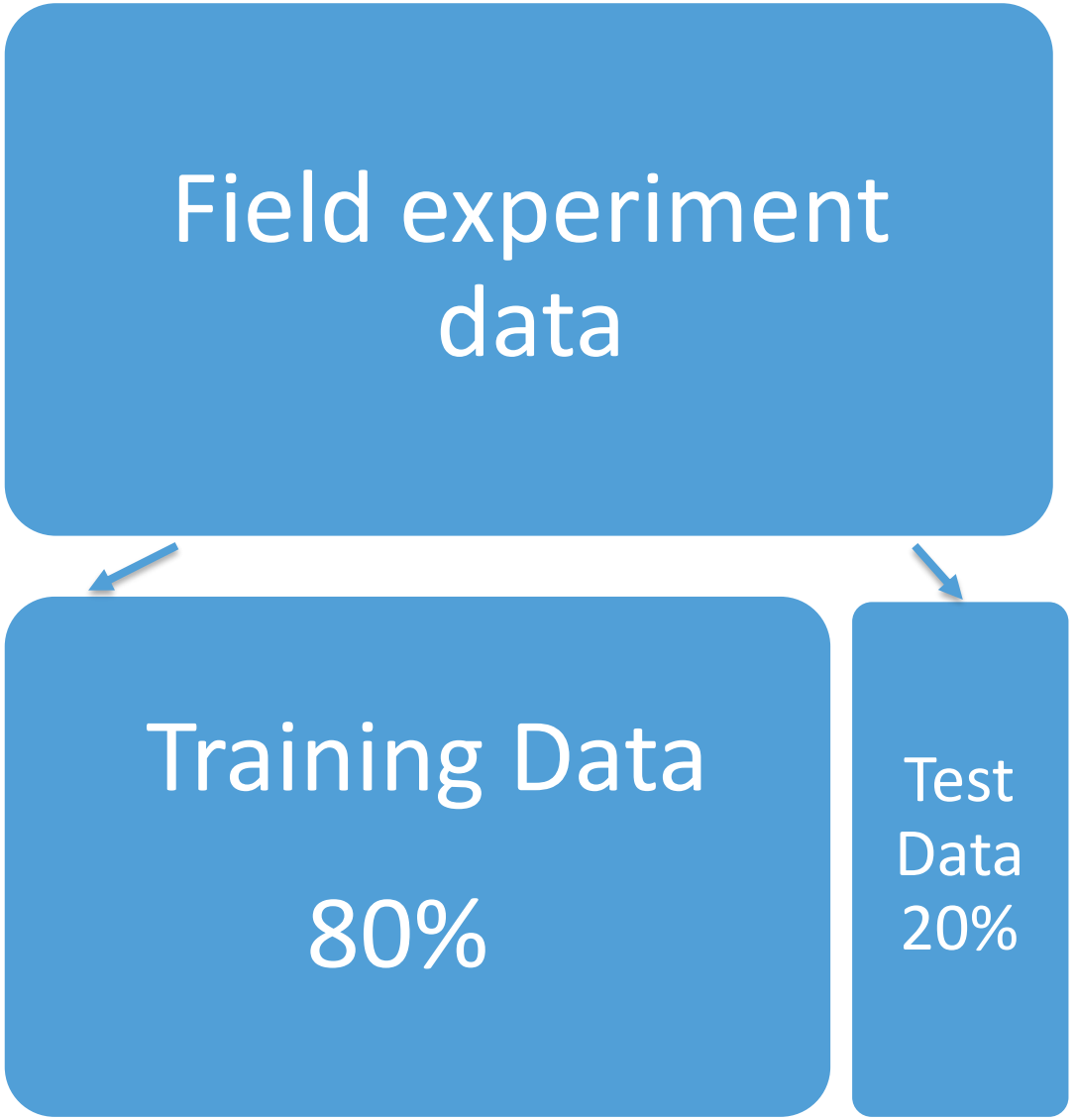
-Fertilizer application

-Yield potential

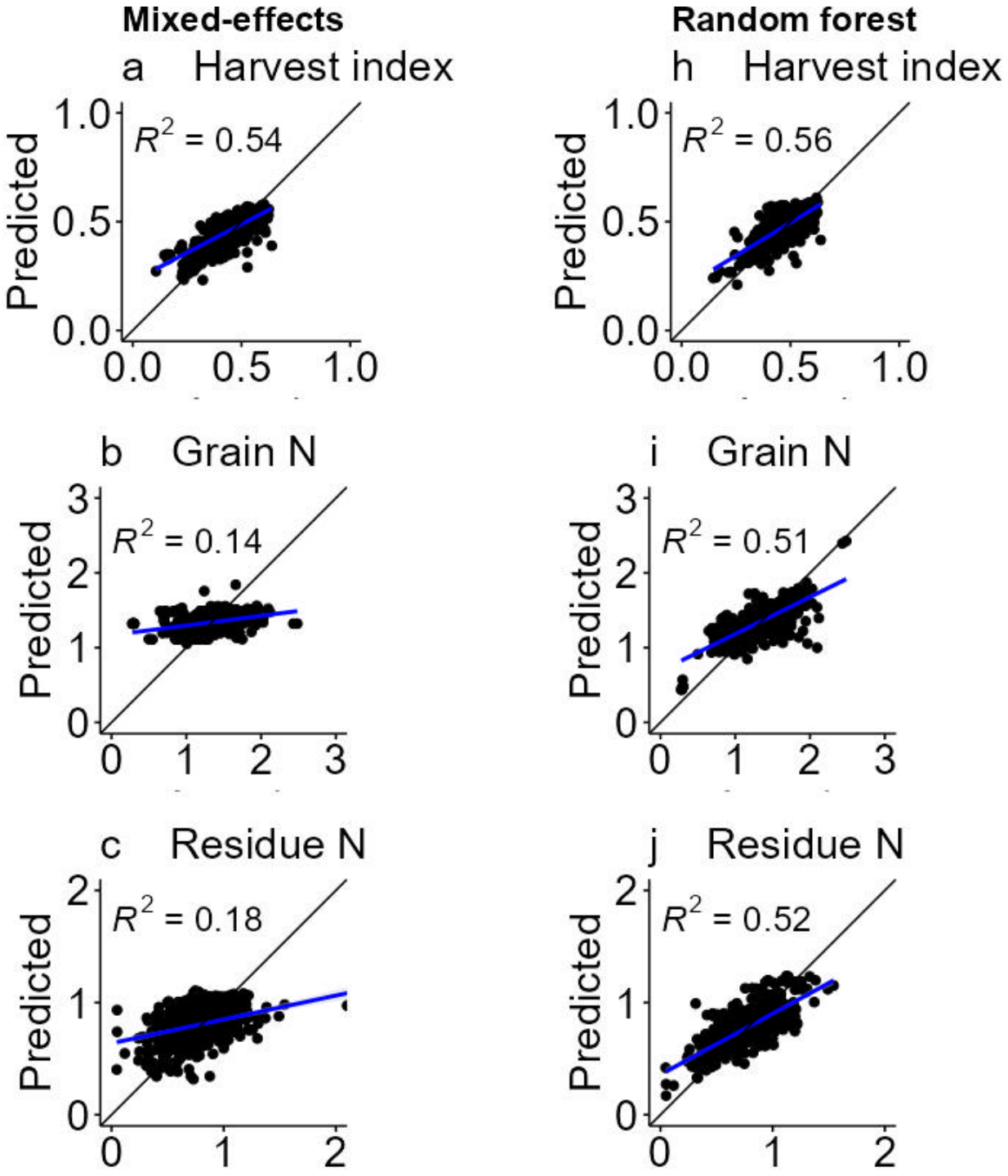
-Location

Models to predict

- **Nutrient in grain and stover**
- **Harvest index**



Best models selected based on prediction accuracy and biological rationale.



