University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
APPALACHIAN LABORATORY

INI 2020
8th GLOBAL NITROGEN CONFERENCE
3rd – 7th MAY 2020 | BERLIN, GERMANY

SUSTAINABLE DEVELOPMENT GOALS

Current state of nitrogen around the world

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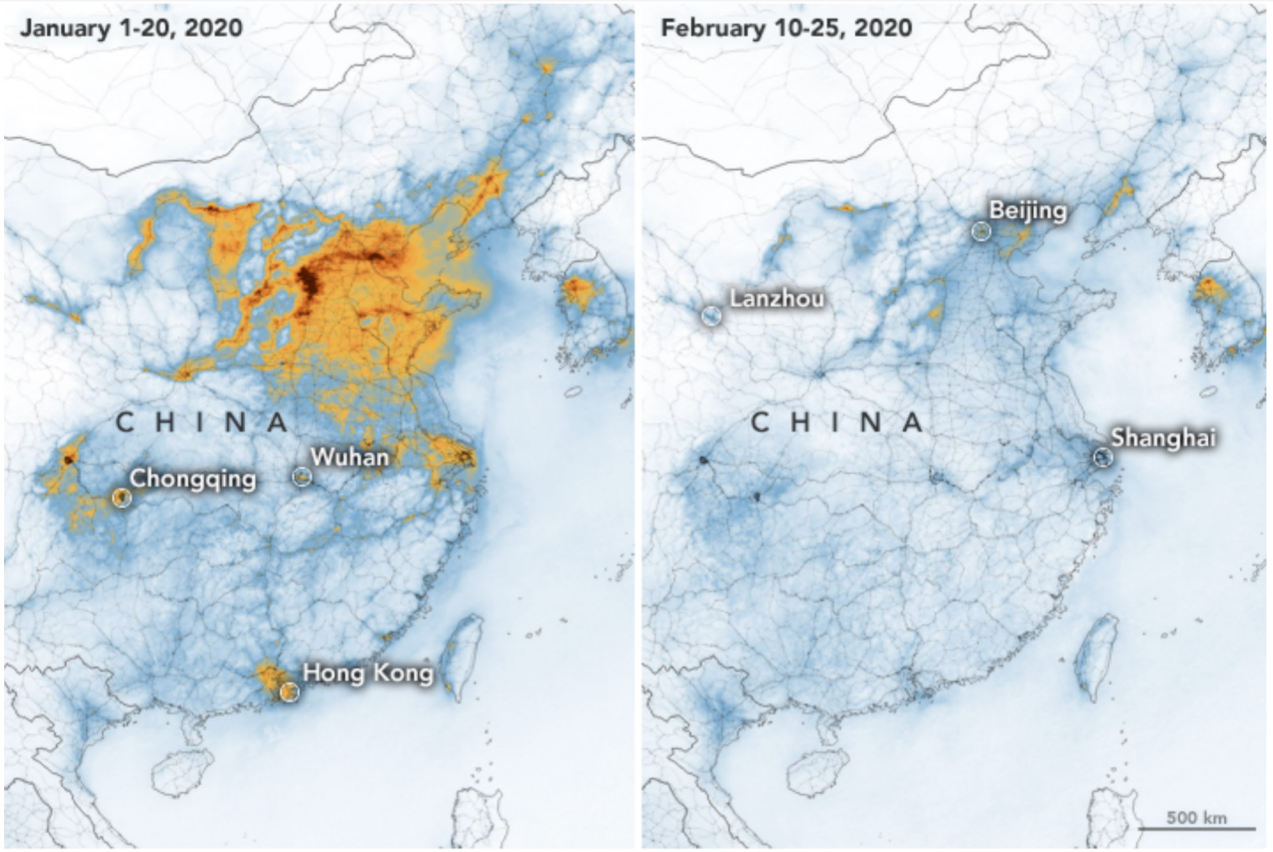
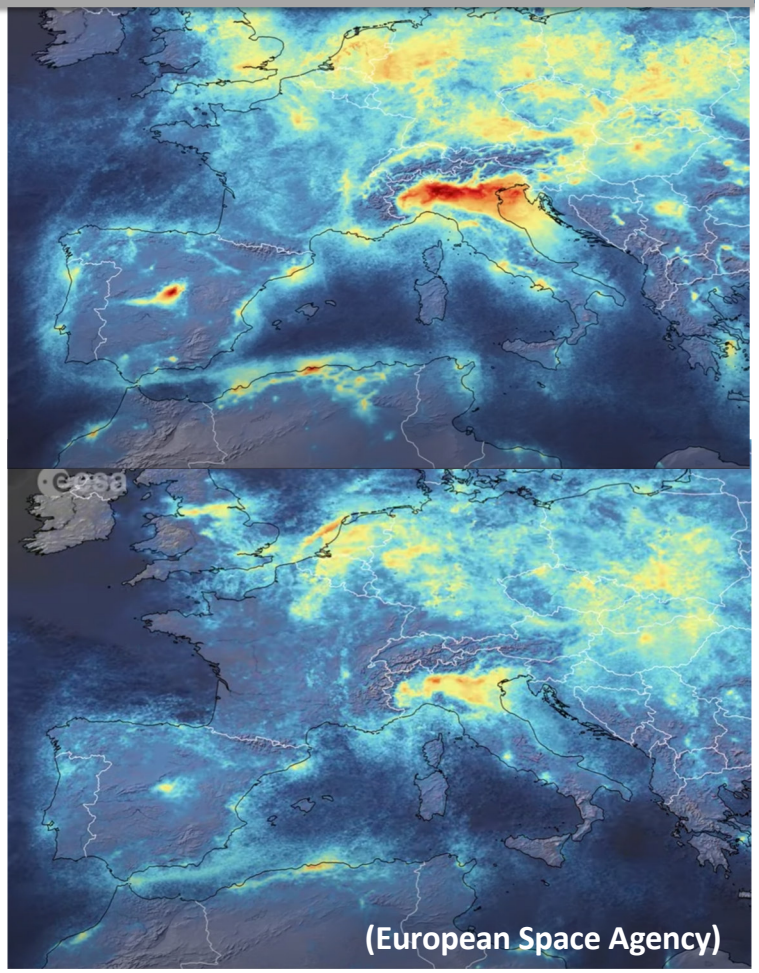
Appalachian Lab

NSF SESYNC OCP FAO NASA

Nitrogen pollution and the pandemic

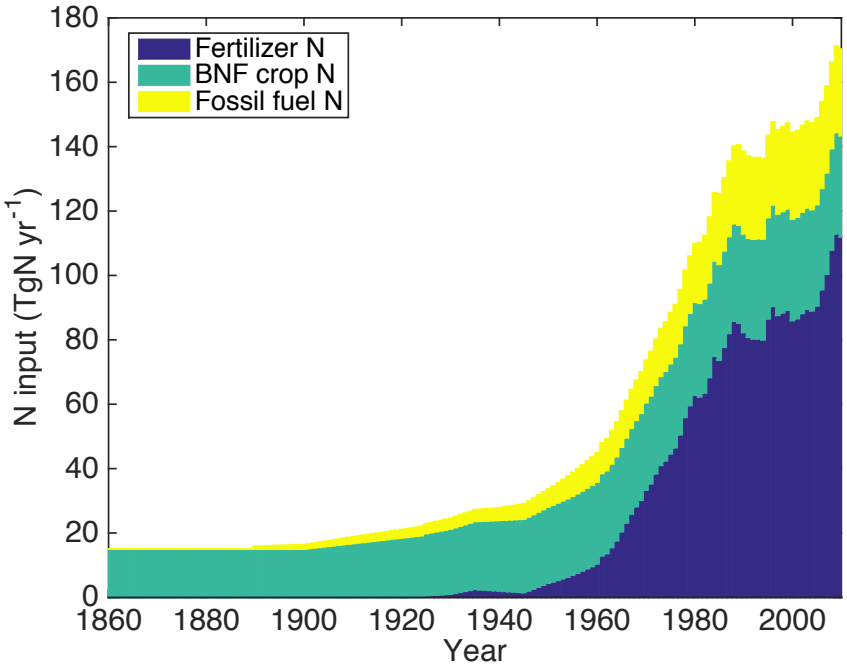


(NASA Earth Observatory)



(European Space Agency)

The Planet Overloaded with Nitrogen

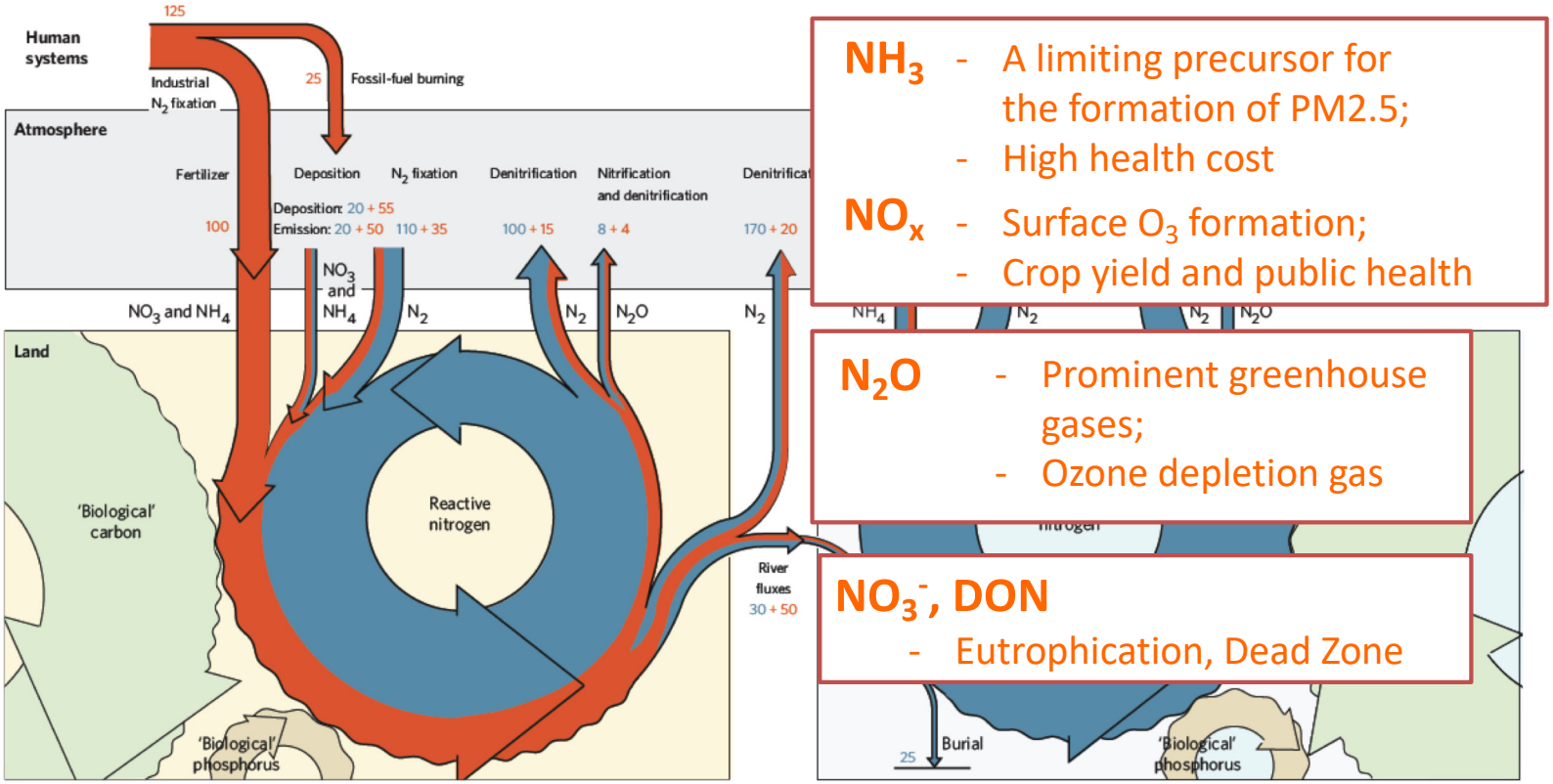


N fixation by ocean
(*Gruber & Galloway, 2008*)

