Realigning 4R Nutrient Stewardship for Future Farming Systems

Webinar 28 February 2022

Moderator: Achim Dobermann, Chief Scientist, IFA

Presented by members of the Scientific Panel on Responsible Plant Nutrition

Tom Bruulsema, Chief Scientist, Plant Nutrition Canada
Kaushik Majumdar, Director General, African Plant Nutrition Institute
Mike McLaughlin, Professor, University of Adelaide
Xin Zhang, Assistant Professor, University of Maryland

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https://www.sprpn.org

Realigning 4R Nutrient Stewardship for Future Farming Systems

OUTLINE

1. Why is 4R important and why does it need to change? - Tom Bruulsema
2. Opportunities and challenges for sub-Saharan Africa - Kaushik Majumdar
3. Innovations in fertilizer source technologies - Mike McLaughlin
4. Extending the 4R scope to improve social equity around the world - Xin Zhang
5. Summary - who needs to do what? and what will success look like? - Tom Bruulsema

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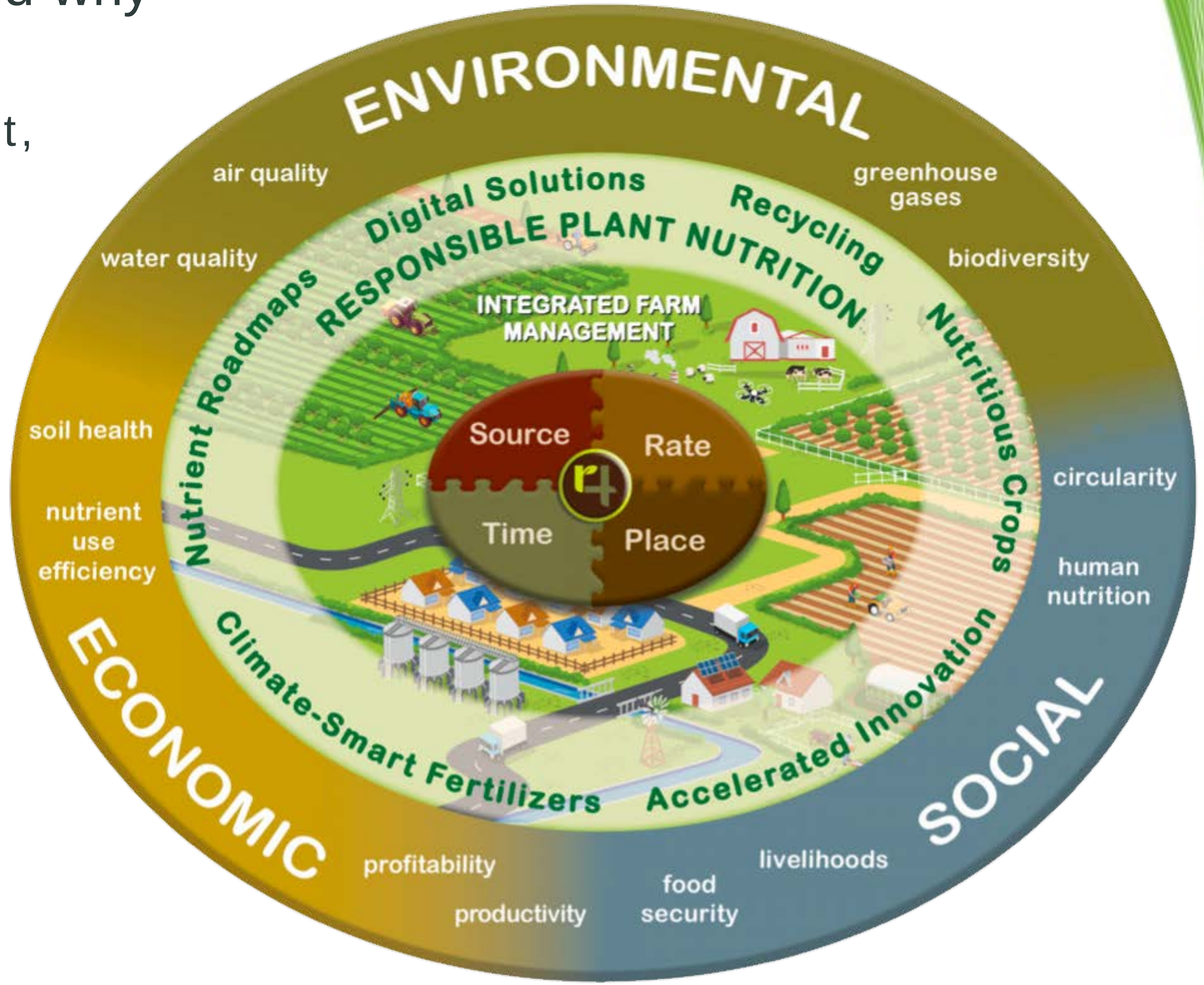
ON RESPONSIBLE PLANT NUTRITION