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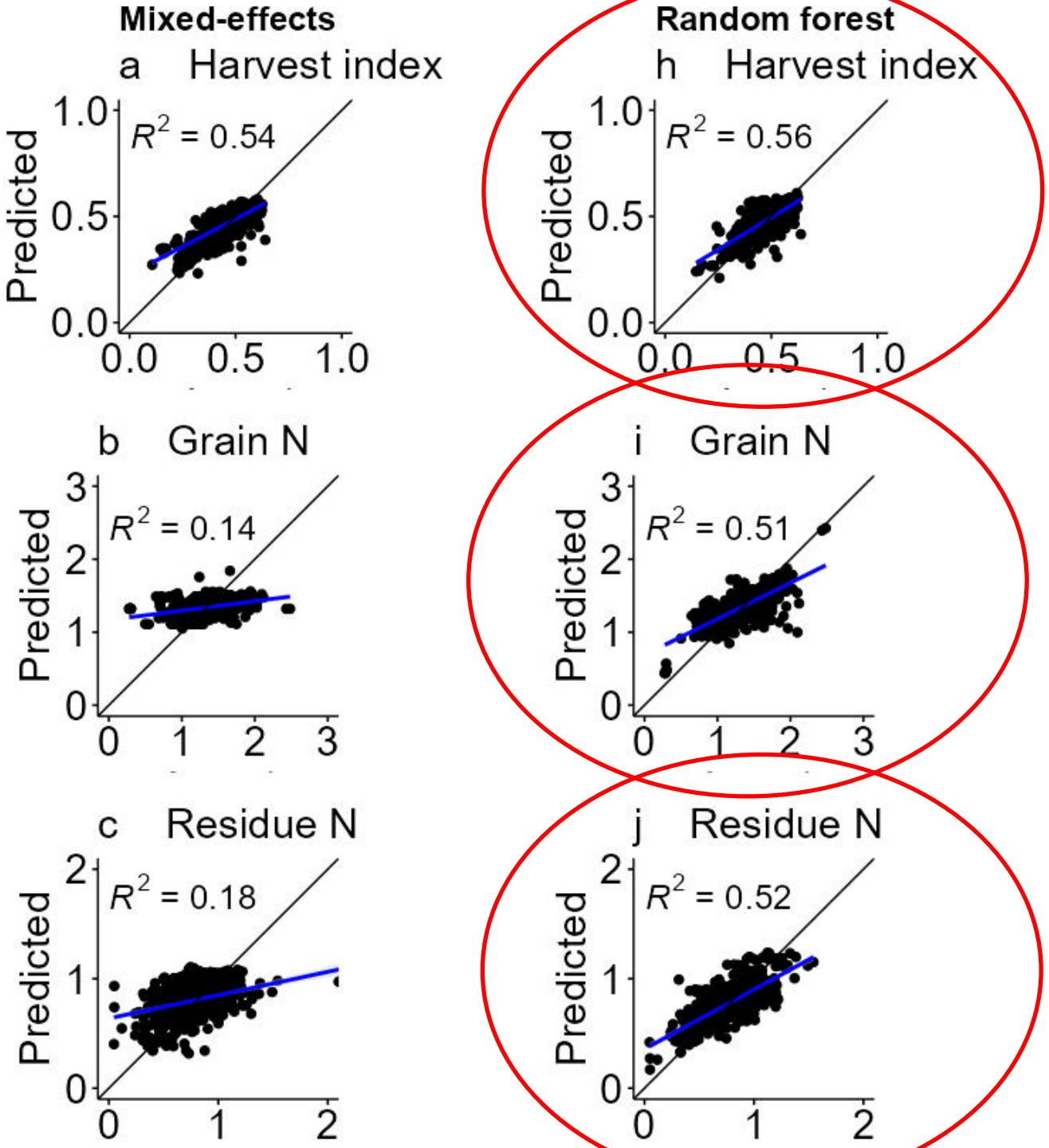
Best models selected based on prediction accuracy and biological rationale.



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Maize nutrient removal estimates

Country	Tier	Nutrient removal kg ha^{-1} $year^{-1}$ (percentage difference versus Tier 1 are in parentheses)		
		Nitrogen	Phosphorus	Potassium
Argentina	1	124	27	87
	3	105 (-15%)	20 (-26%)	89 (2%)
Brazil	1	93	20	66
	3	78 (-16%)	16 (-20%)	79 (21%)
China	1	118	25	98
	3	123 (5%)	19 (-24%)	47 (-52%)
India	1	50	11	36
	3	46 (-7%)	16 (52%)	29 (-19%)
USA	1	135	30	50
	3	125 (-8%)	25 (-15%)	49 (-1%)