N fixation by land
(natural habitat, *Gruber & Galloway, 2008*)

BNF: Biological Nitrogen Fixation
Data source : Oak Ridge National Laboratory

Nitrogen Flow in the Earth System



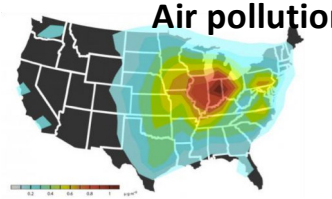
NH_3 - A limiting precursor for the formation of PM2.5;
- High health cost

NO_x - Surface O_3 formation;
- Crop yield and public health

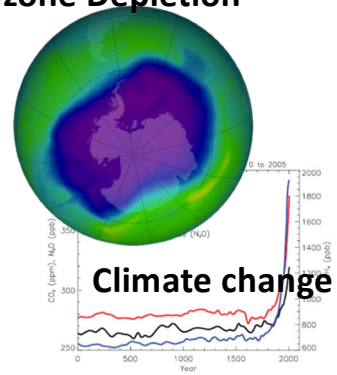
N_2O - Prominent greenhouse gases;
- Ozone depletion gas

NO_3^-, DON
- Eutrophication, Dead Zone

Air pollution



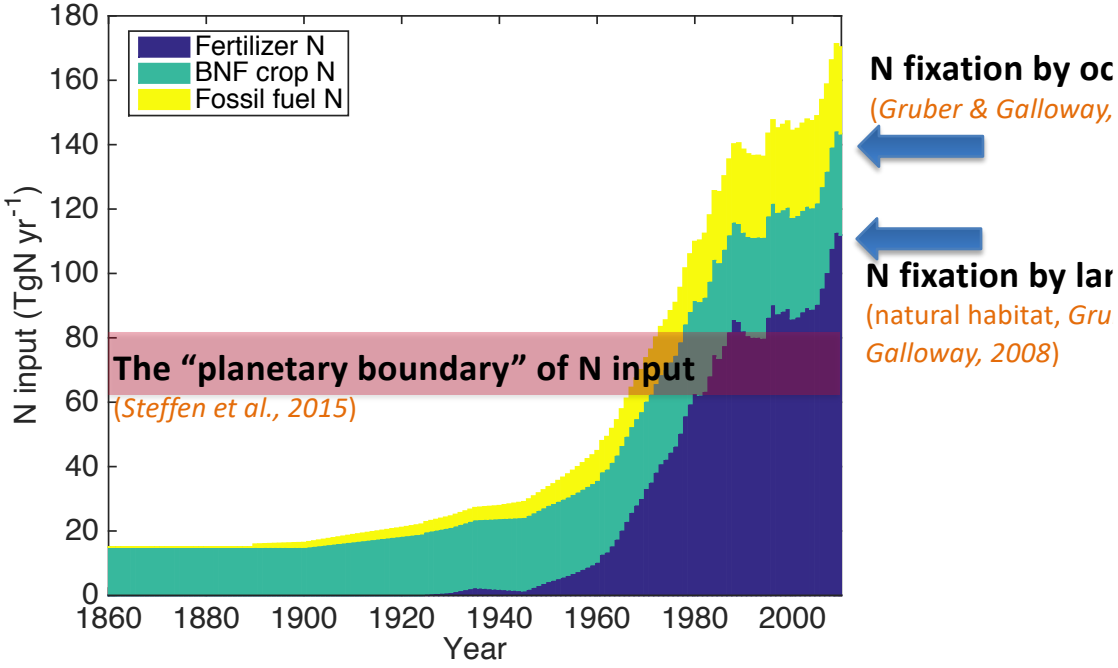
Ozone Depletion



Climate change

(Gruber & Galloway, 2008, *Nature)*

The Planet Overloaded with Nitrogen



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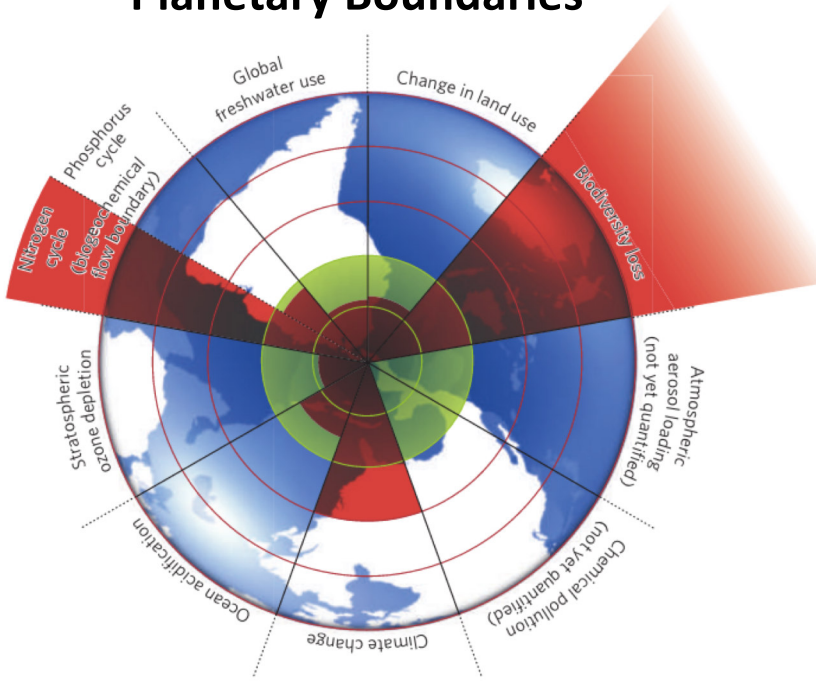
Planetary Boundaries



(Rockström *et al.*, 2009, *Nature*)

