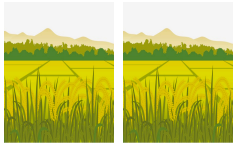
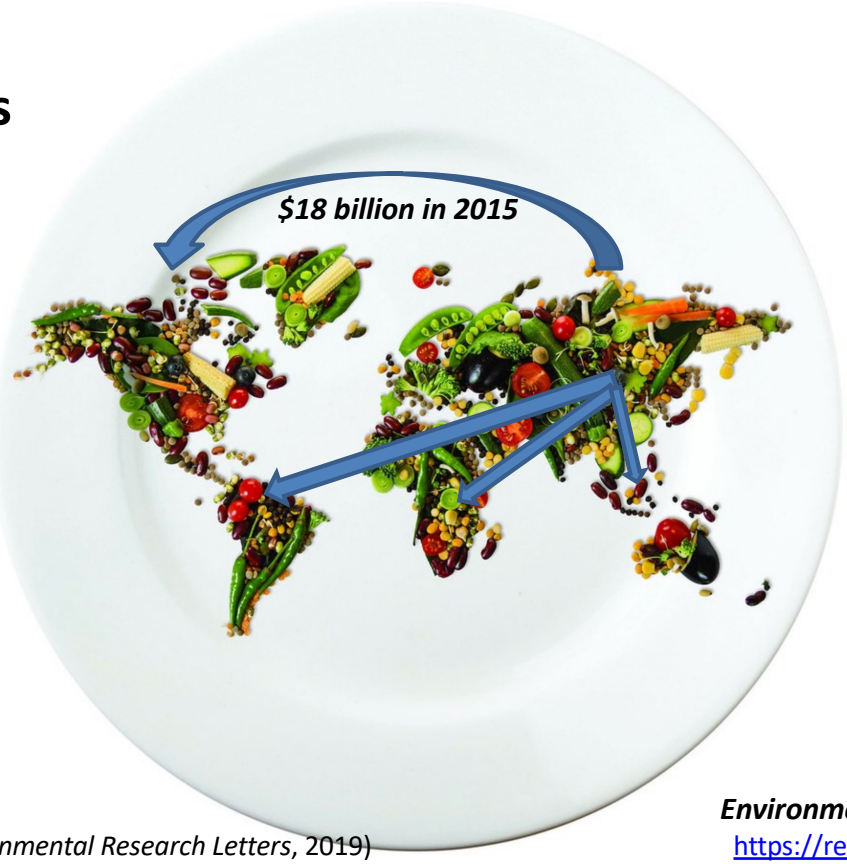
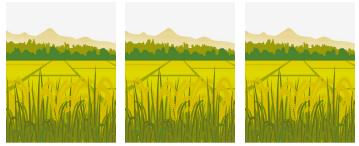
United States





China



(Huang, Zhang et al., *Environmental Research Letters*, 2019)

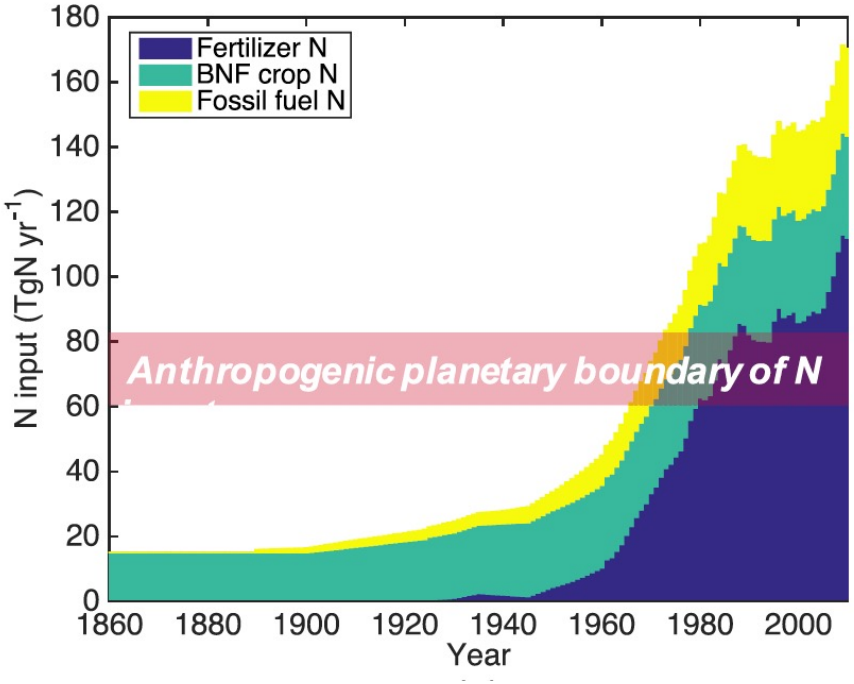
ZHANG LAB
Environmental Science and Policy
https://research.al.umces.edu/xzhang/


University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
APPALACHIAN LABORATORY
To provide sufficient food and bioenergy for the population with minimal impact on the environment worldwide, it really matters what to farm, where to farm, and how to farm.
iFarm Project
Xin Zhang
Associate Professor
University of Maryland Center for Environmental Science
Appalachian Lab
SESYNC
NSF
FAO
FIAT PANIS

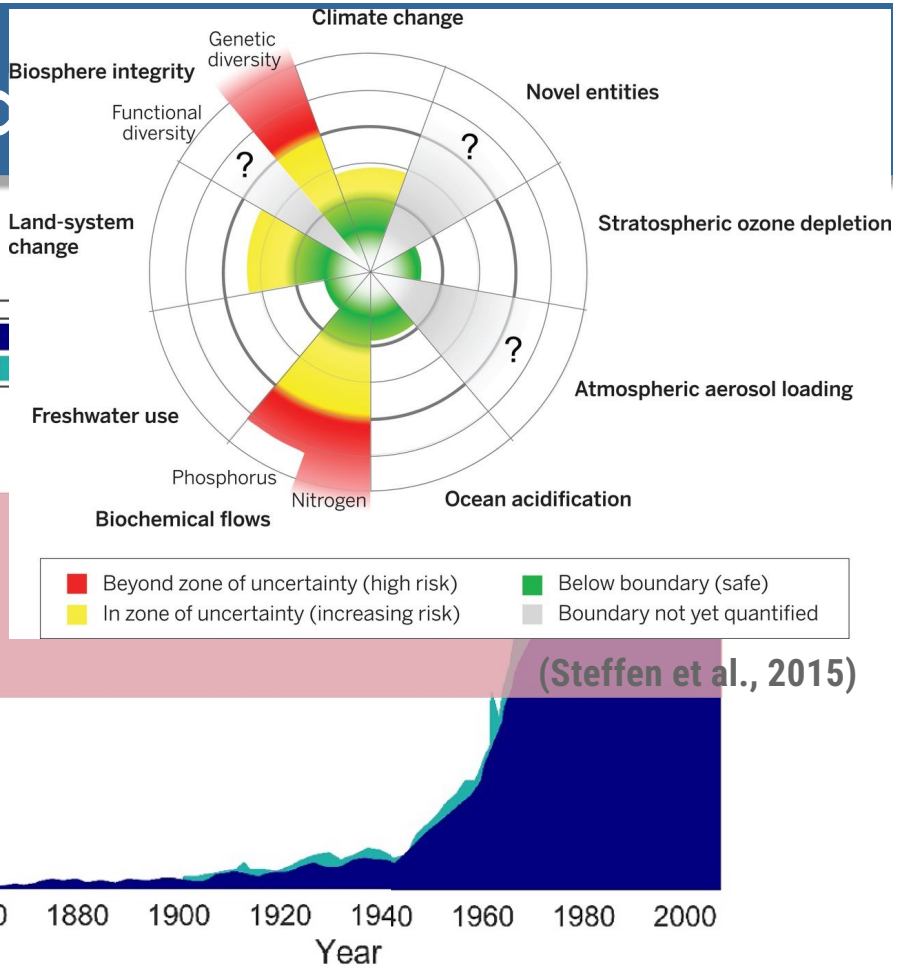
Importance of Nutrients on Food Security

- Nutrients (e.g., Nitrogen, Phosphorus) are critical for crop growth
- Nutrient fertilizer currently supports food production for over 40% of people on earth
- Future larger population will require more food