Maize nutrient removal estimates-typically lower when using Tier 3

Country	Tier	Nutrient removal kg ha^{-1} $year^{-1}$ (percentage difference versus Tier 1 are in parentheses)		
		Nitrogen	Phosphorus	Potassium
Argentina	1	124	27	87
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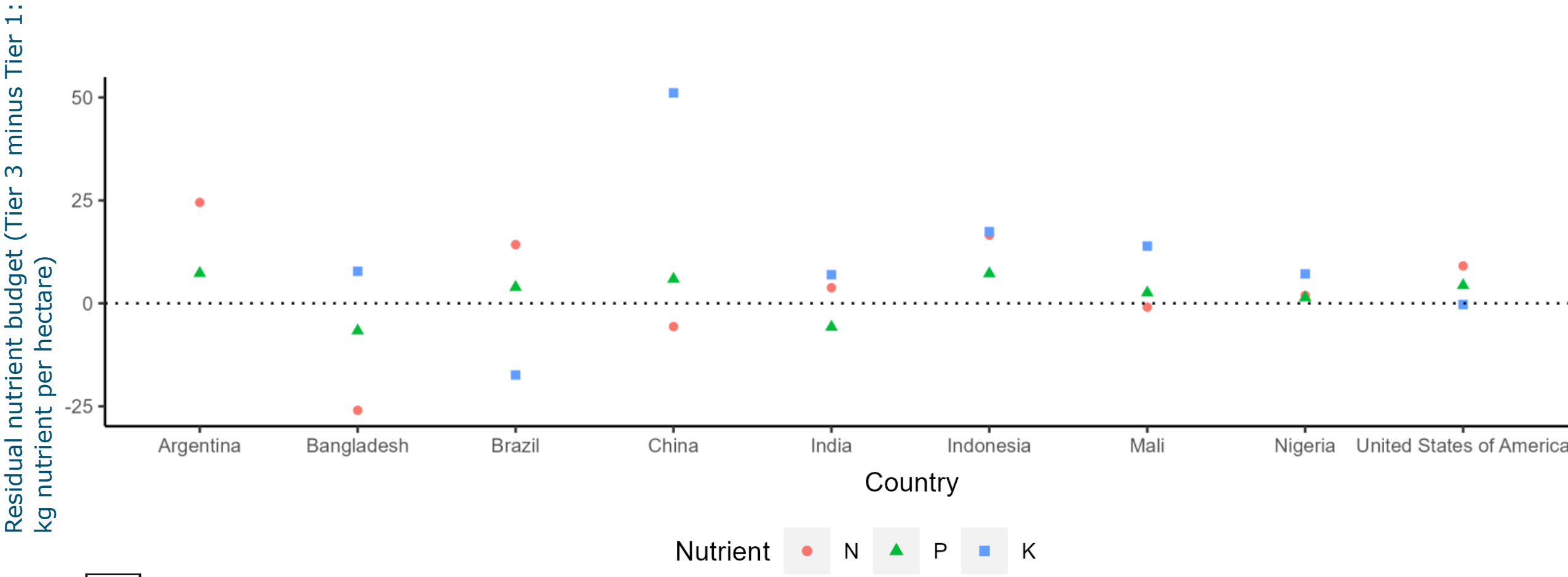
USA	1	135	30	50
	3	125 (-8%)	25 (-15%)	49 (-1%)

Why is Tier 3 maize nutrient removal less than Tier 1?

Tier 1 typically from Northern American ‘high nutrient input’ experiments

Tier 3 tended to have greater maize nutrient budget surpluses (>0 kg nutrient per hectare difference)