Why is 4R important and why does it need to change?

Tom Bruulsema, Chief Scientist,
Plant Nutrition Canada

- Relevant to each of the six actions of the new paradigm for responsible plant nutrition.
- A simple concept, with a critical role in a complex system.
- Apply the right source, at the right rate, at the right time, in the right place.
- What's right? Sustainable.
- Sustainability is not simple. Priorities among outcomes vary. Site-specific.



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The six actions of Responsible Plant Nutrition make specific demands on 4R programs and practices.

1. Nutrient Roadmaps: Global and regional initiatives need 4R practices plugged into policies, business models, platforms, and programs verifying sustainability.
2. Digital Solutions: Delivering data-driven, more precise and more dynamic 4R nutrition decisions.
3. Recycling: Optimizing utilization of renewable nutrient resources requires choices for "right source" to consider recycled forms where feasible.
4. Nutritious crops: Crop nutrient applications that improve human nutrition and health.
5. Climate-Smart Fertilizers: Considering the carbon footprint of nutrient source, including emissions associated with both its manufacture and its use.
6. Accelerated Innovation: Testing 4R components in adaptive management systems for faster translation into practice.

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4R – Opportunities and Challenges in Africa

Kaushik Majumdar
African Plant Nutrition Institute, Morocco

Africa population

In 2021: 1.37 billion; About 18% of world population

In 2100: 4.28 billion; About 41% of world population

Africa food insecurity and malnutrition

98 million people in sub-Saharan Africa have food consumption gaps in 2020 that are reflected by high or above-usual acute malnutrition

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Africa crop production context