The Planet Overloaded



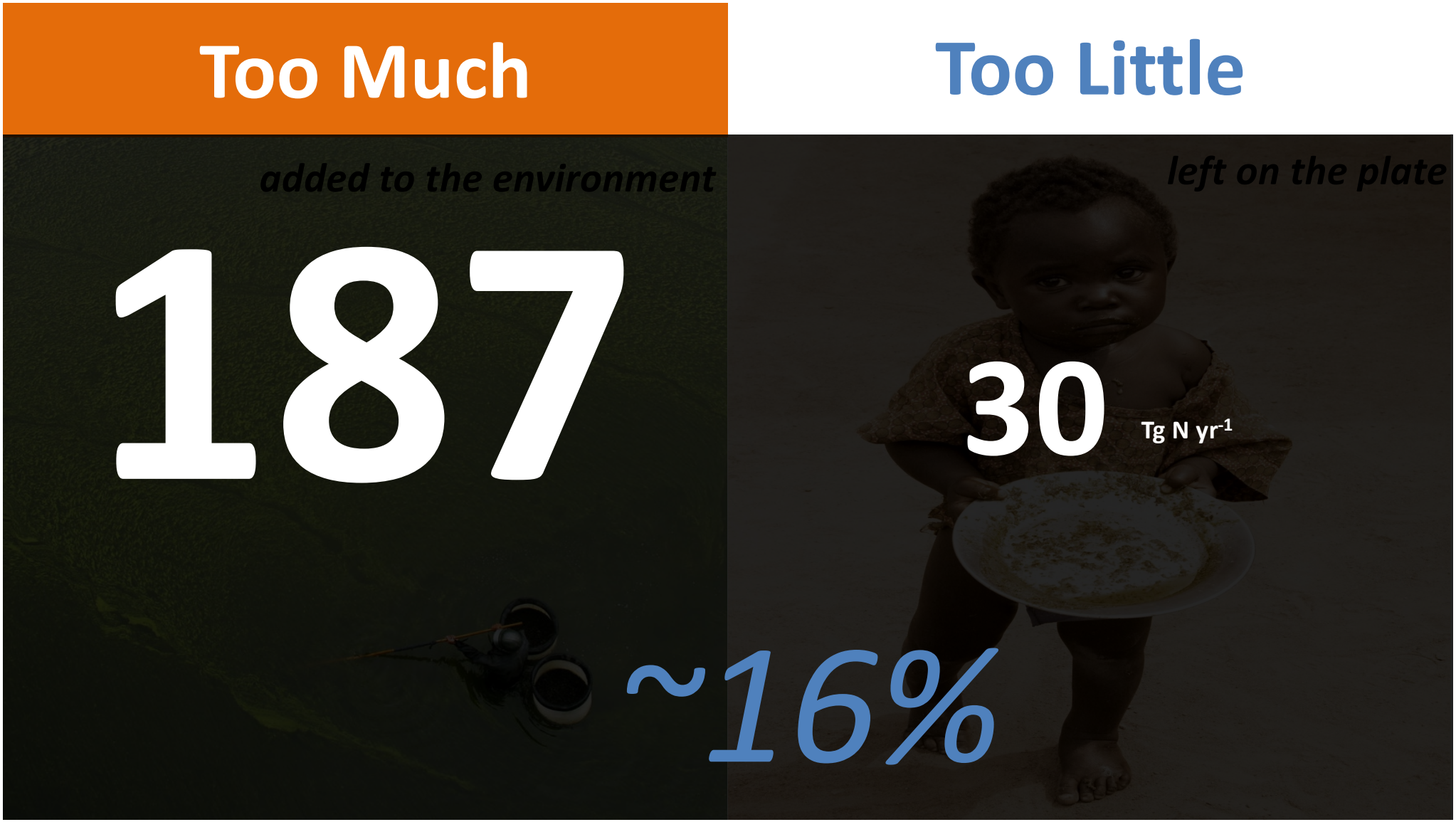
BNF: Biological Nitrogen Fixation



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

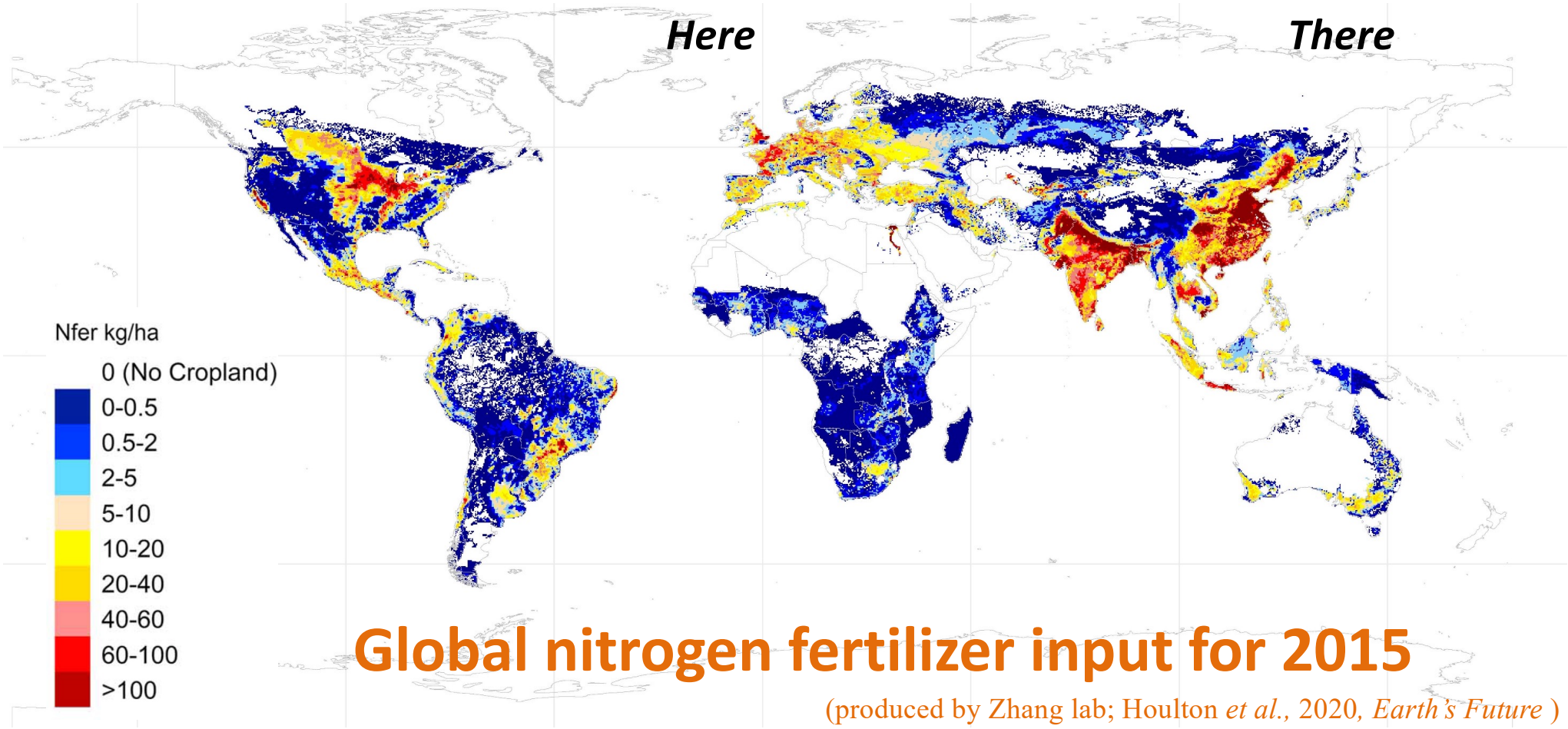
Too Much

Too Little


Too Much
Too Little
added to the environment
left on the plate
187
30 Tg N yr-1
~16%

Too Much

Too Little

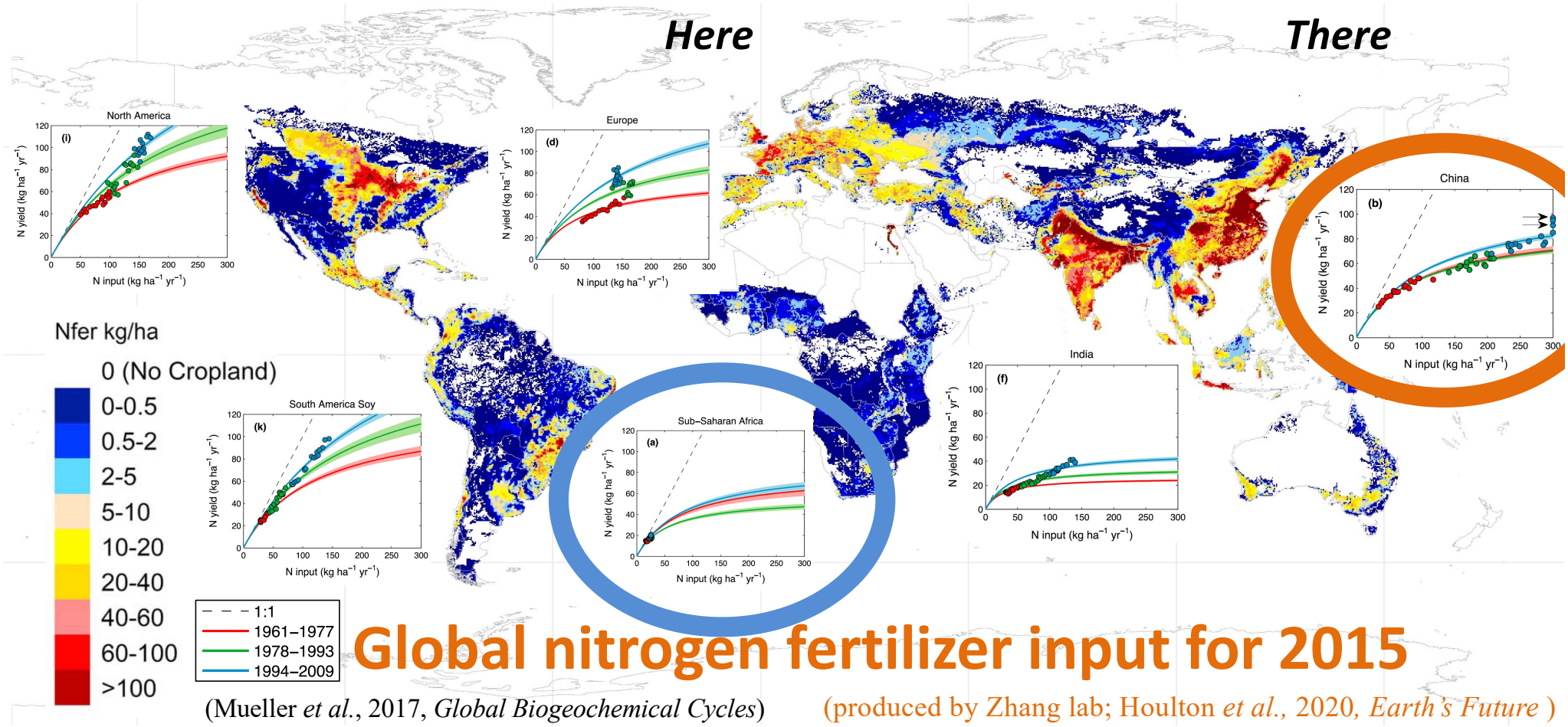


Global nitrogen fertilizer input for 2015

(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?