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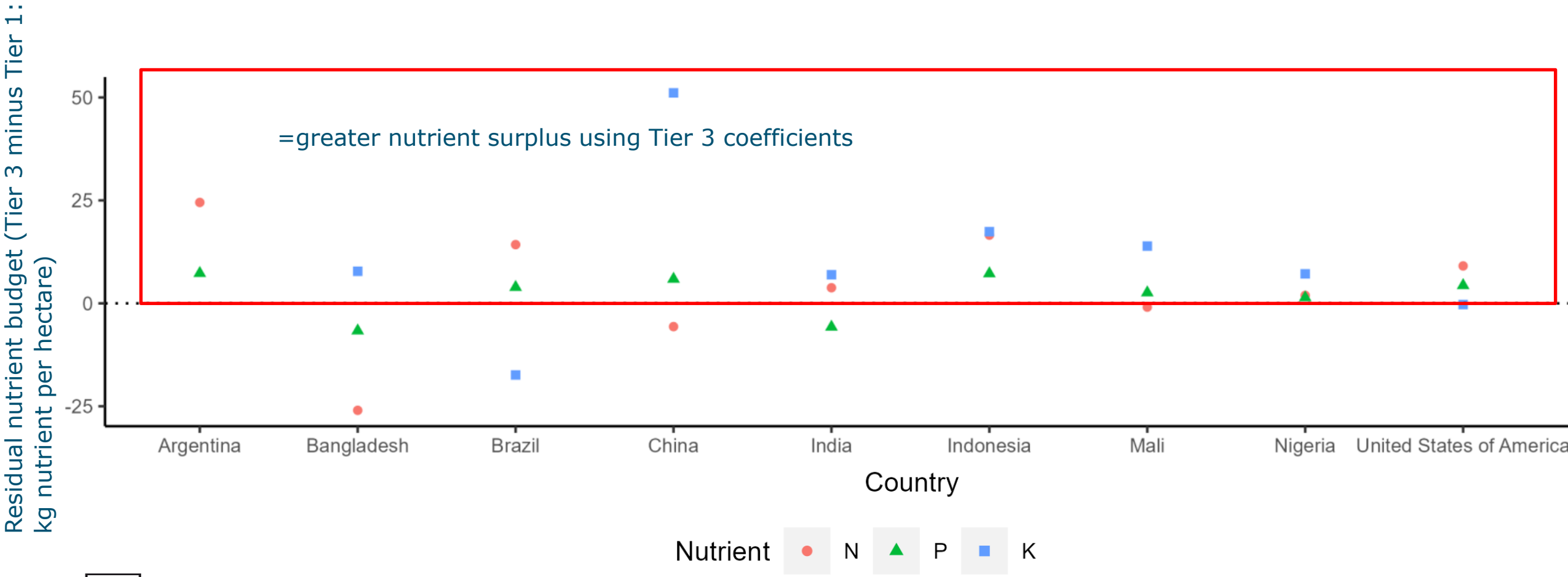
Tier 3 tended to have greater maize nutrient budget surpluses (>0 kg nutrient per hectare difference)



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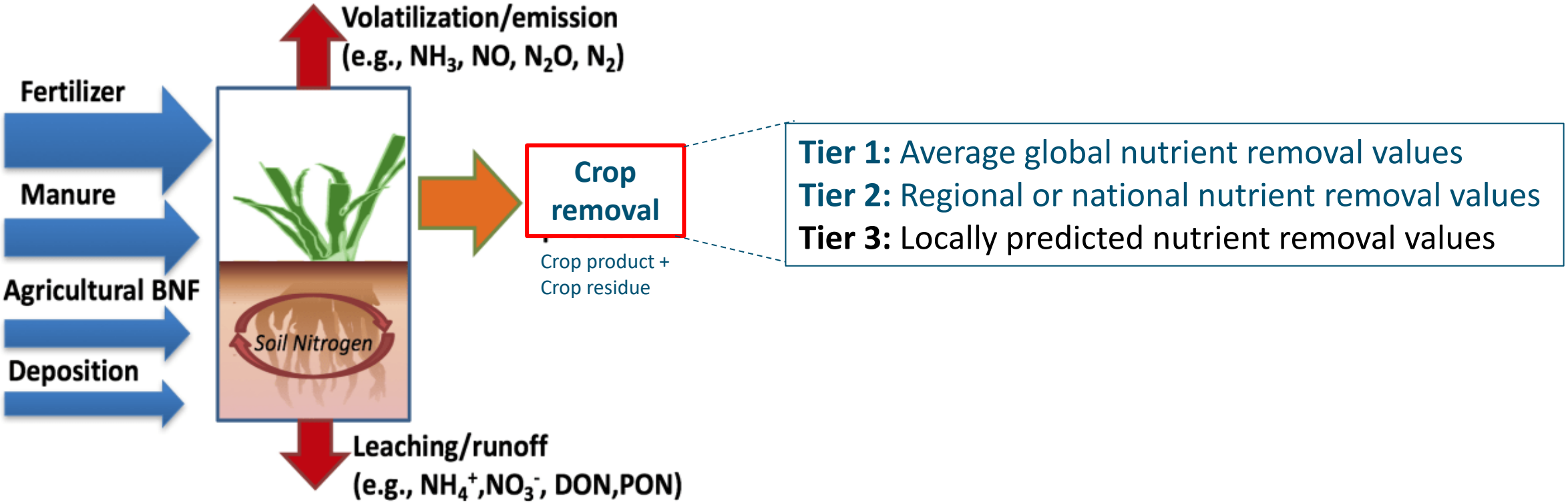
Conclusion