Too Much

Too Little

Too Much

added to the environment

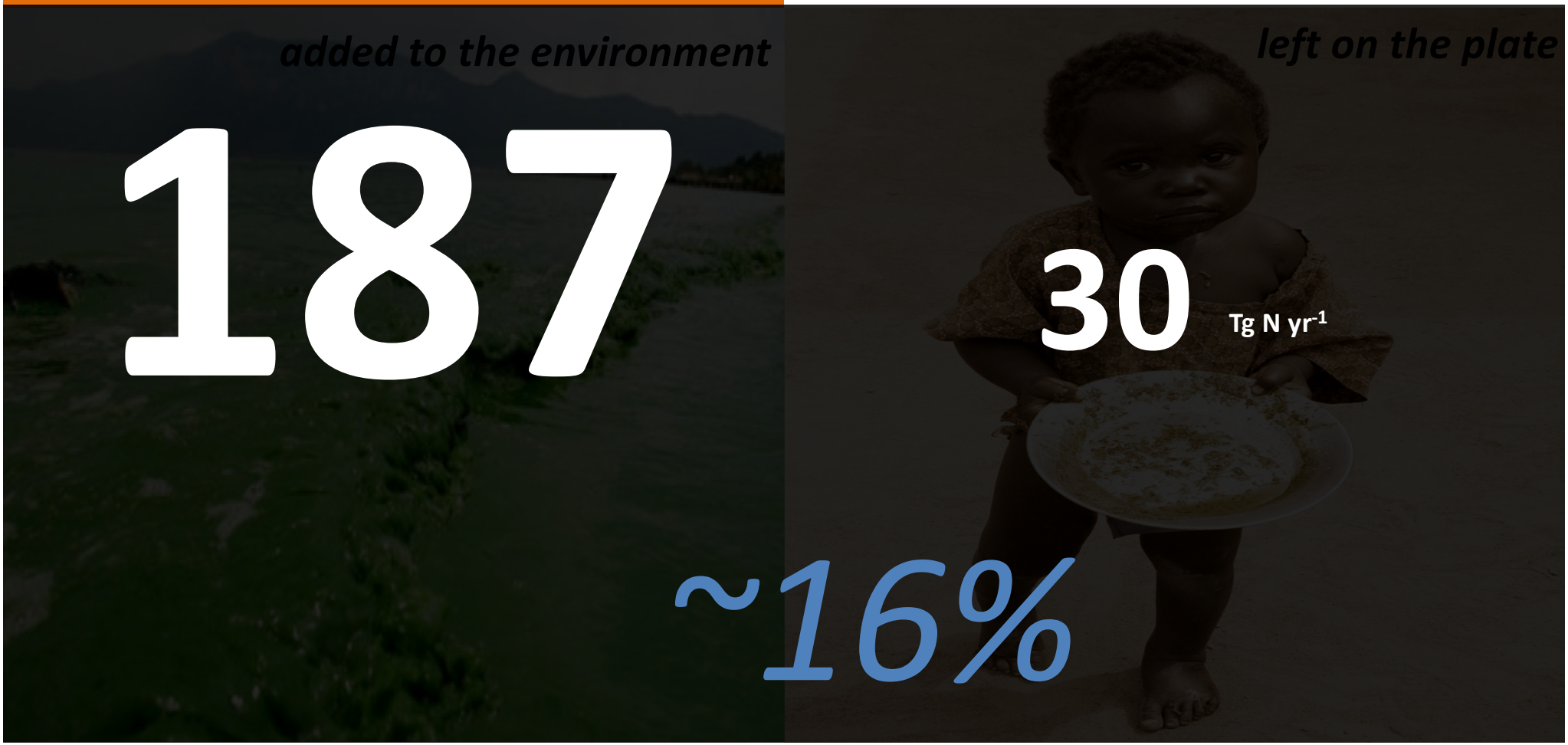
187

Too Little

left on the plate

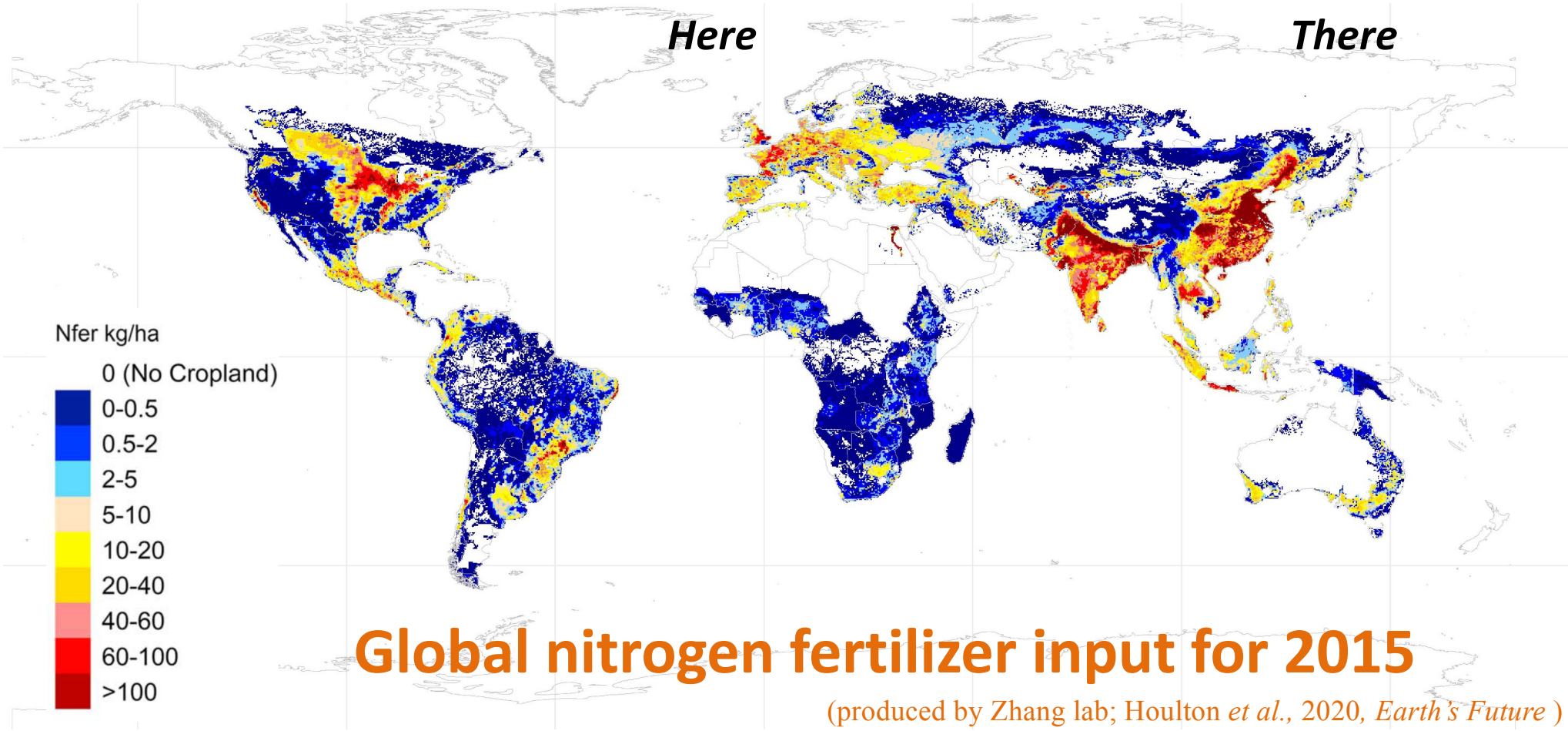
30 Tg N yr^{-1}

~16%



Too Much

Too Little

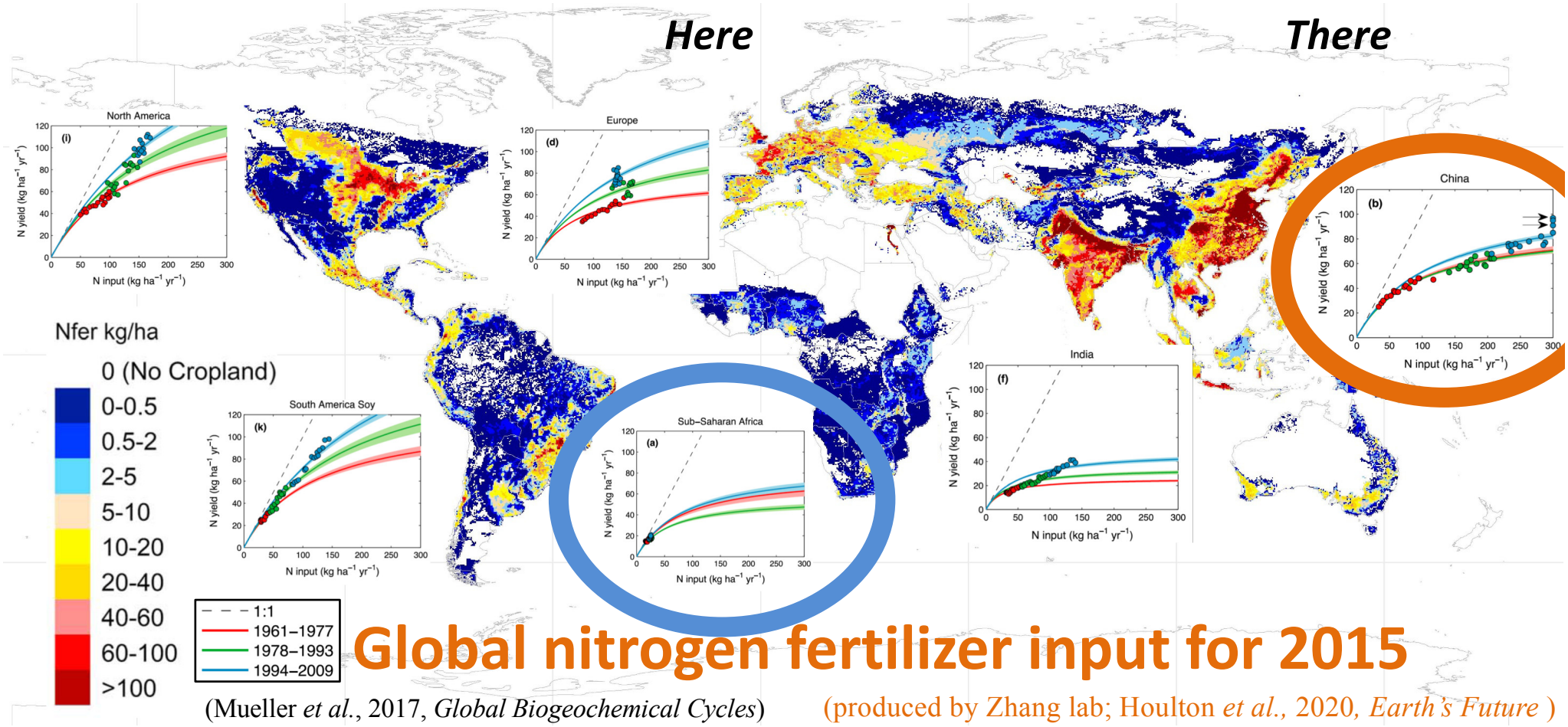


Global nitrogen fertilizer input for 2015

(produced by Zhang lab; Houlton *et al.*, 2020, *Earth's Future*)

Too Much

Too Little



Global nitrogen fertilizer input for 2015

(Mueller *et al.*, 2017, *Global Biogeochemical Cycles*)

(produced by Zhang lab; Houlton *et al.*, 2020, *Earth's Future*)

Too Much

Too Little

How to get it right?

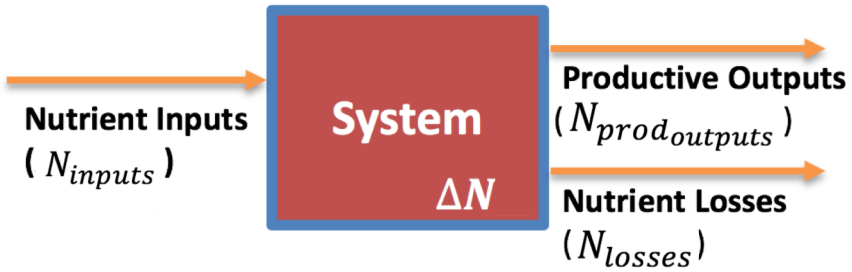
Nitrogen Use Efficiency

- How it is defined?
- How it has been changing?
- Challenges and opportunities?

Global nitrogen fertilizer input for 2015

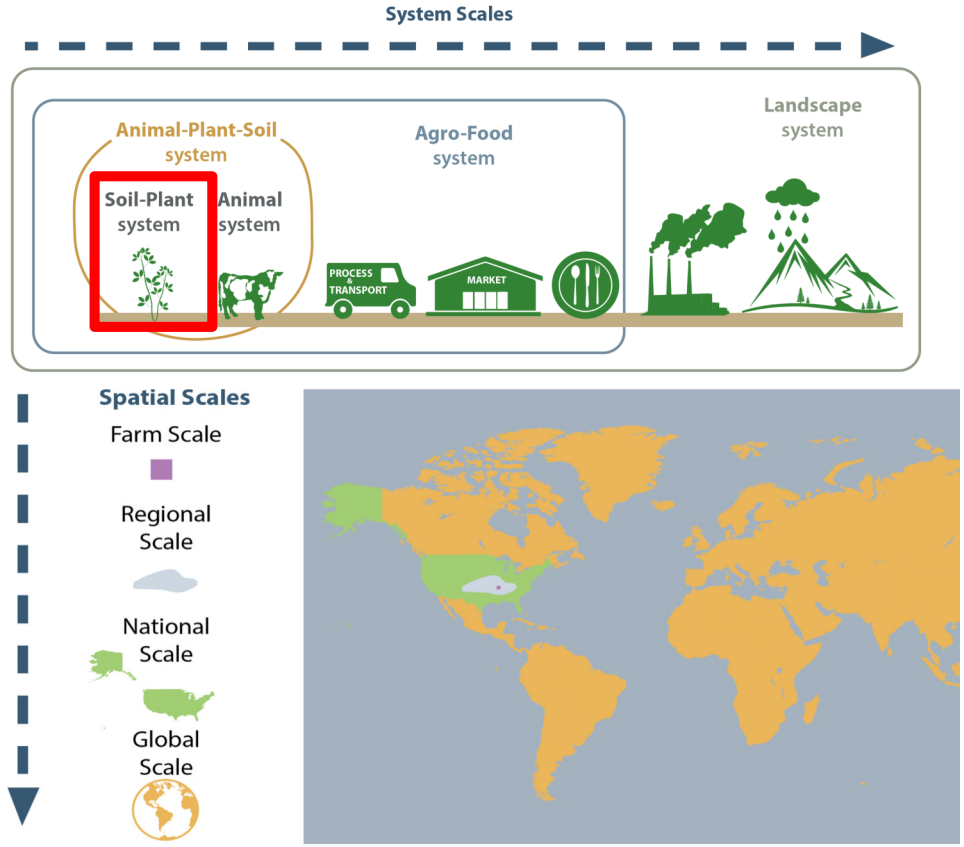
(produced by Zhang lab; Houlton et al., 2020, Earth's Future)