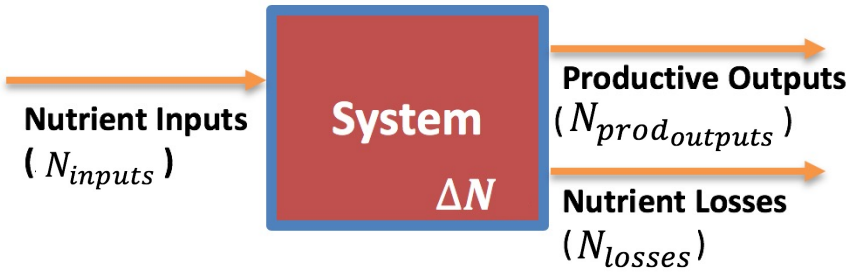
Nutrient Use Efficiency

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

Global nitrogen fertilizer input for 2015

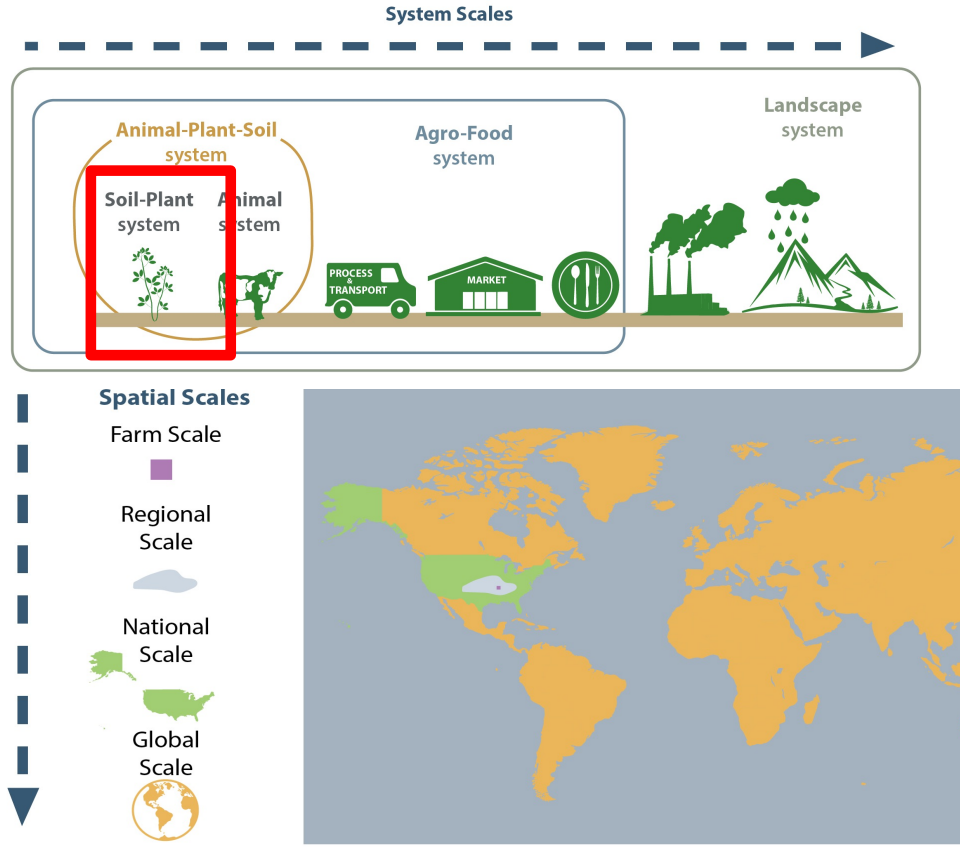
(produced by Zhang lab; Houlton et al., 2020, Earth's Future)

Nutrient budget and Nutrient Use Efficiency



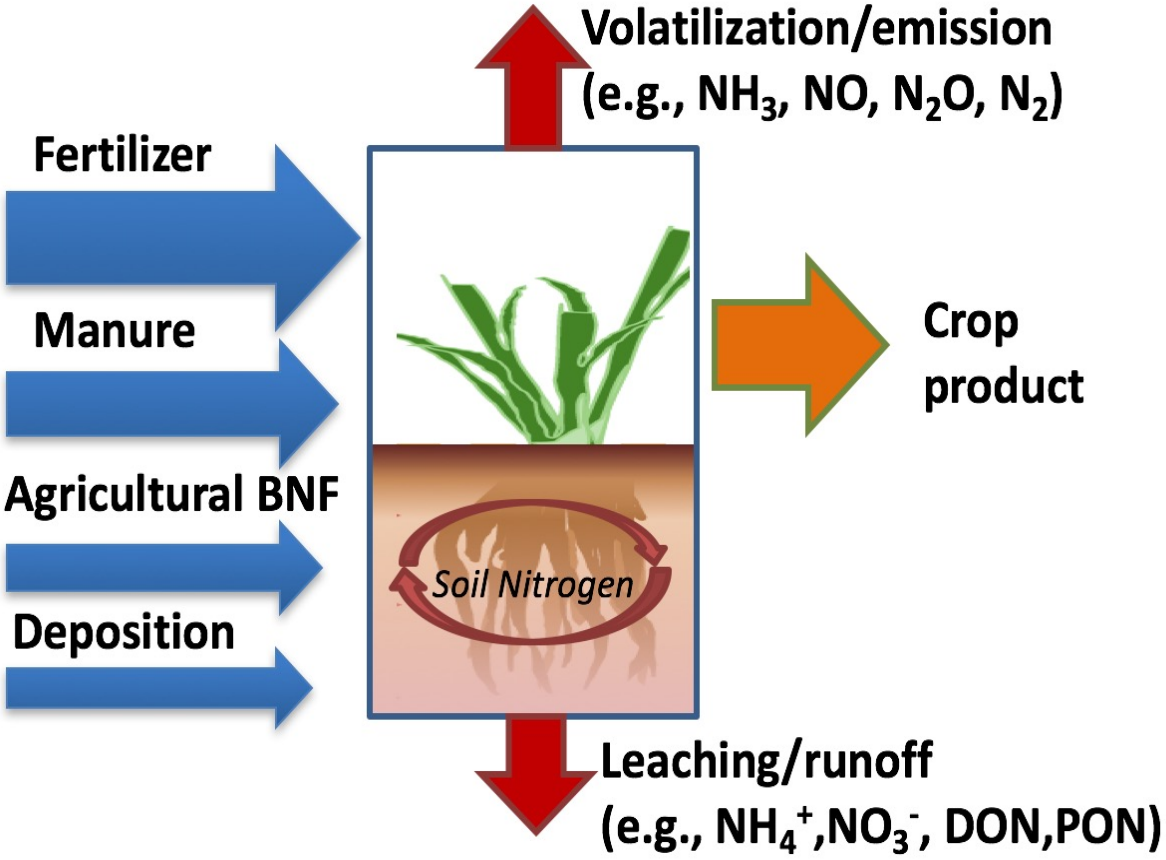
$$\boldsymbol{NUE} = N_{prod\_outputs}/N_{inputs}$$

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



(Zhang *et al.*, 2020, *Global Biogeochemical Cycles;* Quan, Zhang *et al.*, 2021, *Nature Food*)