Soils are low in plant nutrients & organic matter

46 M hectares or over 60% of the arable land are degraded

Average plant nutrient application in sub-Saharan Africa is 16 kg/ha/yr

Africa tree cover loss

39 million hectares of tree cover lost between 2001-2015

About 93% tree cover loss caused by shifting cultivation

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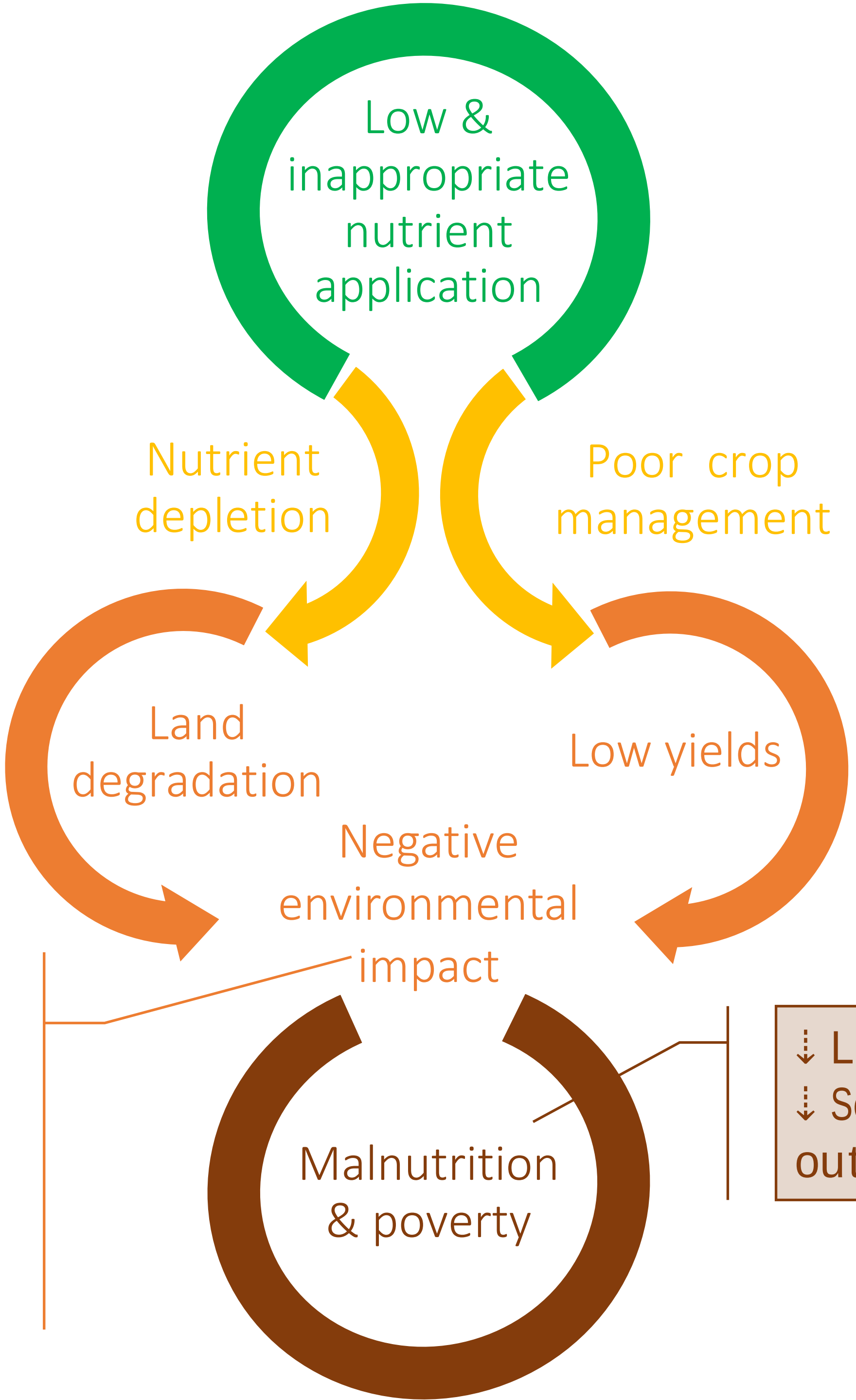
Vicious cycle triggered by low & inappropriate nutrient applications



↑ Extensive agricultural systems
↑ Carbon & biodiversity losses
↓ Ecosystem services
↑ GHG (burning biomass)
↑ Climate change aggravation

↓ Livelihood qualities
↓ Socio-economic outcomes

4R SOLUTIONS PROJECT

Solution

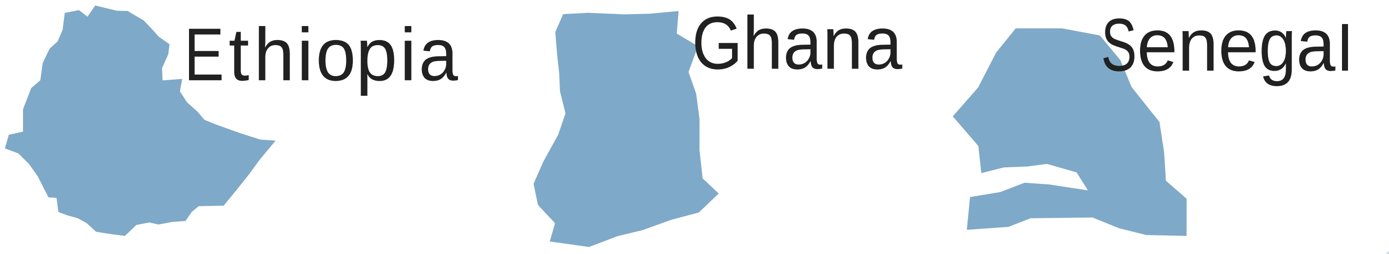
www.4Rsolution.org

- Integrate 4R Nutrient Stewardship
- Improve agricultural productivity and farm income
- Incorporate important gender and environmental resilience strategies