Nitrogen Use Efficiency



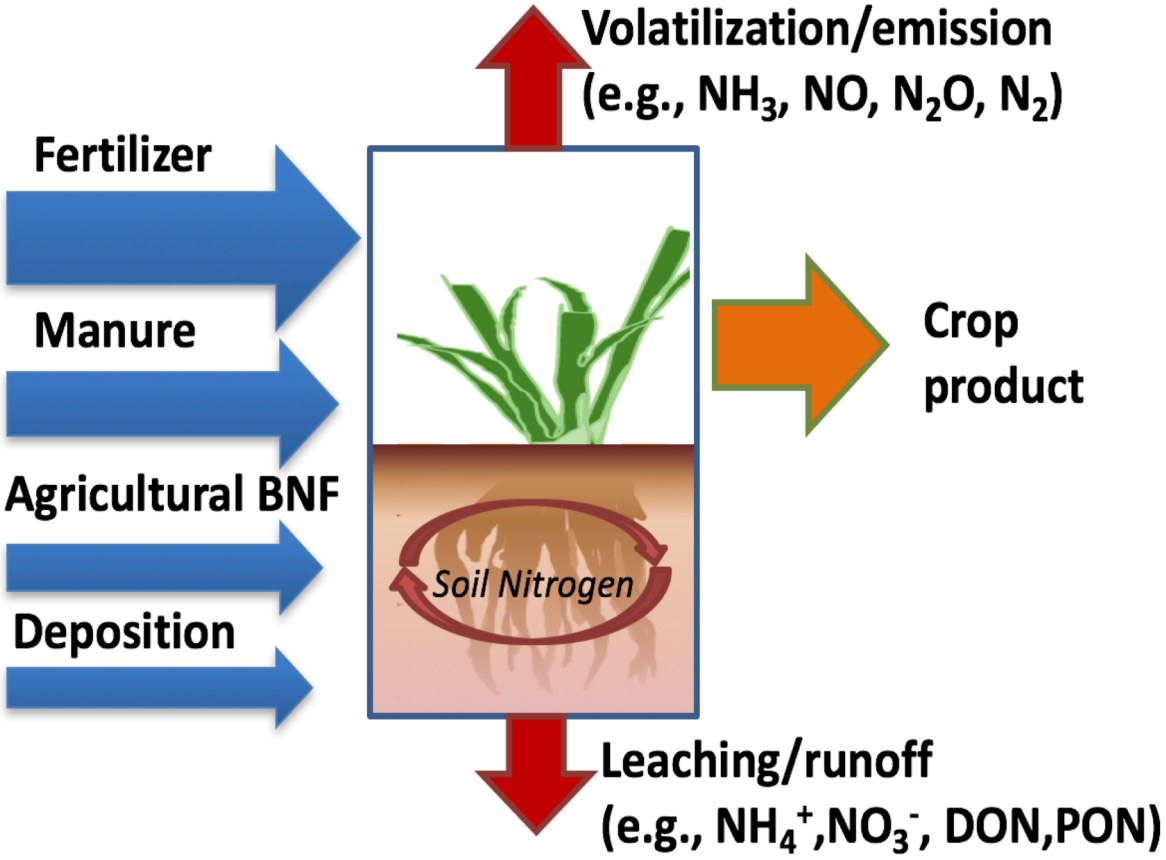
$$\boldsymbol{NUE} = N_{prod\_outputs}/N_{inputs}$$

$$\boldsymbol{NSur} = N_{inputs} - N_{prod_{outputs}} = N_{losses} + \Delta N$$



(Zhang *et al.*, 2020, Global Biogeochemical Cycles)

Nitrogen Use Efficiency for Crop production

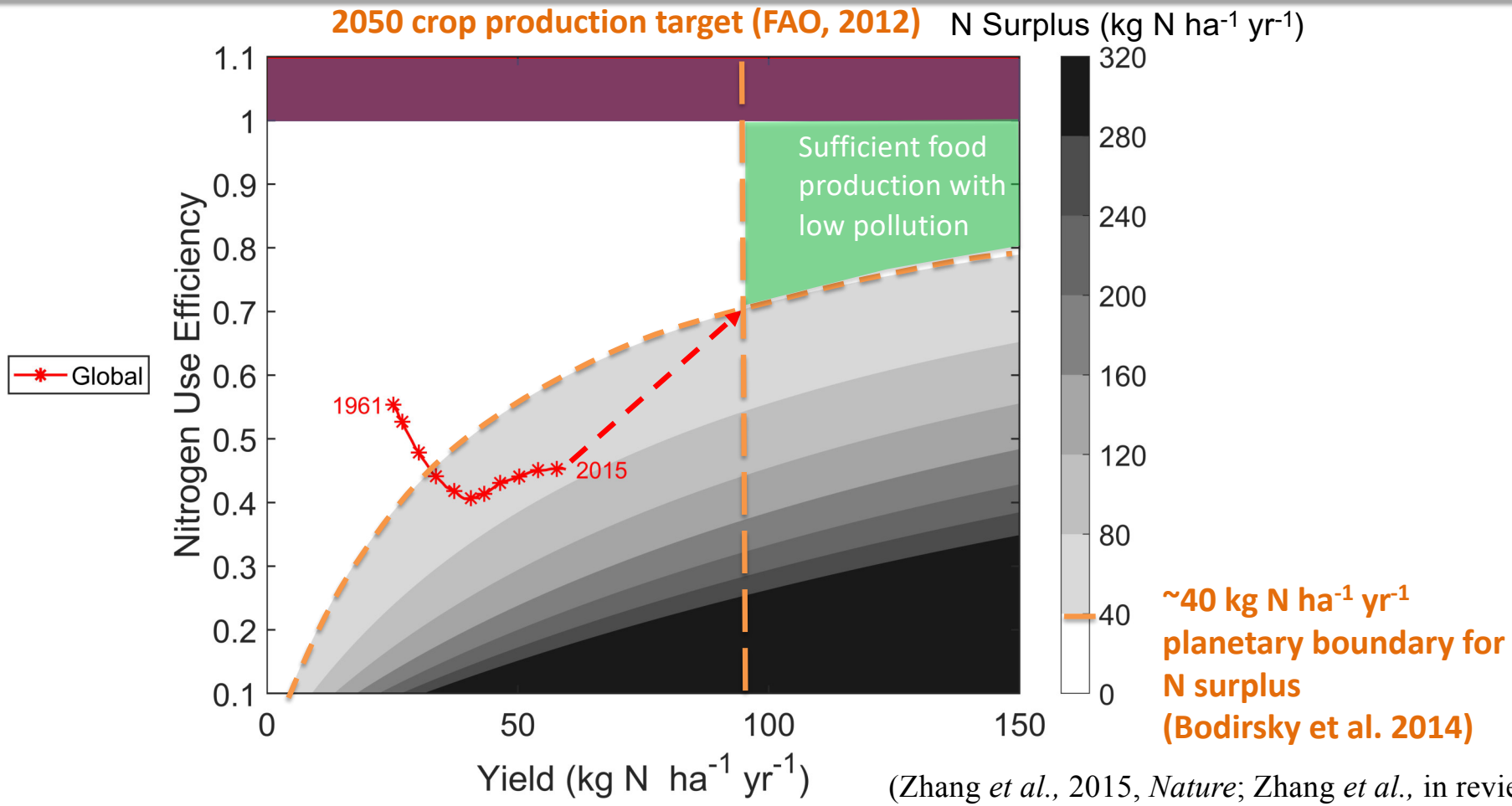


$$NUE = \frac{\text{Harvested Nitrogen}}{\text{Nitrogen input}}$$

$$N\ surplus = \text{Nitrogen input} - \text{Harvested Nitrogen}$$

(Zhang *et al.*, 2015, *Nature*)

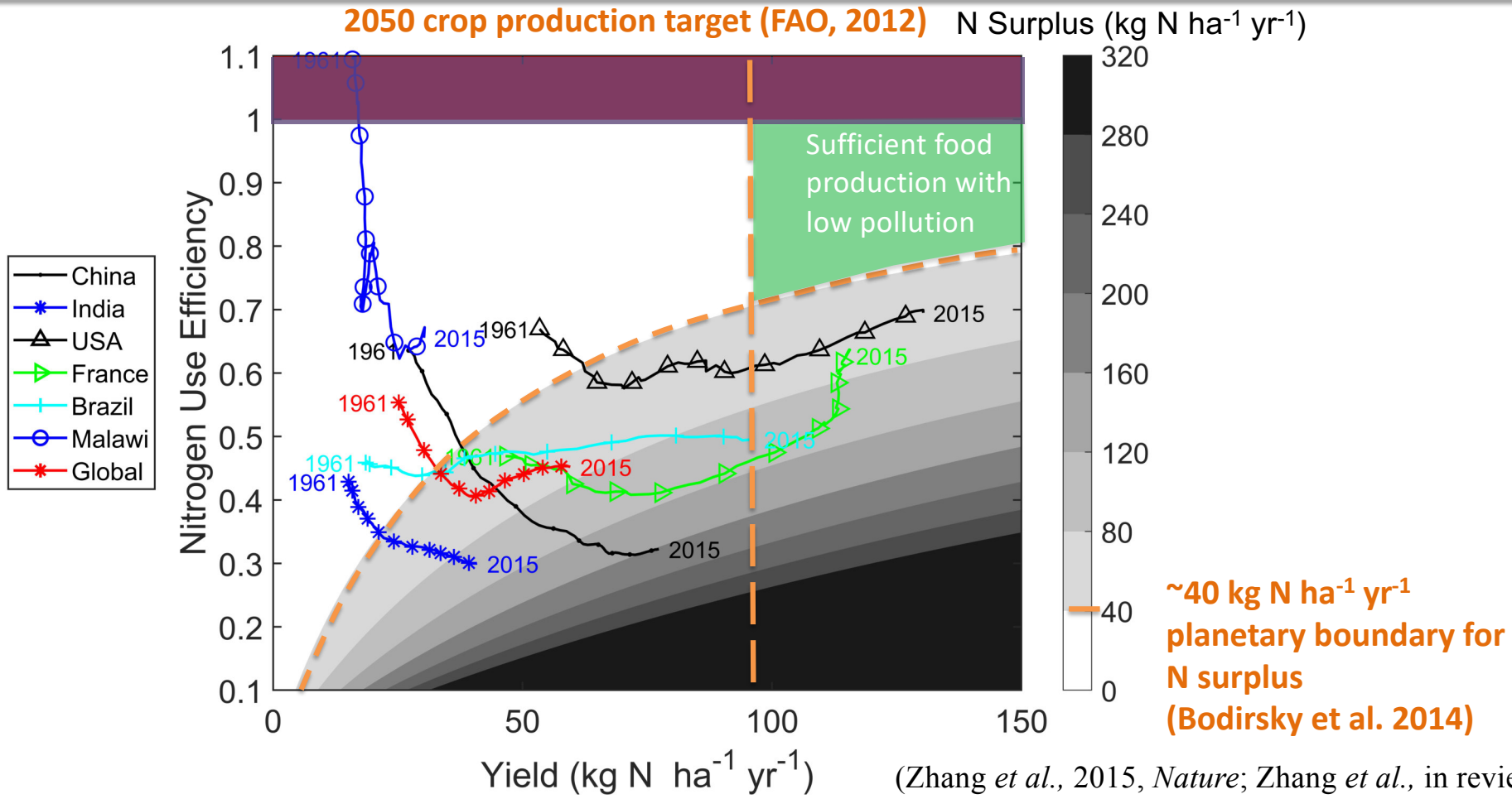
NUE Trend for crop production



~40 kg N ha^{-1} yr^{-1} planetary boundary for N surplus (Bodirsky et al. 2014)