Nitrogen Use Efficiency for Crop production

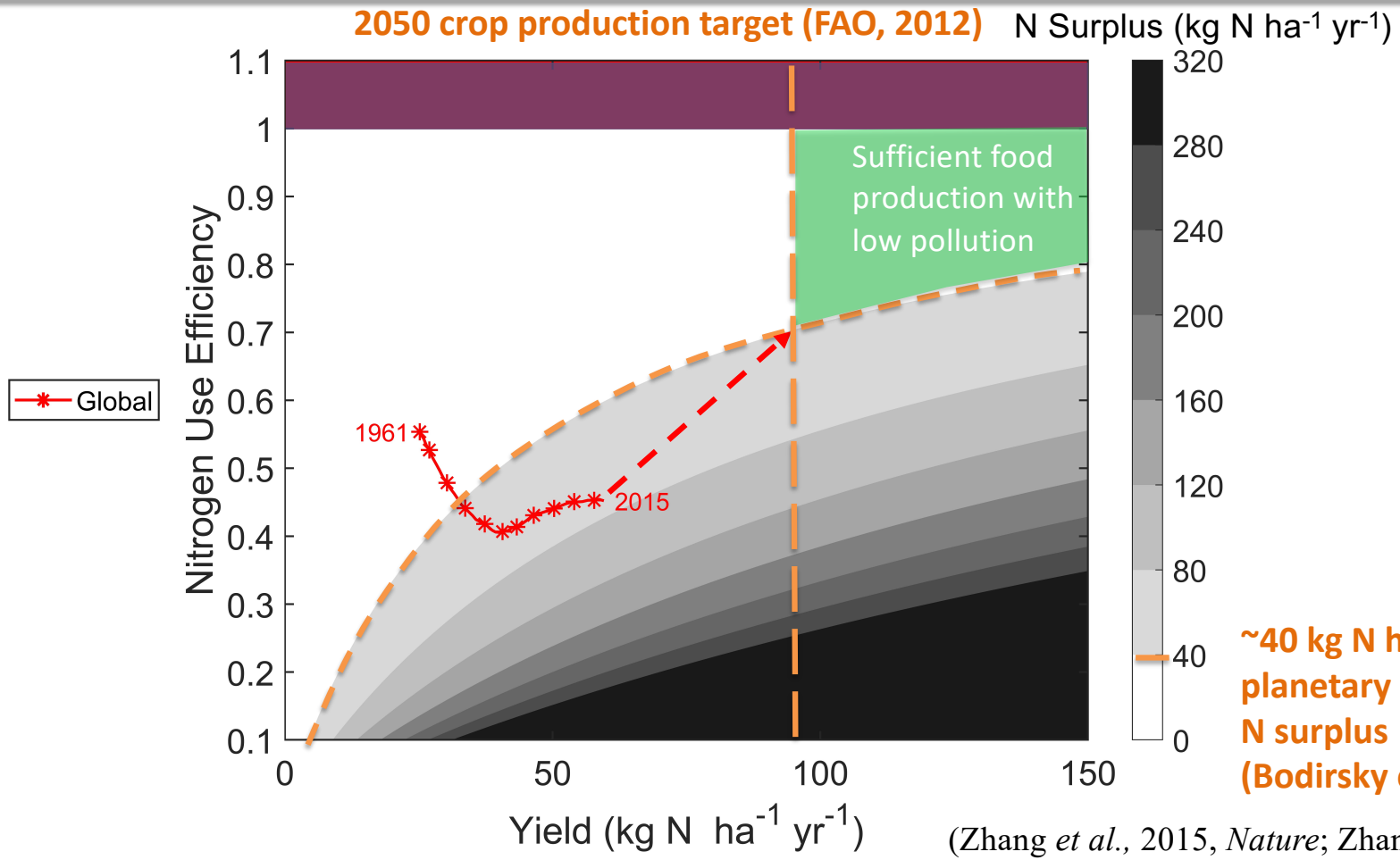


$$NUE = \frac{\text{Harvested Nitrogen}}{\text{Nitrogen input}}$$

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

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

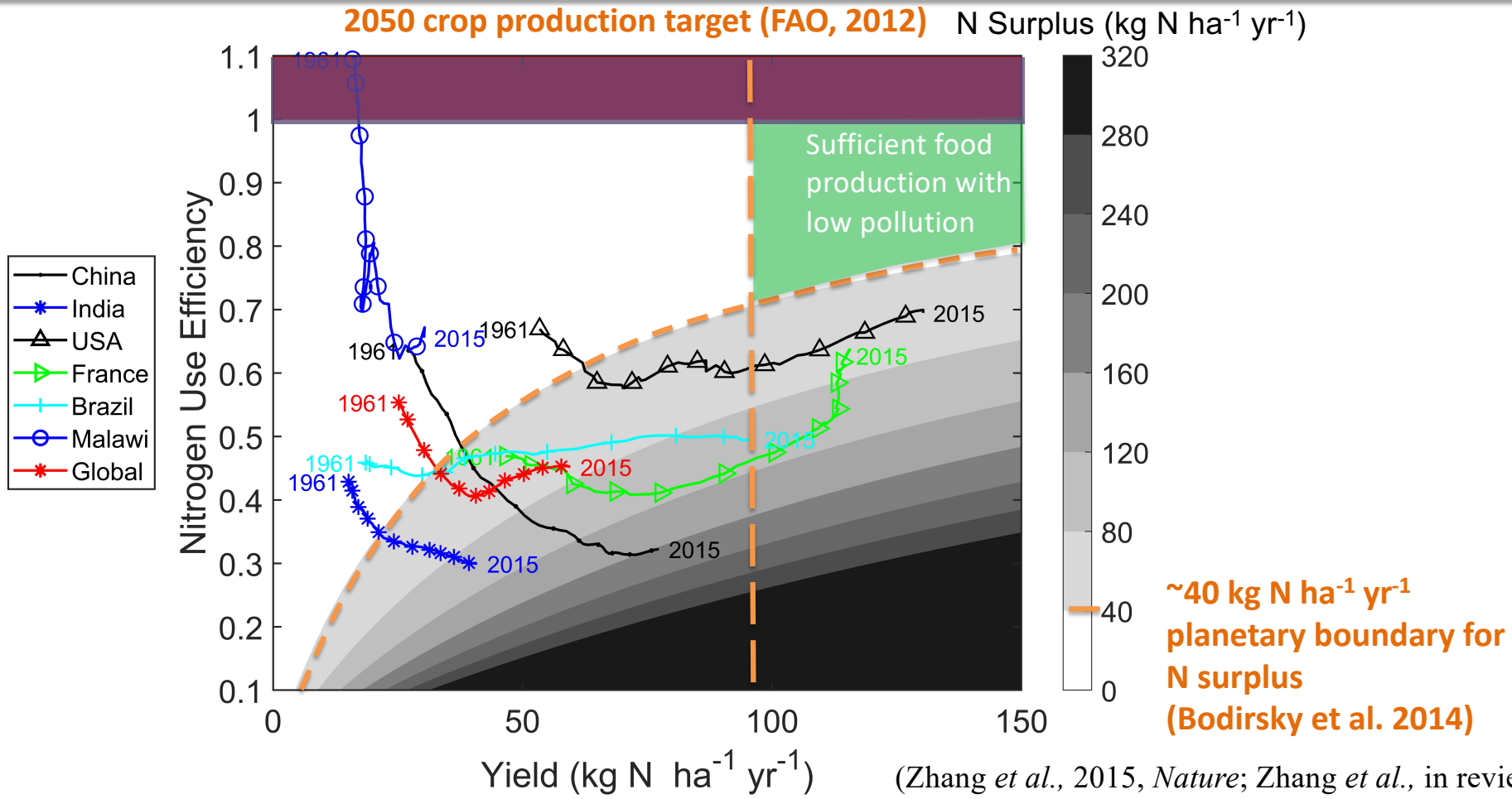
NUE Trend for crop production



~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



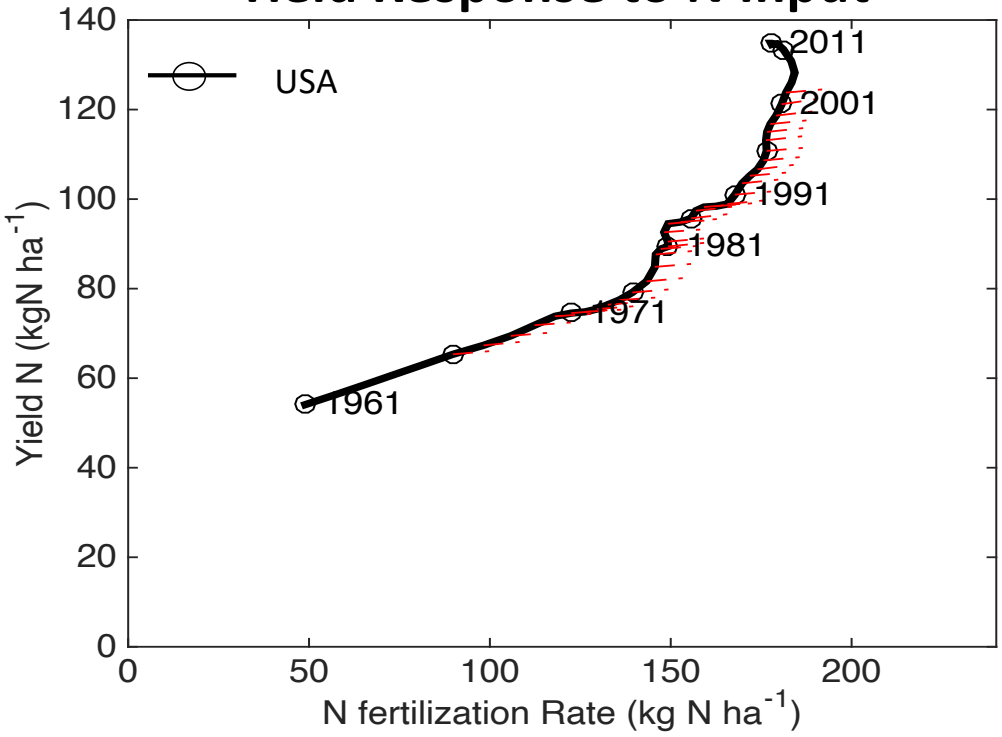
(Zhang *et al.*, 2015, *Nature*; Zhang *et al.*, in review)

NUE drivers

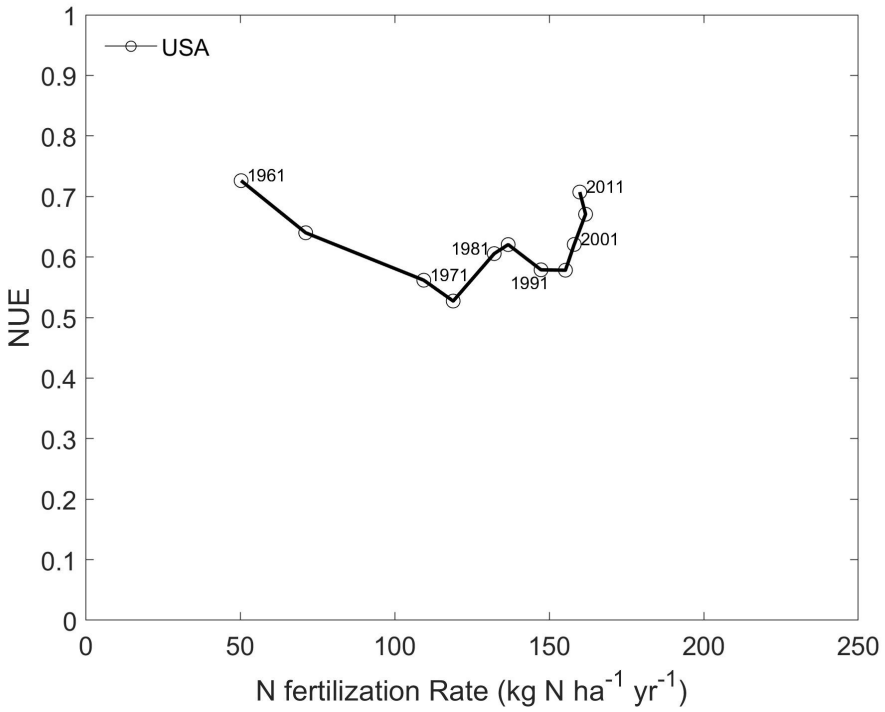
The role of different types of TMP

TMP: Technologies and Management Practices

Yield Response to N Input



Nitrogen Use Efficiency



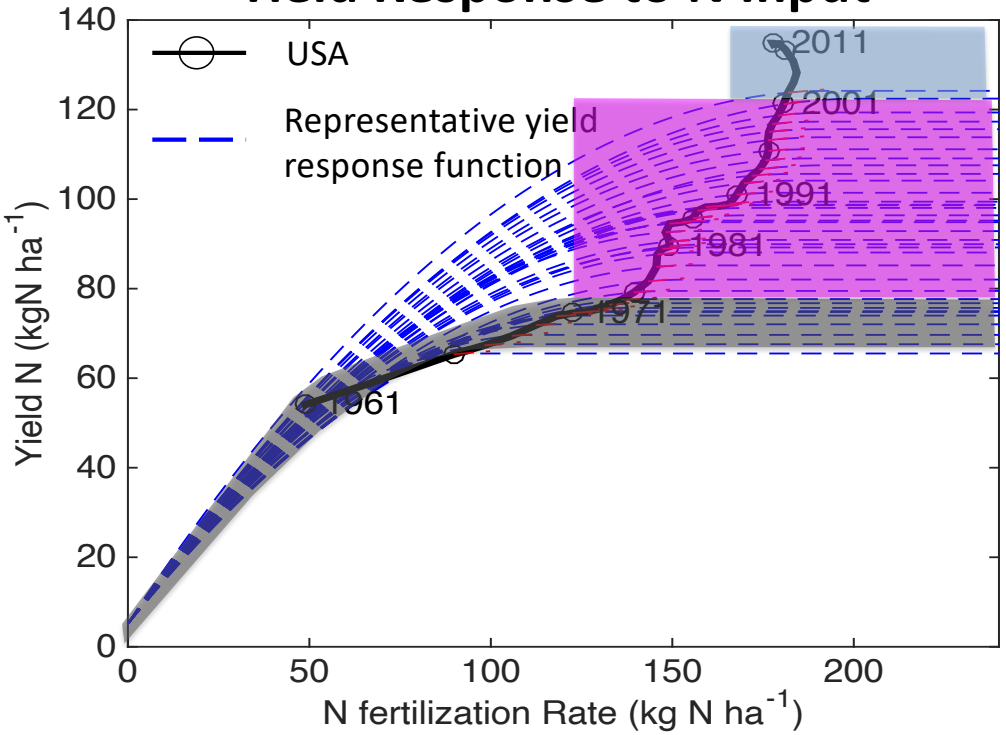
Data Source: Global Database of Nitrogen Budget in Crop Production (Zhang *et al.*, 2015, *Nature*)