Tier 3 estimates indicate greater maize nutrient budget surpluses than Tier 1

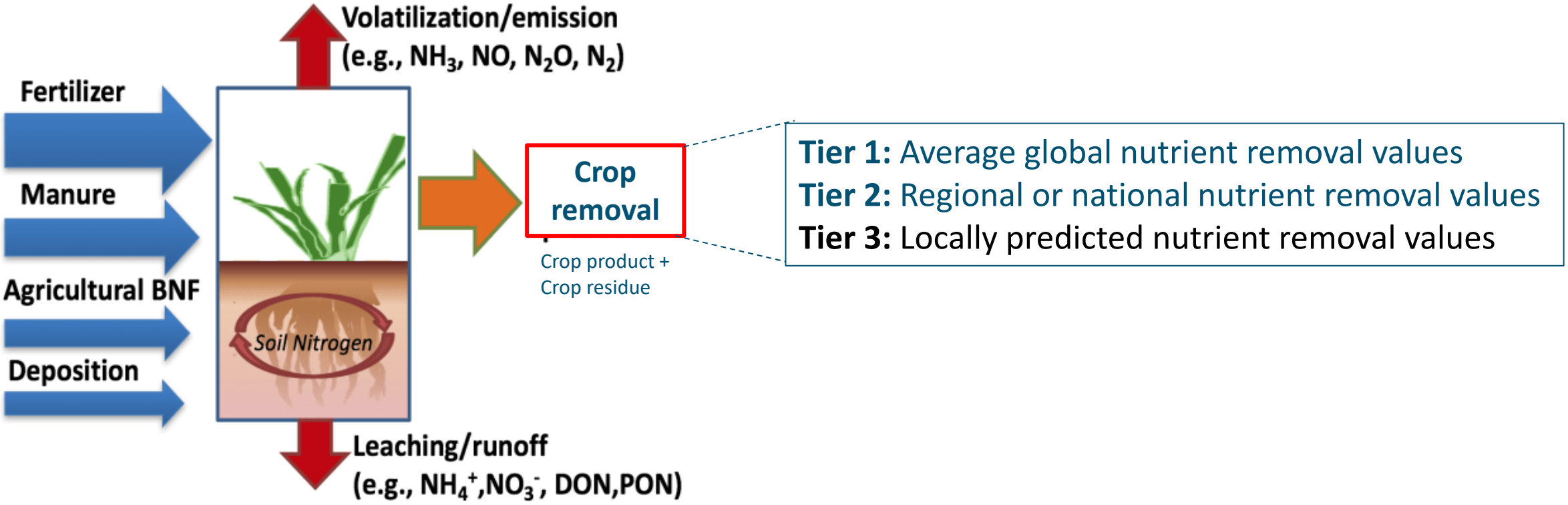
Models show promise to improve estimates of crop nutrient removal for nutrient budgets. e.g. FAO Cropland Nutrient Budget (which currently use Tier 1 assumptions)



Conclusion

Before we apply our models for use in global databases we need to test against on-farm data

We also need to incorporate more data from literature into Tier 1 and 2 estimates



Convince people to share data (time/legal)

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Ambiguities in datasets

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On-farm data hard to find for evaluation

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On-farm data hard to find for evaluation

Ensure database/code are readily updatable

Convince people to share data (time/legal)

Ambiguities in datasets

On-farm data hard to find for evaluation

Ensure database/code are readily updatable

Long term investment

Contributors

>60 contributors so far from >40 organisations

Organisations:

Rothamsted UK, Uni New England-Australia, CGIAR/World Agroforestry Centre, University of Hohenheim, University of Nebraska-Lincoln, Georg-August-University Göttingen, CSBP Ltd Australia, IPNI, ZALF Lepizig, Anglo American, SRUC Scotland, AfricaRice, Uni Zimbabwe/Uni Montpellier, CIRAD, Aarhus Uni Denmark, Debark Uni Ethiopia, Purdue Uni USA, ARS USDA, Hohenheim Uni Germany, Research Institute of Organic Agriculture (FiBL), Uni of Paris-Saclay, IRRI, Uni of Tehran Iran, Chiang Mai University Thailand, INTA Argentina, Nottingham Uni UK, Uni of Faisalabad Pakistan, Uni Belgrade Serbia, Kogi State Uni Nigeria, Michigan State Uni USA, SARDI Australia,RIT Rajaramnagar India, Universidad Nacional de Centro Beunos Aires Argentina, ADAS UK, Ente Nazionale Risi Italy, International Fertilizer Association, Wageningen University & Research, Uni Sydney Australia, Tribhuvan Uni Nepal, Uni Cambridge UK, Hassan II Uni of Casablanca Morocco, Selale Uni Ethiopia, FAR NZ, Thuenen Institute of Agricultural Technology Germany, Maize Research Institute Serbia.