(Zhang *et al.*, 2015, *Nature*; Zhang *et al.*, in review)

NUE Trend for crop production



~40 kg N ha^{-1} yr^{-1} planetary boundary for N surplus (Bodirsky et al. 2014)

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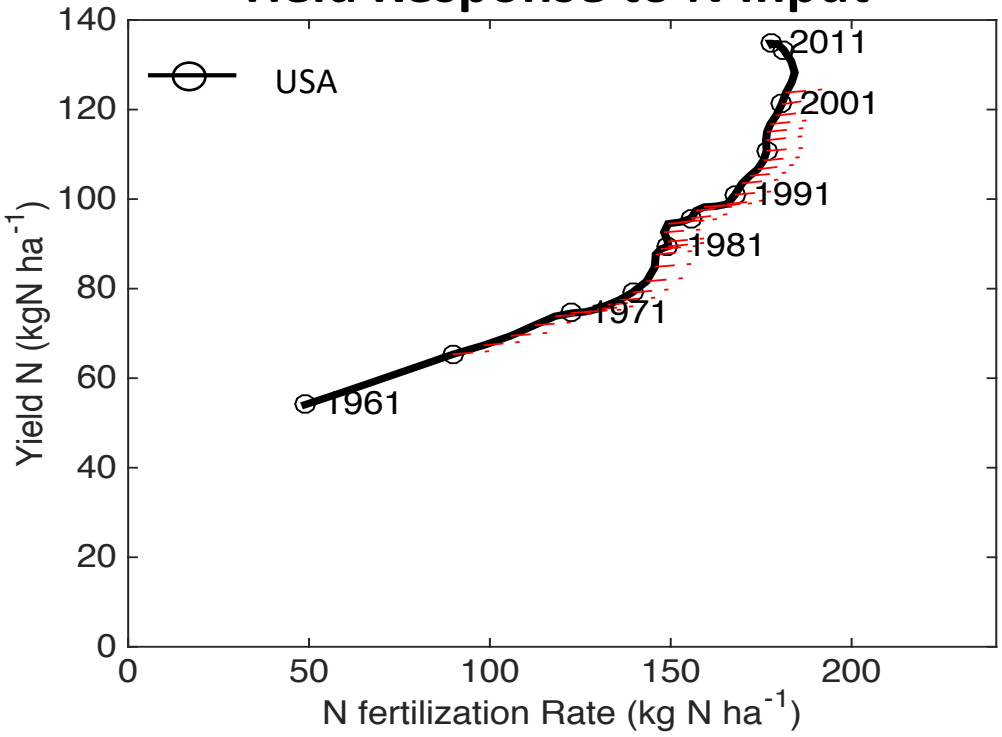
NUE drivers

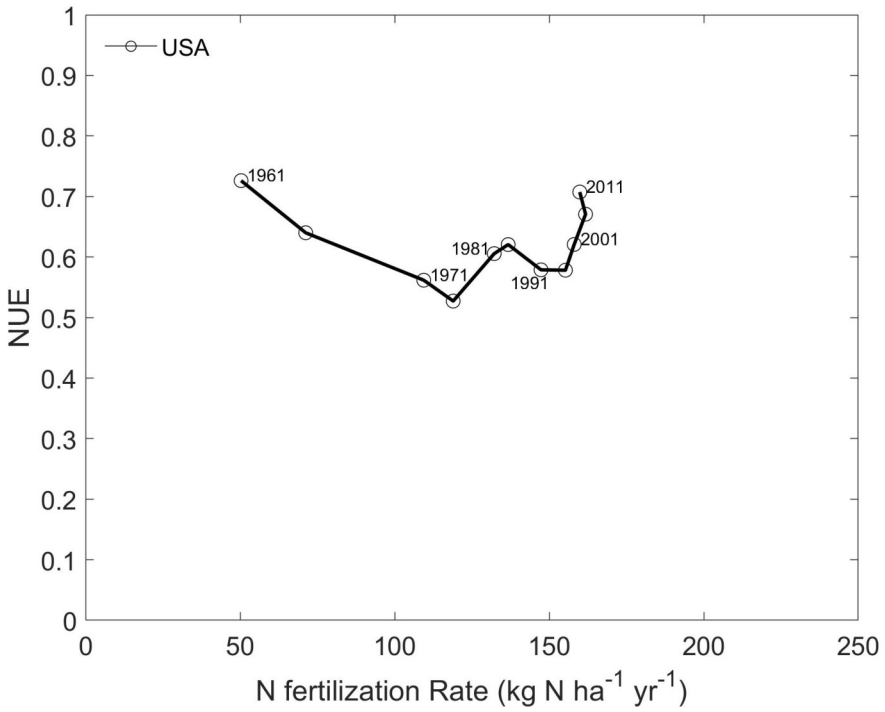
The role of different types of TMP

TMP: Technologies and Management Practices

Yield Response to N Input



Nitrogen Use Efficiency



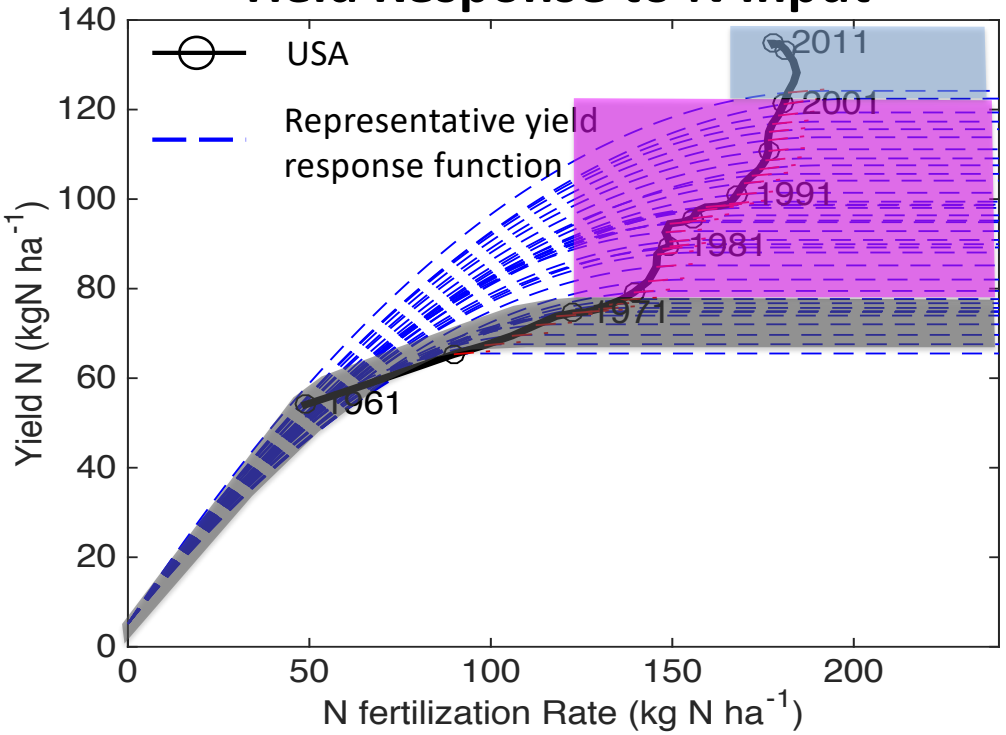
Data Source: Global Database of Nitrogen Budget in Crop Production (Zhang *et al.*, 2015, *Nature*)

NUE drivers

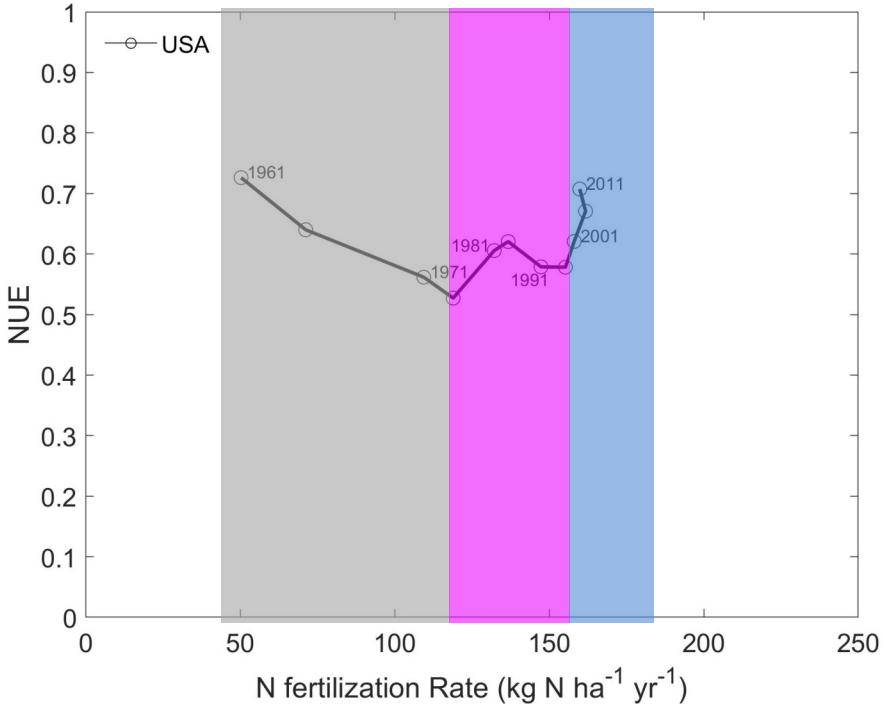
The role of different types of TMP

TMP: Technologies and Management Practices

Yield Response to N Input



Nitrogen Use Efficiency



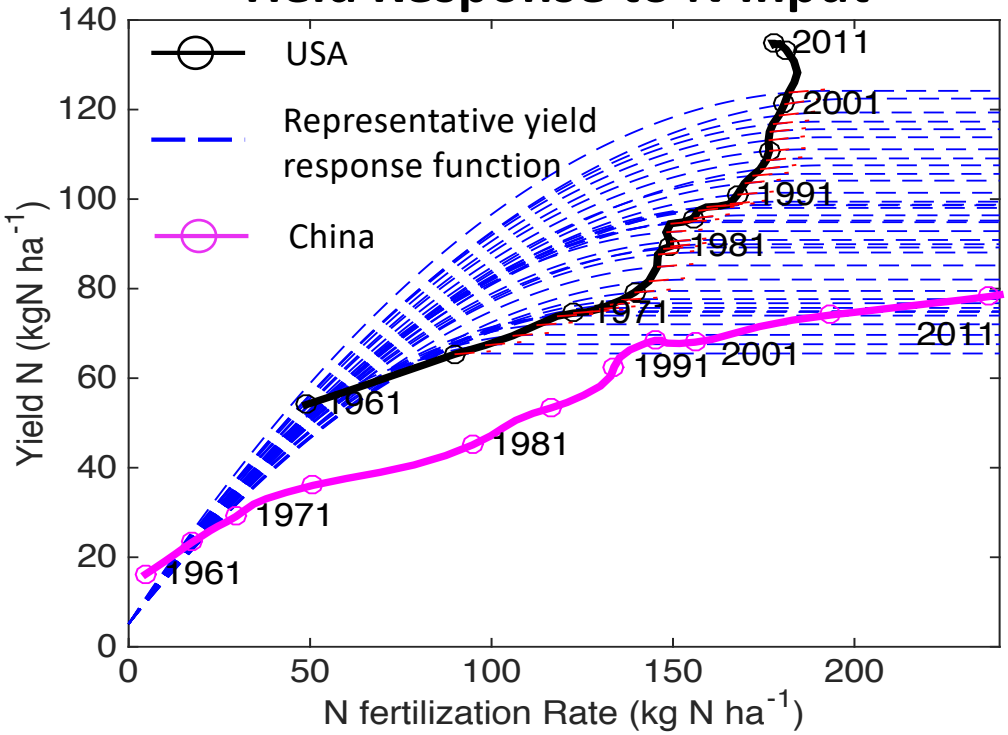
(Method for Yield Response Function: Zhang *et al.*, 2015, *Journal of Environmental Quality*)