NUE drivers

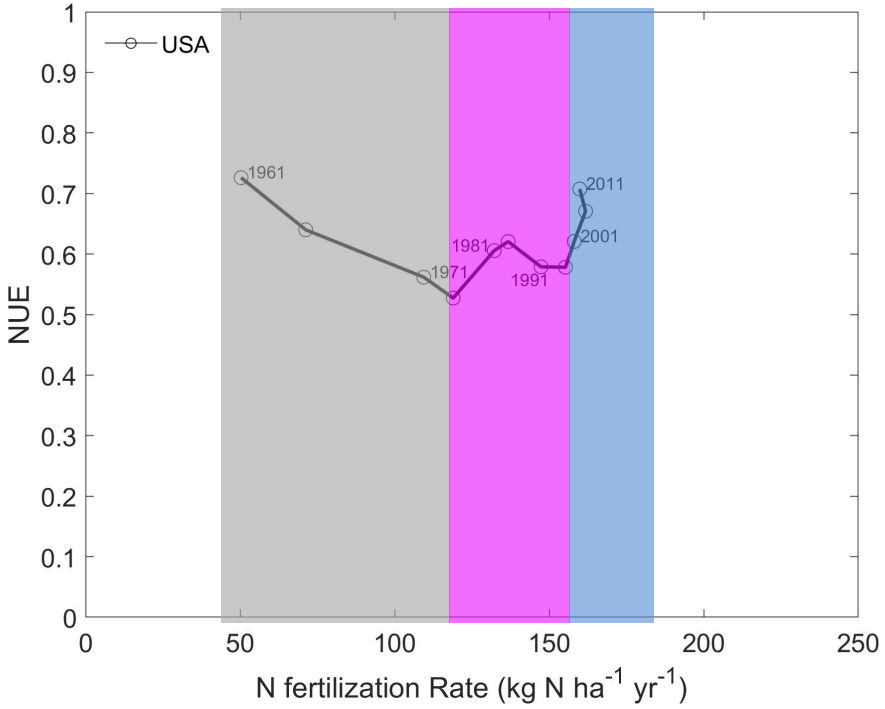
The role of different types of TMP

TMP: Technologies and Management Practices

Yield Response to N Input



Nitrogen Use Efficiency



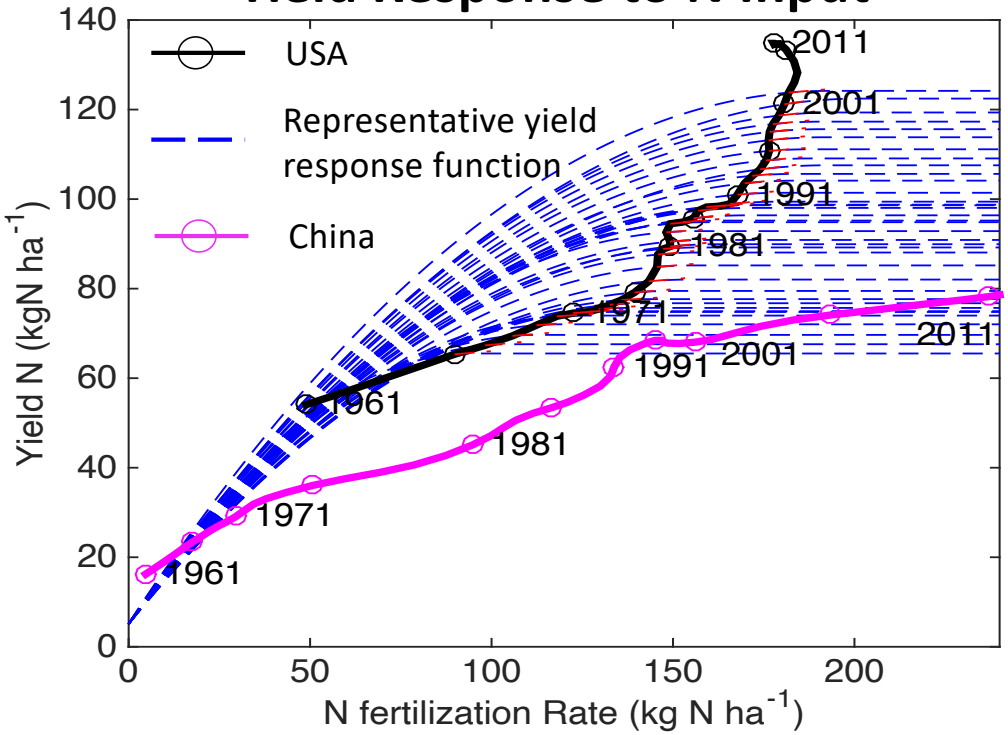
(Method for Yield Response Function: Zhang *et al.*, 2015, *Journal of Environmental Quality*)

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

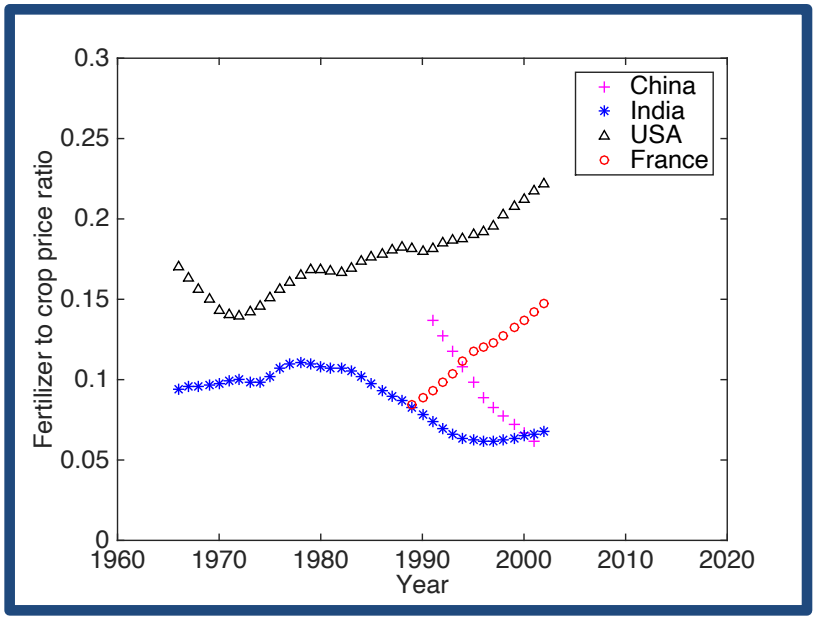
NUE drivers

The role of the fertilizer to crop price ratio

Yield Response to N Input



Fertilizer to Crop Price Ratio

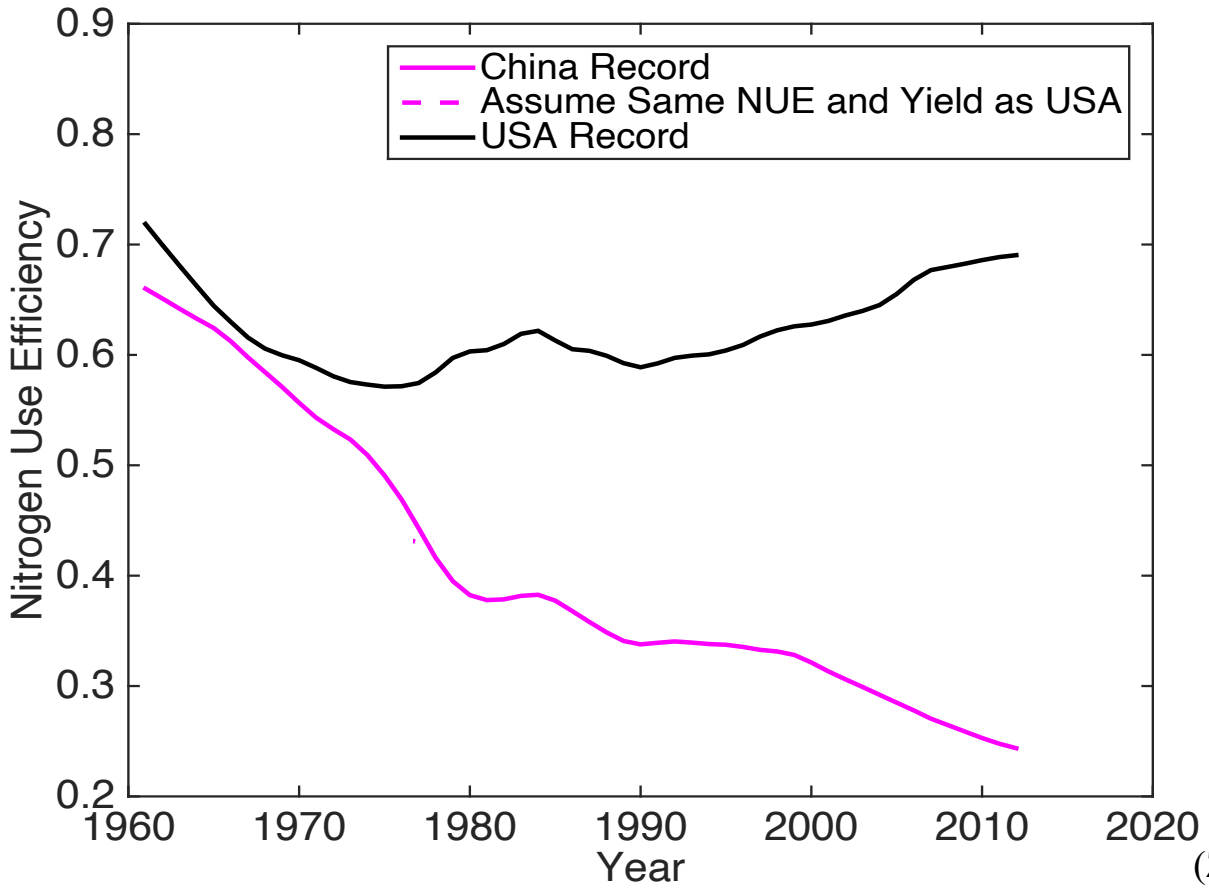


Data Source: Global Database of Nitrogen Budget in Crop Production (Zhang *et al.*, 2015, *Nature*)