>80 who have promised to share data:

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Global Crop Nutrient Removal Database team members: Renske Hijbeek, Marloes van Loon, Martin van Ittersum (Wageningen University & Research), Scott Murrell (African Plant Nutrition Institute), Achim Dobermann (International Fertilizer Association).

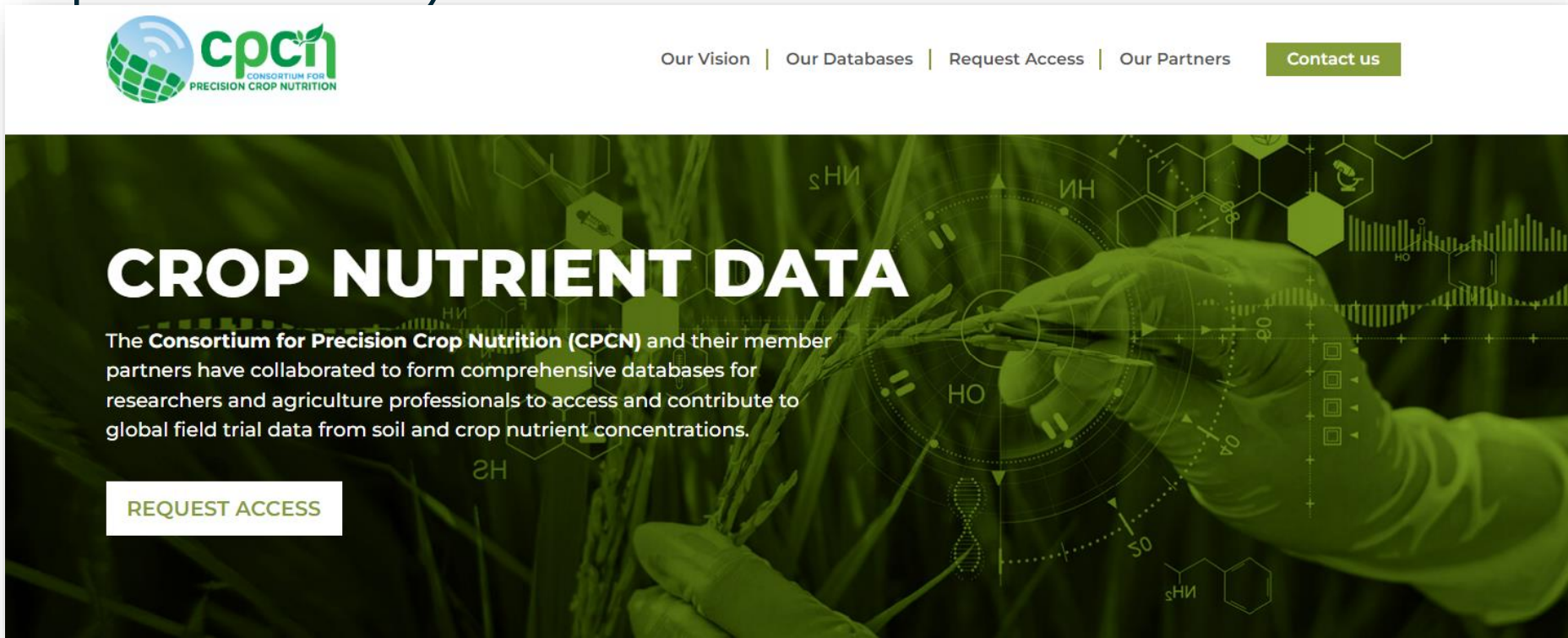
Funding for Global Crop Nutrient Removal Database project: International Fertilizer Association

We need more field experiment and on-farm data to evaluate models. Want to share your data?

Cameron.ludemann@wur.nl

www.cropnutrientdata.net

(free access to field experiment data)



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