Data Source: Global Database of Nitrogen Budget in Crop Production (Zhang *et al.*, 2015, *Nature*)

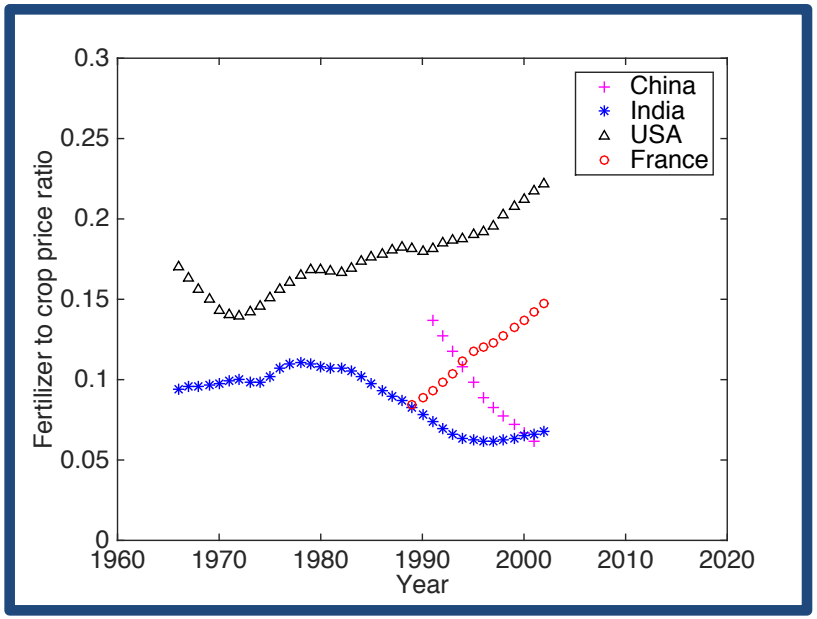
NUE drivers

The role of the fertilizer to crop price ratio

Yield Response to N Input



Fertilizer to Crop Price Ratio

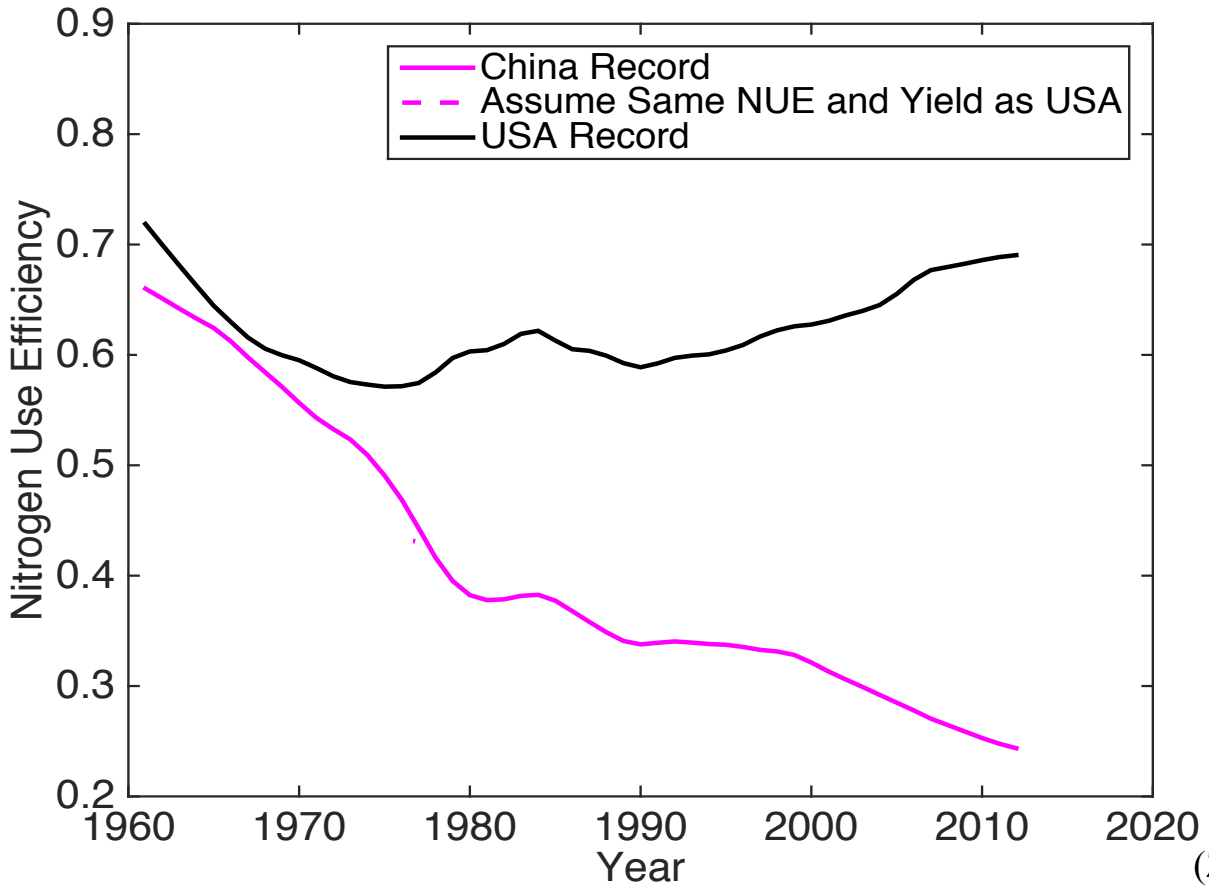


Data Source: Global Database of Nitrogen Budget in Crop Production (Zhang *et al.*, 2015, *Nature*)

NUE drivers

Differences in crop types matter

Aggregated Nitrogen Use Efficiency (All crops)

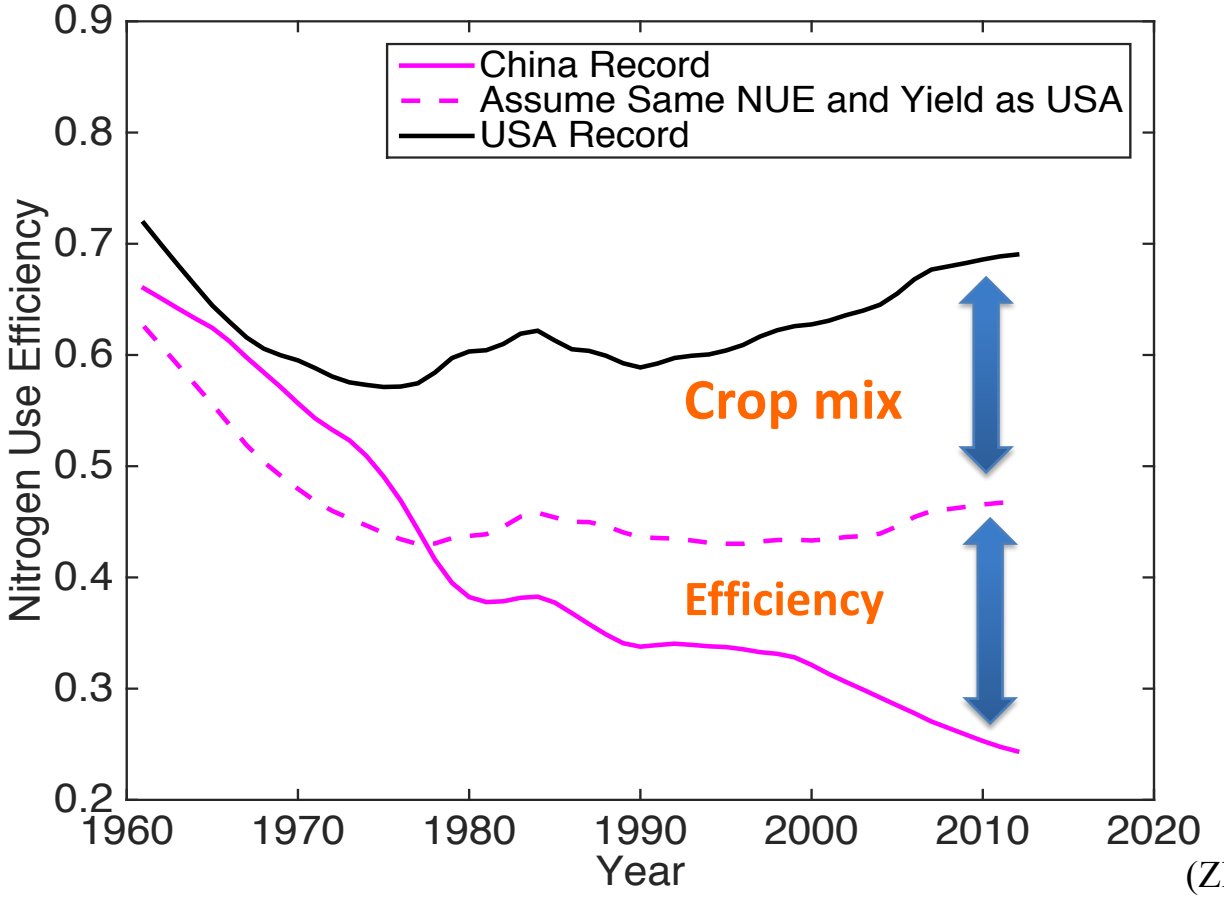


(Zhang *et al.*, 2015, *Nature*)