NUE drivers

Differences in crop types matter

Aggregated Nitrogen Use Efficiency (All crops)

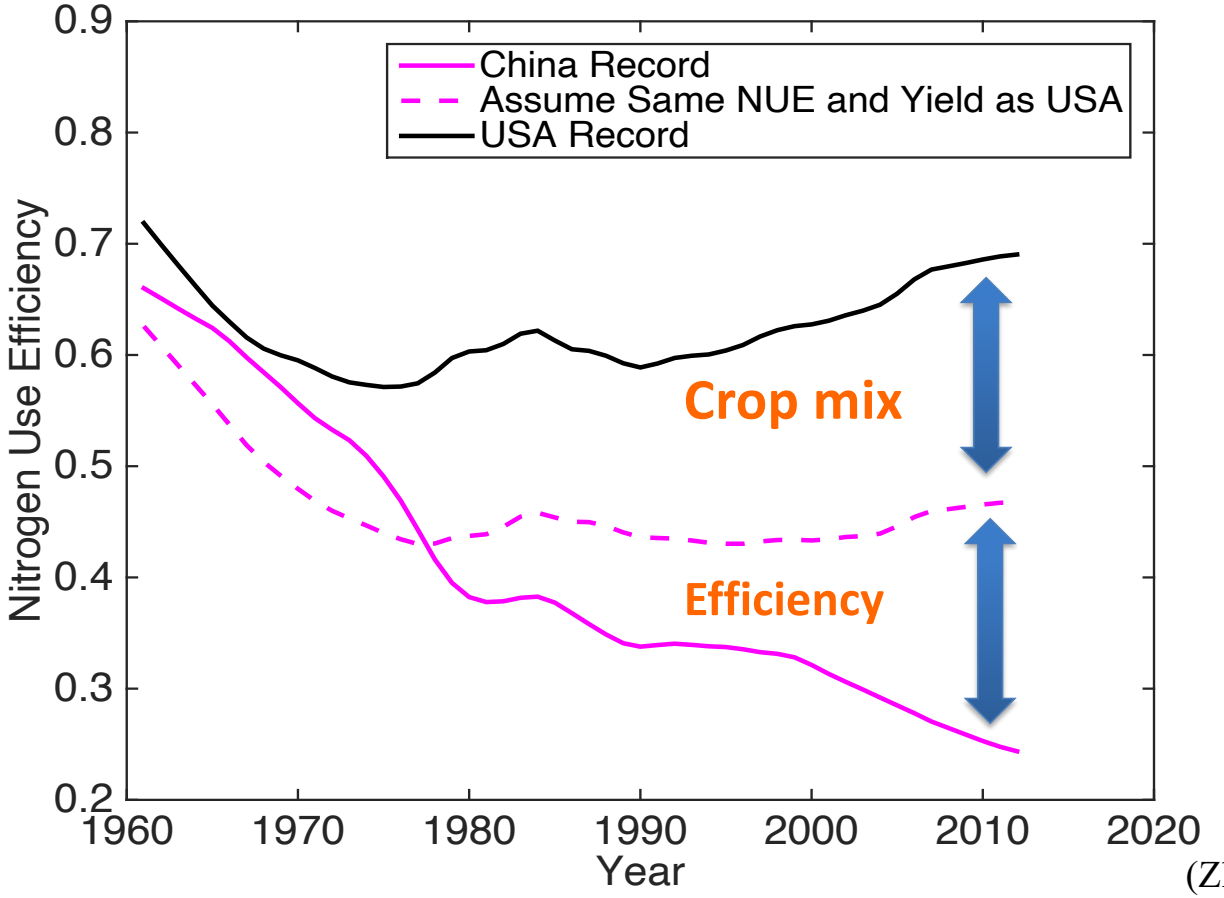


(Zhang *et al.*, 2015, *Nature*)

NUE drivers

Differences in crop types matter

Aggregated Nitrogen Use Efficiency (All crops)



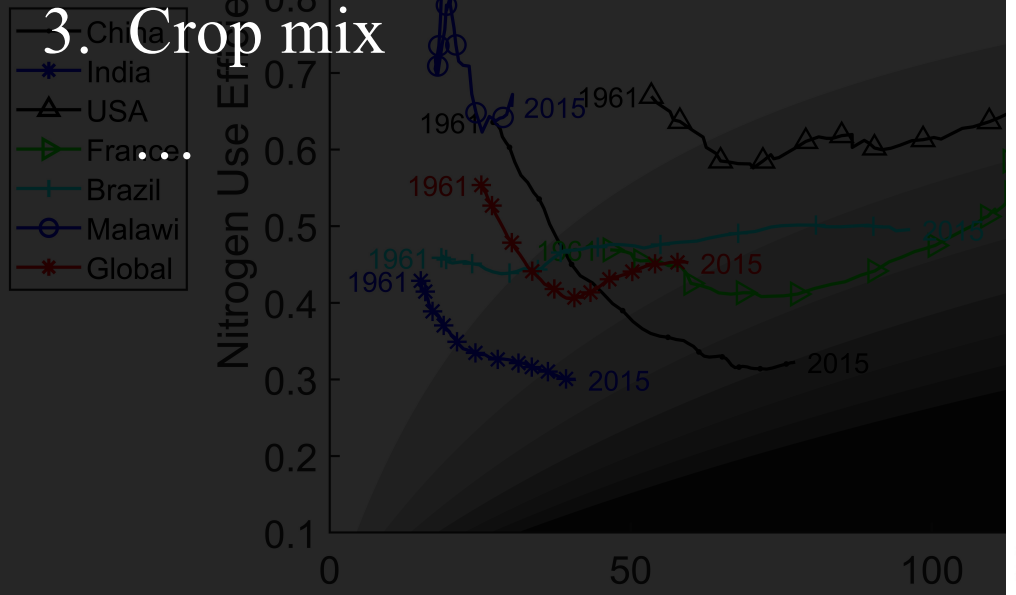
(Zhang *et al.*, 2015, *Nature*)

➢ *Drivers for NUE?*

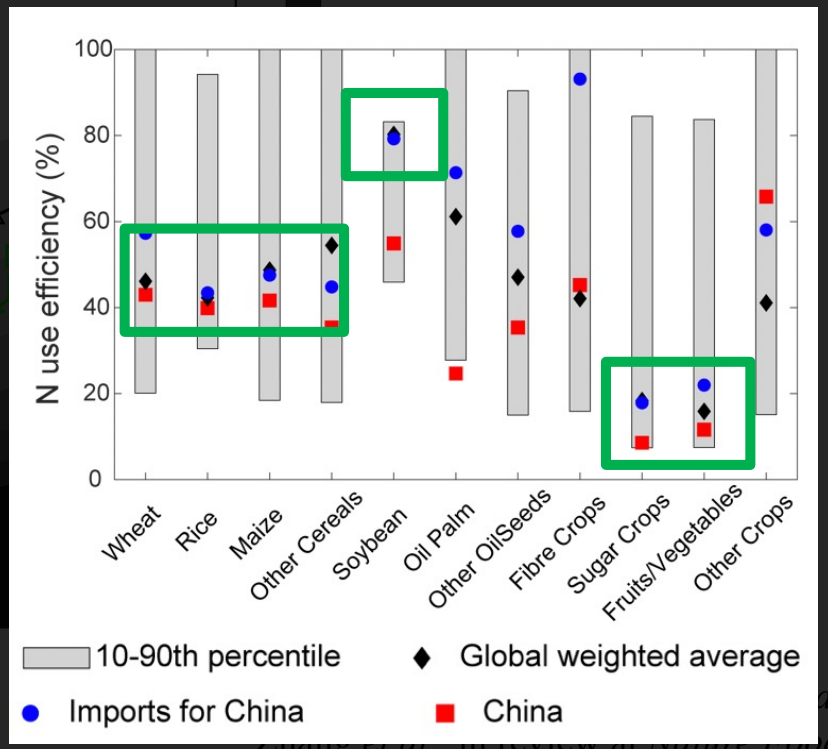
Converge socioeconomic and ecological processes

NUE Drivers

1. Fertilizer-to-crop price ratio
2. The role of different types of Technologies and Management Practices
3. Crop mix
4. …



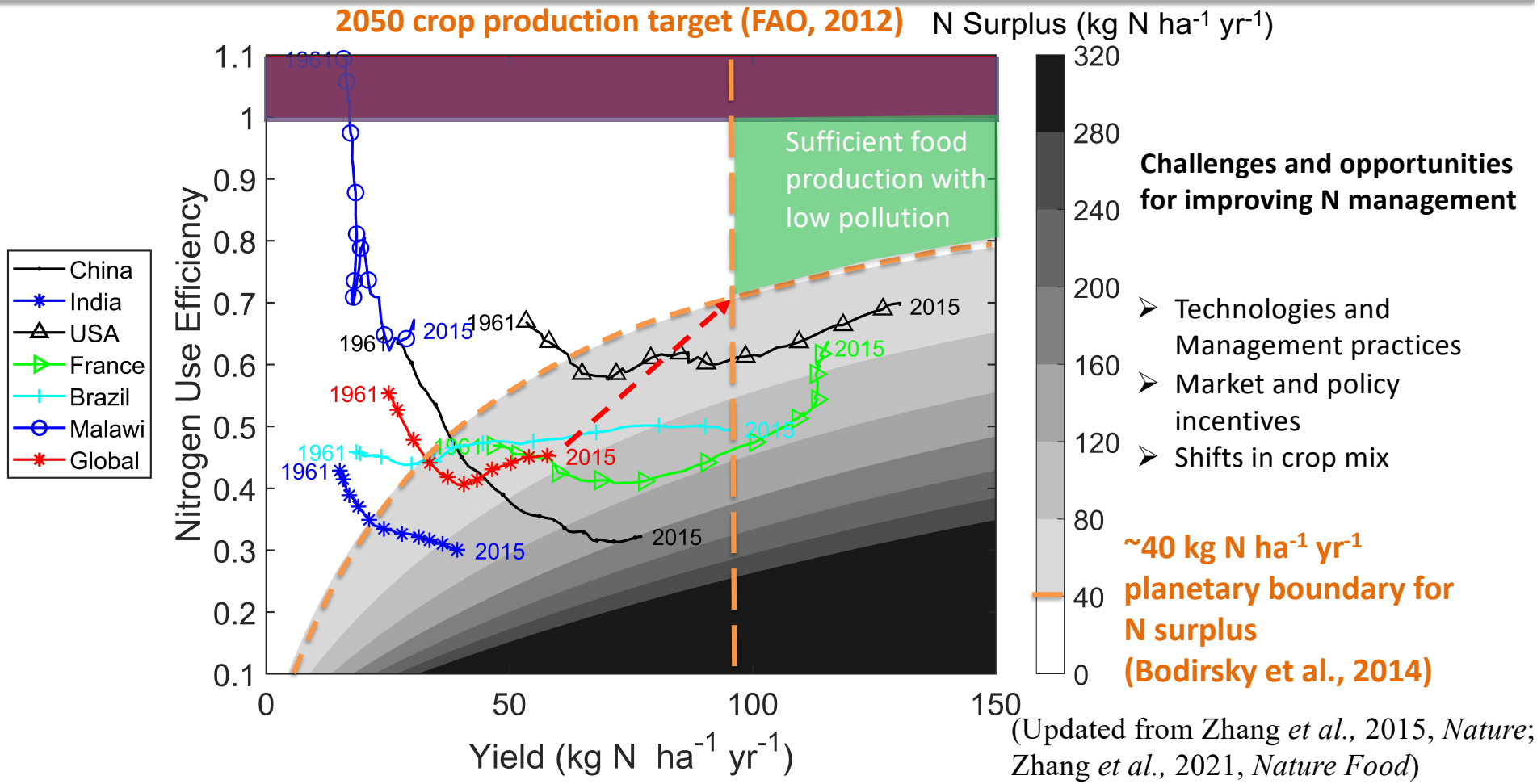
(Huang *et al.*, 2019, *Environmental Research Letter*)



Zhang *et al.*, in review at *Nature Food*)

➢ *NUE Challenges and Opportunities ?*

Meeting the Food and Environment target in 2050



Challenges and opportunities for improving N management

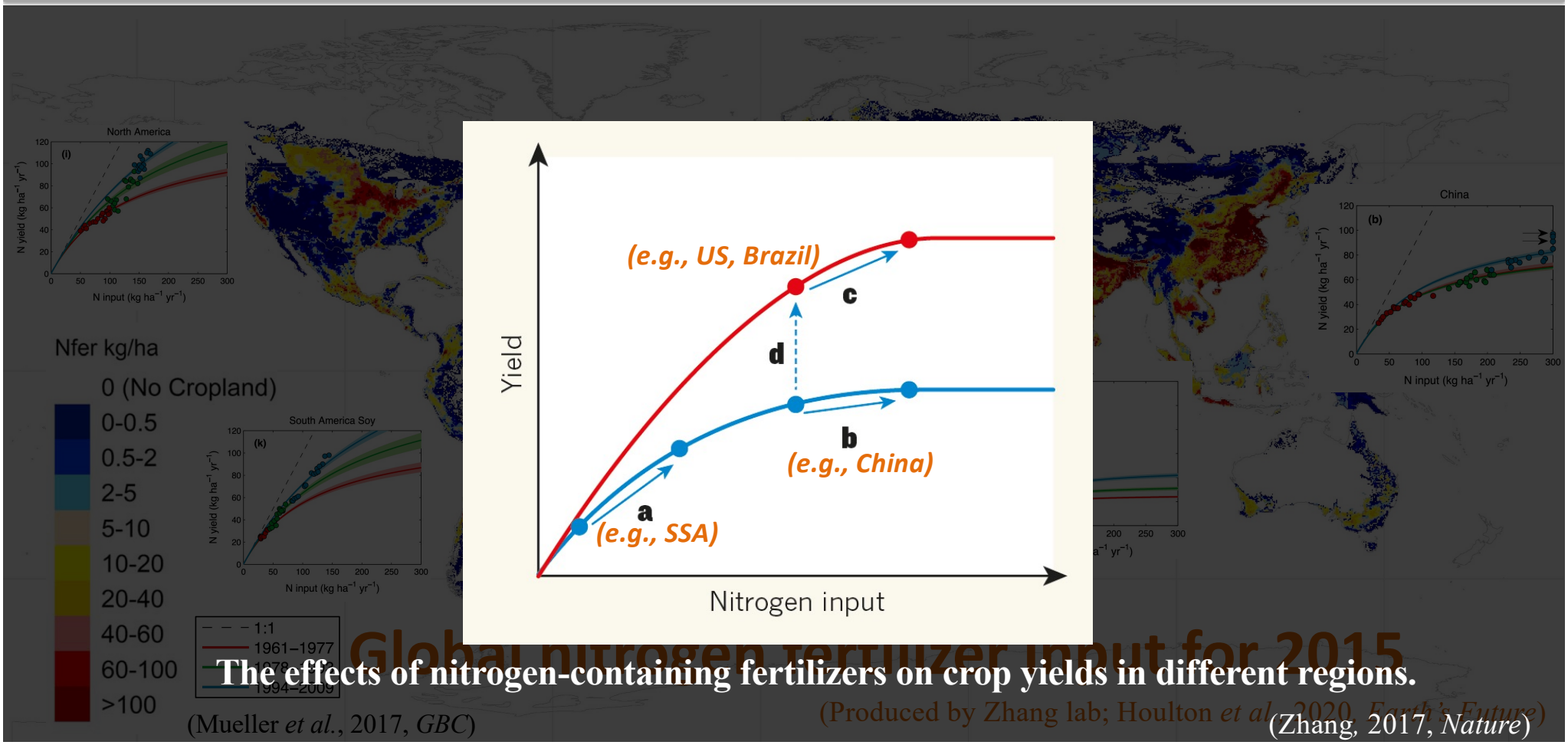
- Technologies and Management practices
- Market and policy incentives
- Shifts in crop mix

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

(Updated from Zhang *et al.*, 2015, *Nature*; Zhang *et al.*, 2021, *Nature Food*)

➢ *NUE Challenges and Opportunities ?*

Reallocating Food Production Around the World



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

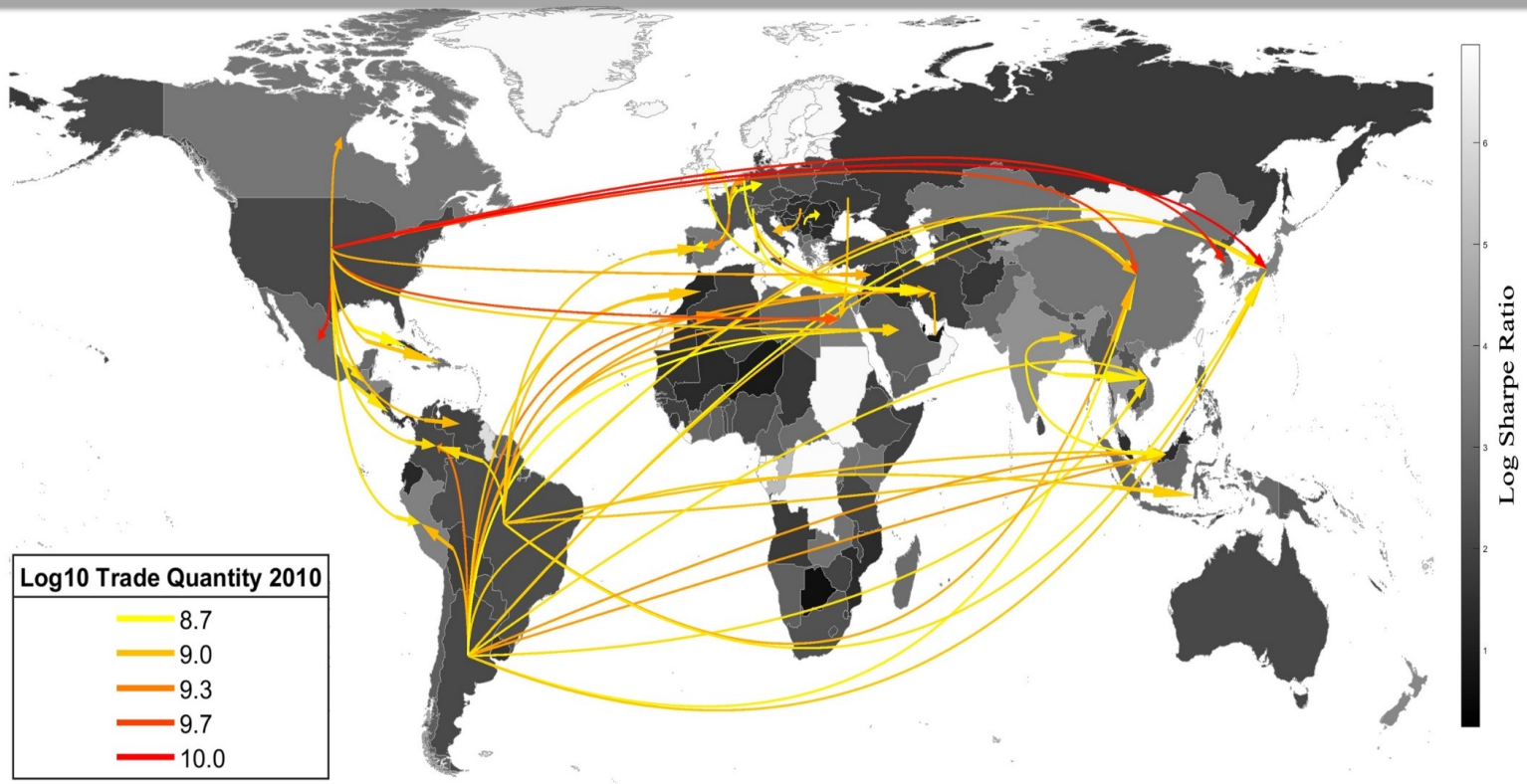
(Mueller *et al.*, 2017, *GBC*)