NUE drivers

Differences in crop types matter

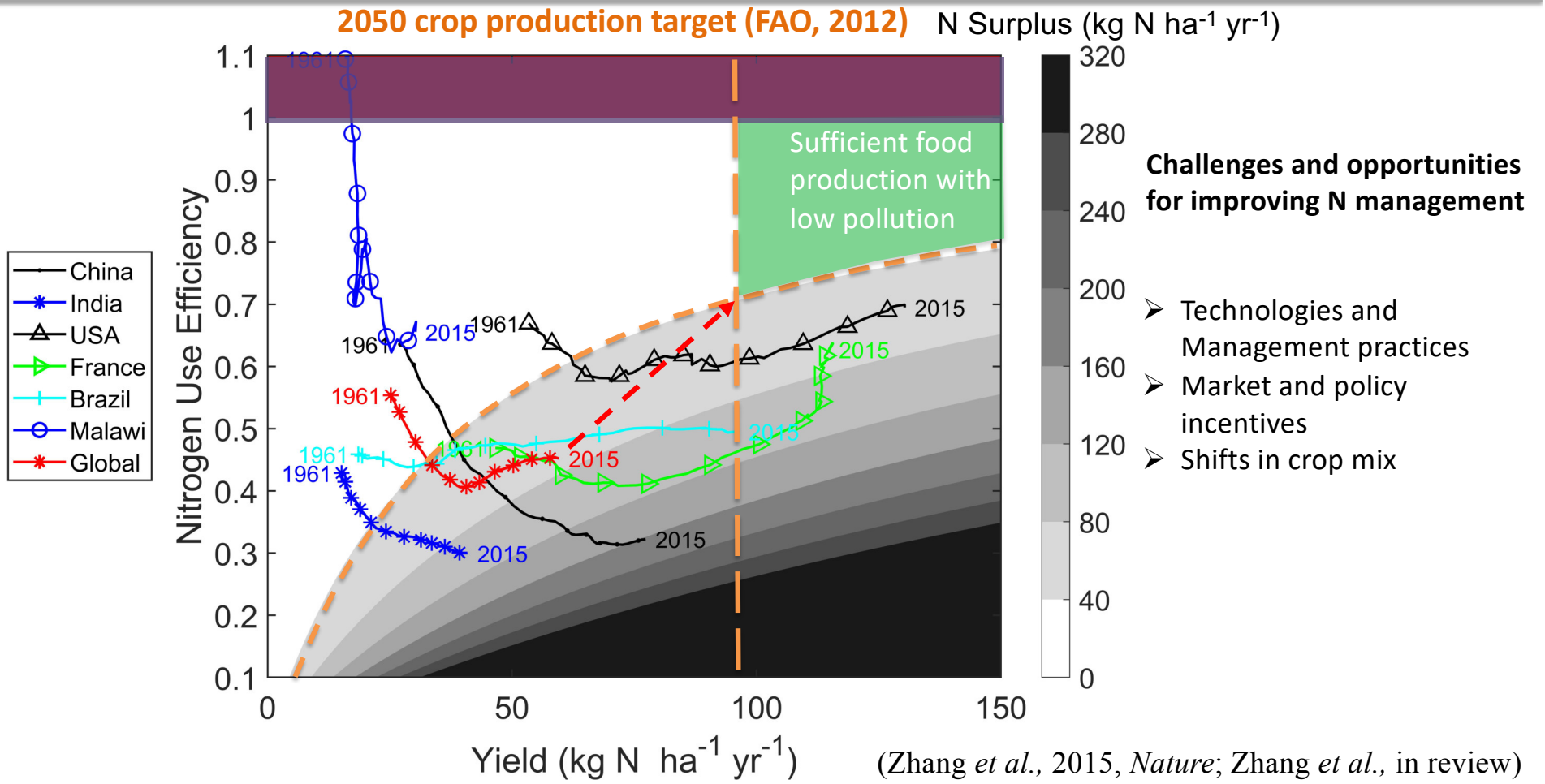
Aggregated Nitrogen Use Efficiency (All crops)



(Zhang *et al.*, 2015, *Nature*)

NUE Challenges and Opportunities

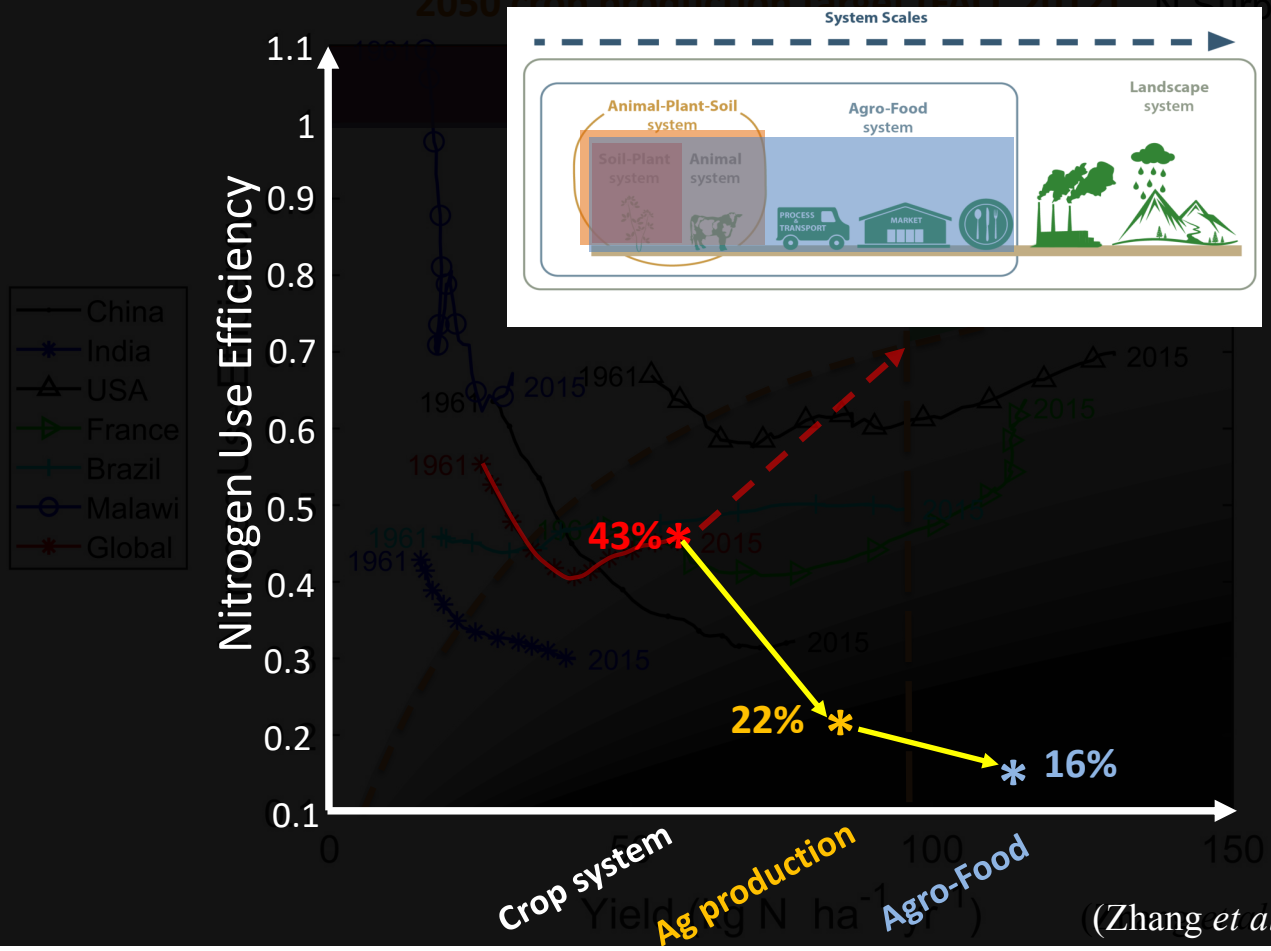
Meeting the Food and Environment target in 2050



(Zhang *et al.*, 2015, *Nature*; Zhang *et al.*, in review)

NUE Challenges and Opportunities

NUE beyond crop production



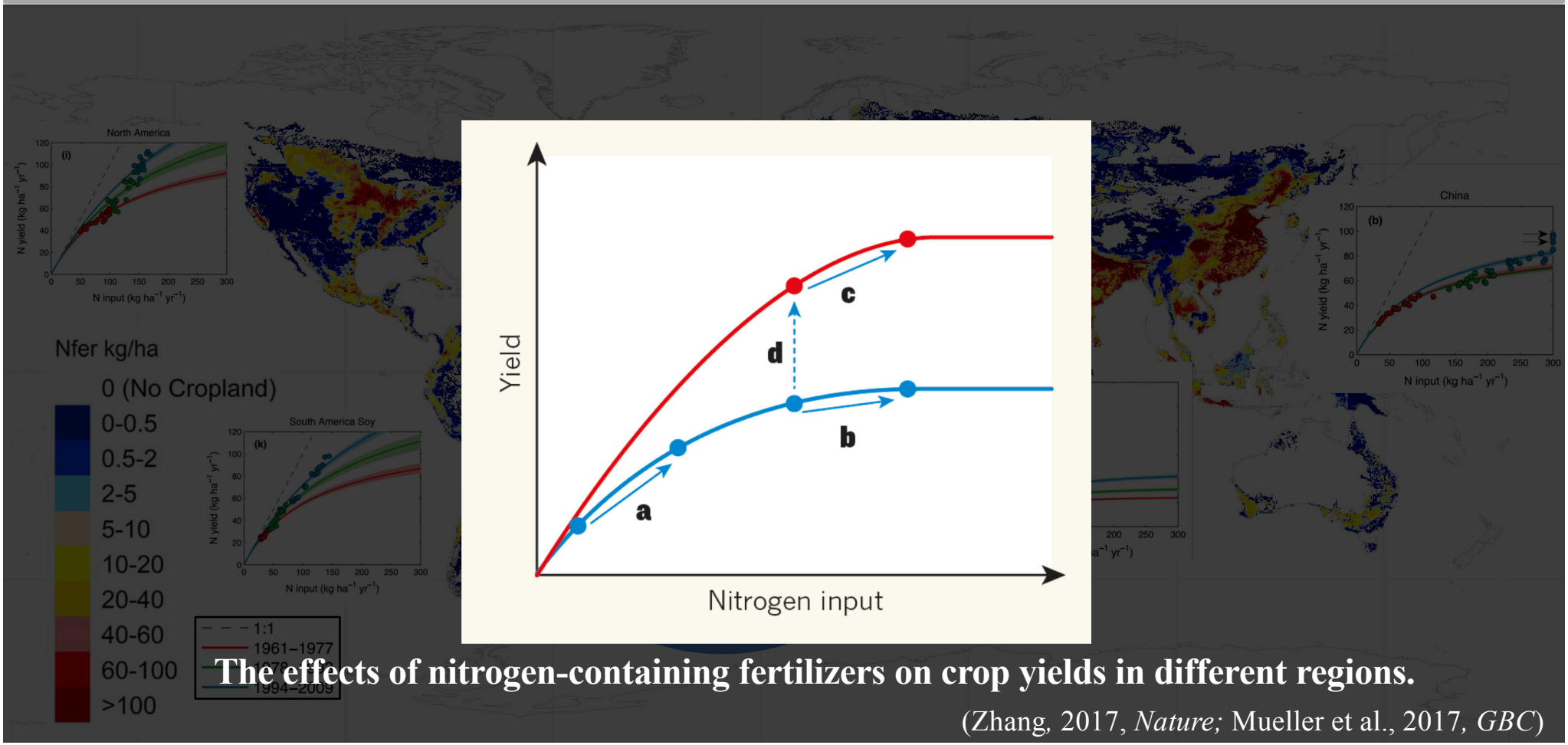
Challenges and opportunities for improving N management

- Technologies and Management practices
- Market and policy incentives
- Shifts in crop mix
- Low NUE in livestock production
- Insufficient recycling of livestock manure
- Food waste throughout the supply chain
- Dietary and consumption

(Zhang *et al.*, 2020, GBC; Li & Zhang *et al.*, 2019)

NUE Challenges and Opportunities

Reallocating Food Production Around the World

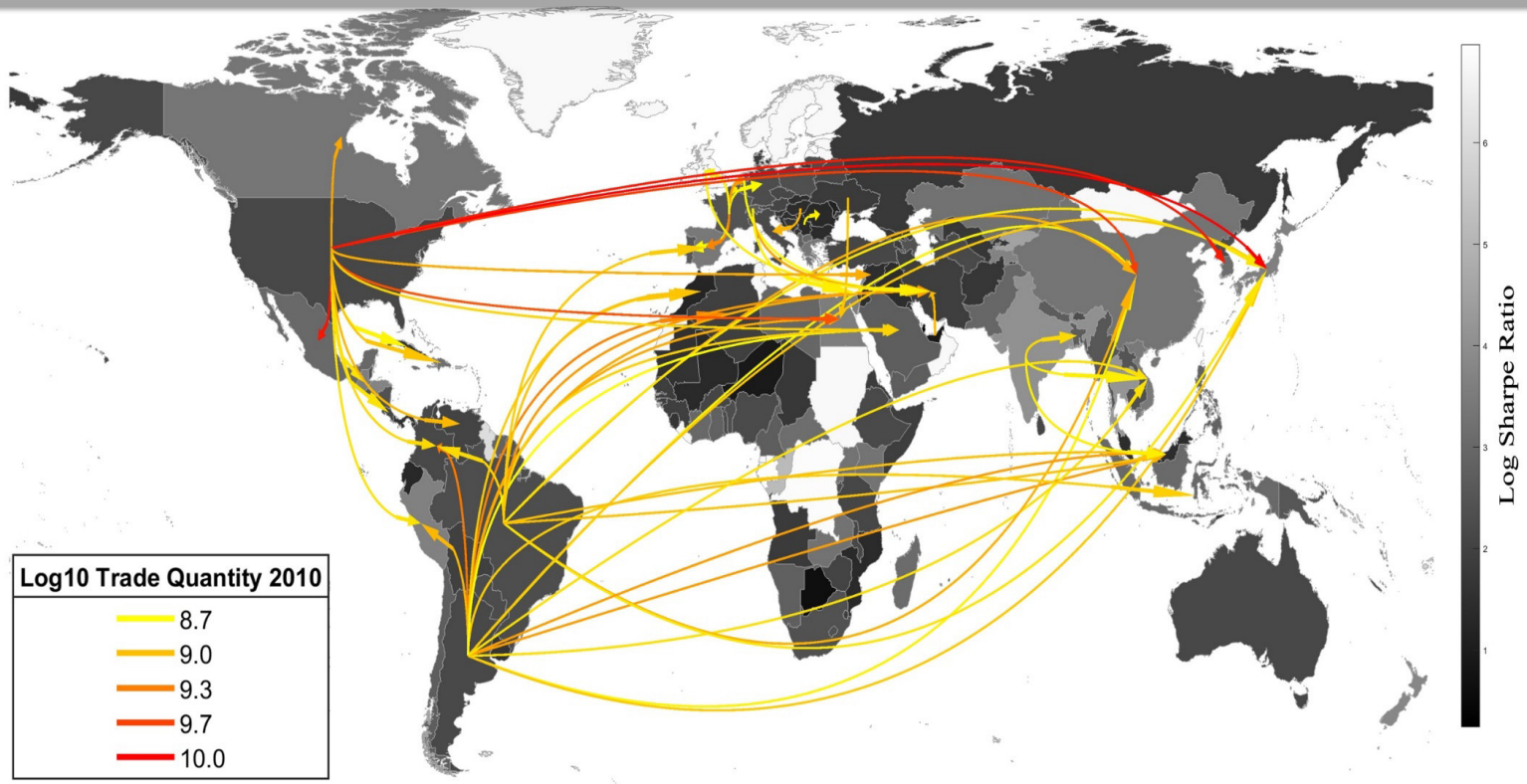


The effects of nitrogen-containing fertilizers on crop yields in different regions.

(Zhang, 2017, *Nature;* Mueller et al., 2017, *GBC*)

NUE Challenges and Opportunities

Systemic risk in agricultural production and trade

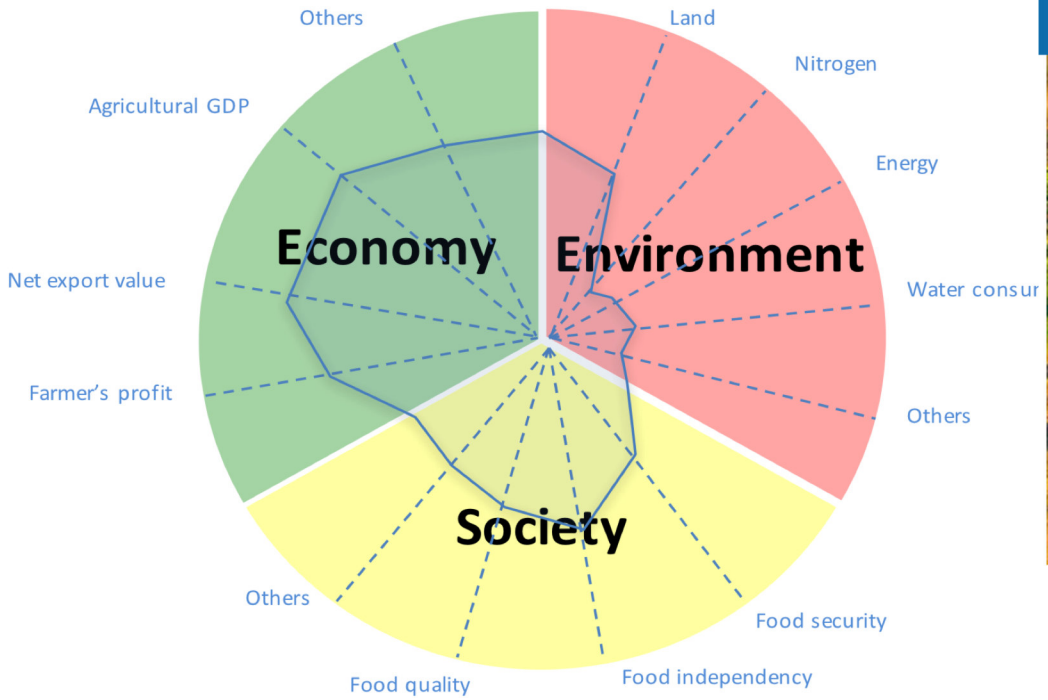


A preliminary result of global Sharpe ratio (shown in gray scale; where lower values with darker shading signify greater inter-annual variation) and the quantity of bilateral trade (shown as colored arrows, accounting for 75% of the global total trade volume) for corn yield for the period of 2010-2014. (Product from National Science Foundation awards CNS-1739823 to Zhang)

NUE Challenges and Opportunities

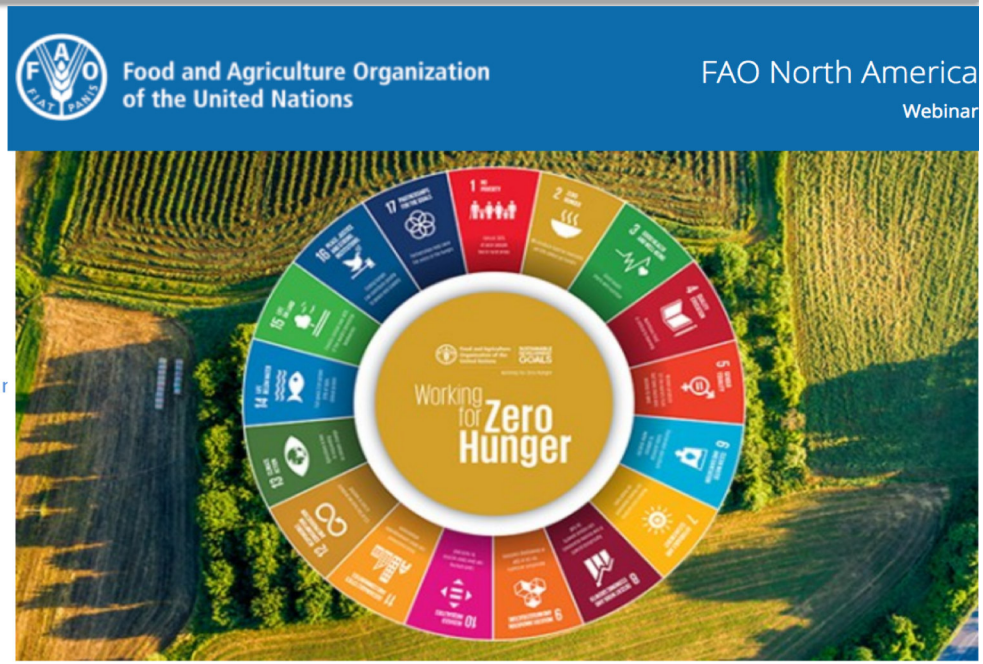
Beyond Nitrogen: N and Sustainable Agriculture

Sustainable Agriculture Matrix (SAM)



A radar chart for visualizing a country's performance in sustainable agricultural production.

Project website: https://research.al.umces.edu/sam/



FAO North America and the University of Maryland present a webinar on:

Synergies and Tradeoffs in Sustainable Agriculture

Tuesday, May 12 from 10:00 - 11:15 am EDT

Take home messages

- Human activities are adding reactive nitrogen to the earth system at the rate far exceeding the planetary boundary.
- Nitrogen management is facing several “too much” and “too little” challenges.
- Improving NUE is critical, requires not only technological advancement, but also improvement in socio-economic conditions.
- Meeting the Food and Environment target requires the global crop NUE to increase from 40% to 70%; while systemic changes are necessary throughout the food system.

Acknowledgement Thank you!

Major Collaborators

Eric A. Davidson, *University of Maryland Center for Environmental Science (UMCES)*; Kimberly Pfeifer, *Oxfam America*; Luis Lassaletta, *Technical University of Madrid;* Denise L. Mauzerall, *Princeton University;* David R. Kanter, *New York University;* Carole Dalin, *University College London;* Adam Komarek, *International Food Policy Research Institute;* Timothy D. Searchinger, *World Resources Institute*; Guorui Huang, *Tsinghua University;* Patrice Dumas, *CIRAD, France;* Paolo d'Odorico, *UC Berkeley;* Fernando Galeana Rodriguez, *Cornell University;* Christian Folberth, *IIASA*; Bill Dennison, Tan Zou, Srishti Vishwakarma, Guolin Yao, Jing Zhao, Matt Lisk, *UMCES*

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Yale Center for Environmental Law & Policy Research Prize Fellowship

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