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

(Zhang, 2017, *Nature*)

➢ *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)

Transdisciplinary & Transnational

The impact of trade policies beyond N

nature food

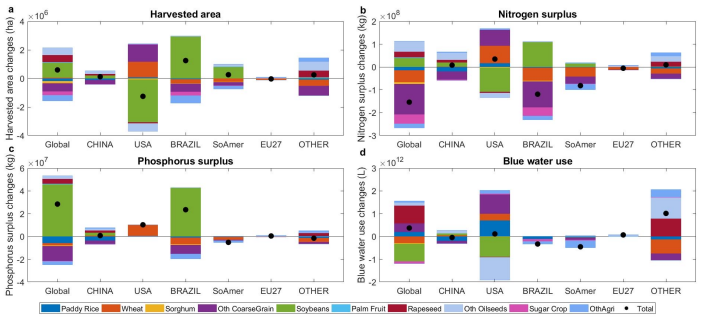
ARTICLES

https://doi.org/10.1038/s43016-021-00338-1

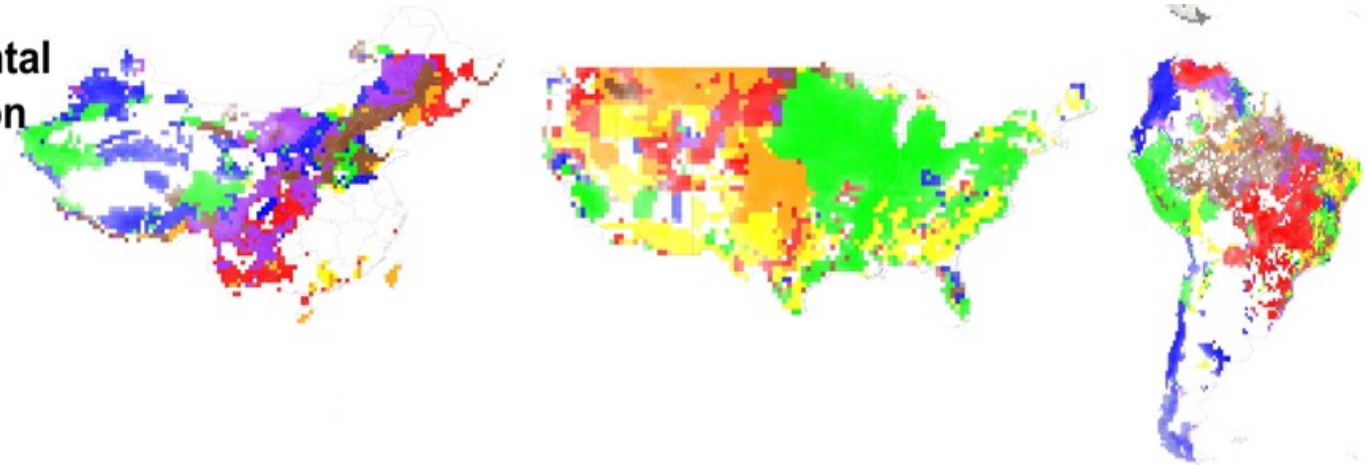
Check for updates

The increasing global environmental consequences of a weakening US–China crop trade relationship

Guolin Yao[1]✉, Xin Zhang[1]✉, Eric A. Davidson[1] and Farzad Taheripour[2]



Environmental degradation hotspots



iFarm Student Investigation

Welcome to iFarm!

Walk into any grocery store, and you will find bananas from Brazil, rice from China, olive oil from Italy, strawberries from Mexico, and more. As we move boatloads and plane loads of food all around the world every day, we are transporting massive amounts of water, nutrients and energy from one continent to the other. As a consequence, we can no longer manage farms on a county-by-county basis or even a country-by-country basis.

Pick a country/region/issue of interest?

Regression Model and Forecasts for Nitrogen Emissions

Peter Andriszak

Directed Consulting 495

Use your statistical modeling skill?
What are the drivers for…?

Main Results Summary

- The regression model with a log transform on either the production amount or crop value worked the best.
- Europe has better NUE, but higher crop value possibly as a result
- An ARIMA model with Box-Cox transform was appropriate and gives us a fair forecast for nitrogen emissions into 2028 (could be extended out further)
- We found out either the U.S. is more wasteful in some ways in NUE, or for some reason India just uses significantly less nitrogen for their crops.

- Other variables should be looked for that may be significant in relation to nitrogen emission level predicted from GDP of country
- The Tukey pair wise mean comparison test will work for specific countries but there'd be many different combinations with this method. A Fischer's LSD test or some other method may be used

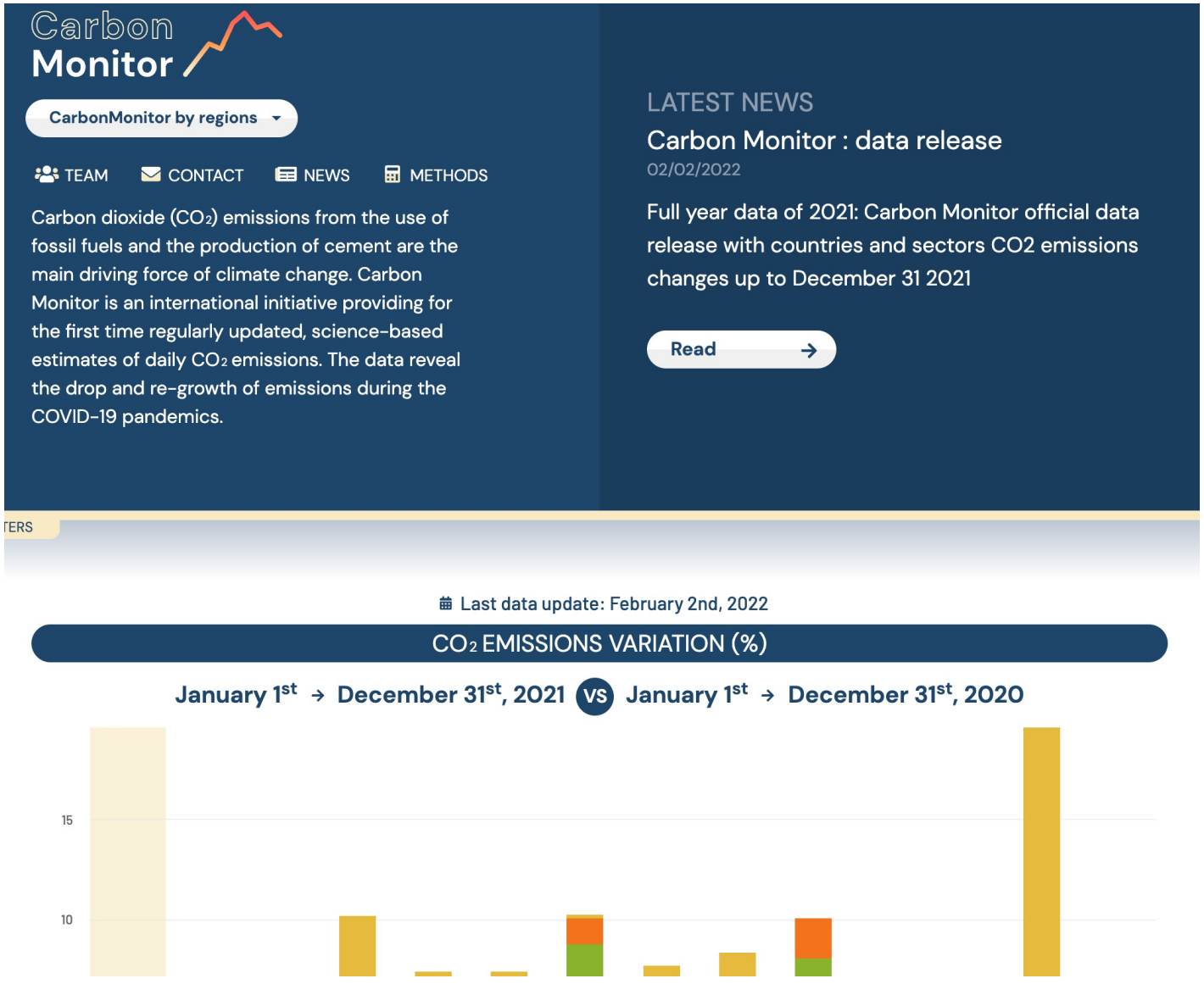
An Individual Crop's Influence on the Global Nitrogen Pollution

Mitchell Krystofiak, Justin Ventura

Use your skills in mechanistic modeling?
IF…(trade shift, diet change) then...

Our Research Goals

- Part of our big focus is to examine how any one particular crop impacts the total Nitrogen pollution of both individual countries and the whole world. This project focuses on the select few crops that reflect both the high and low contributors.
- Another goal of this project is to examine the volatility of a crop and how it impacts different countries and the world. What would happen if we removed this crop entirely, and replaced it with a similar agricultural product that produced less Nitrogen pollution?
- The final goal we have is to examine the volatility of imports and exports on the Nitrogen economy. What would happen if we stopped the import of a crop, and grew it domestically instead?



Data Visualization and communication?
e.g. A Nitrogen Monitor webpage?

https://carbonmonitor.org/

Acknowledgement

Major Collaborators at UMCES

Eric A. Davidson, Vyacheslav Lyubchich, Cathlyn D. Stylinski, William Dennison, Andrew Elmore, Mark Cochrane, Tan Zou, Srishti Vishwakarma, Guolin Yao, Jing Zhao, Mary Ollenburger, Matthew Lisk, Cassie Doty, …
Faculty advisory Committee: Keith Eshleman, Matthew Fitzpatrick

Major Collaborators at Other Institutions

Page Kyle, PNNL; Kimberly Pfeifer, *Oxfam America*; Luis Lassaletta, *Technical University of Madrid;* Ray R. Weil, University of Maryland; Denise L. Mauzerall, *Princeton University;* David R. Kanter, *New York University;* Carole Dalin, *University College London;* Adam Komarek, *University of Queensland;* 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*; Weifeng Zhang, China Agricultural University; Baojing Gu, Zhejiang University; Xiaoyuan Yan, China Academy of Science;…

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United States Department of Agriculture- Agriculture and Food Research Initiative;
Yale Center for Environmental Law & Policy Research Prize Fellowship

Thank you!

Website: https://research.al.umces.edu/xzhang/