Funded by Global Affairs Canada to improve the livelihoods of **80,000 smallholder farmers.**

Activities led by apni

Identification of crop production constraints → Development of site-specific 4R-based solutions → Dissemination & scaling of 4R solutions



IMPLEMENTING PARTNERS

Fertilizer Canada / Fertilisants Canada

Co-operative Development Foundation of Canada since 1947

apni African Plant Nutrition Institute

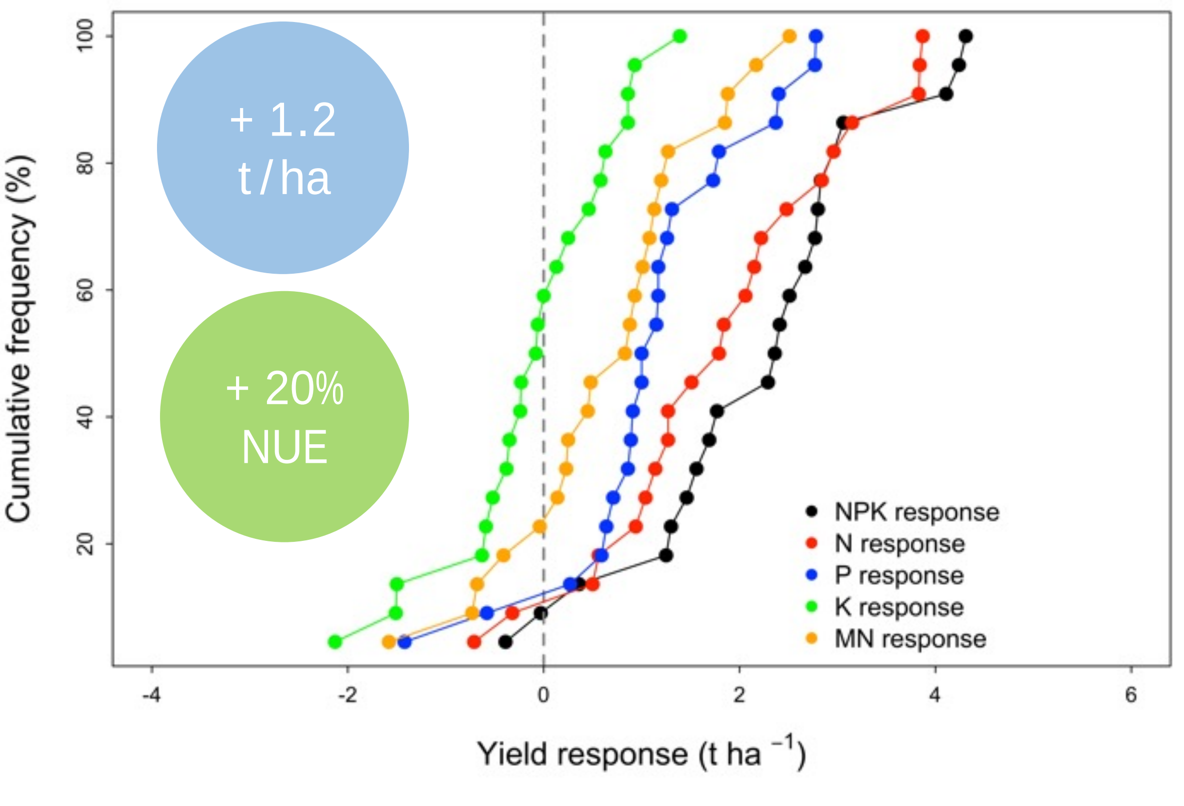
Global Affairs Canada / Affaires mondiale Canada

Plant Nutrition Canada

Achieving impact with 4Rs –

Strong maize micronutrient (MN) responses in Ghana

- Identification of crop production constraints
- Development of site-specific 4R-based solutions
- Dissemination & scaling of 4R solutions

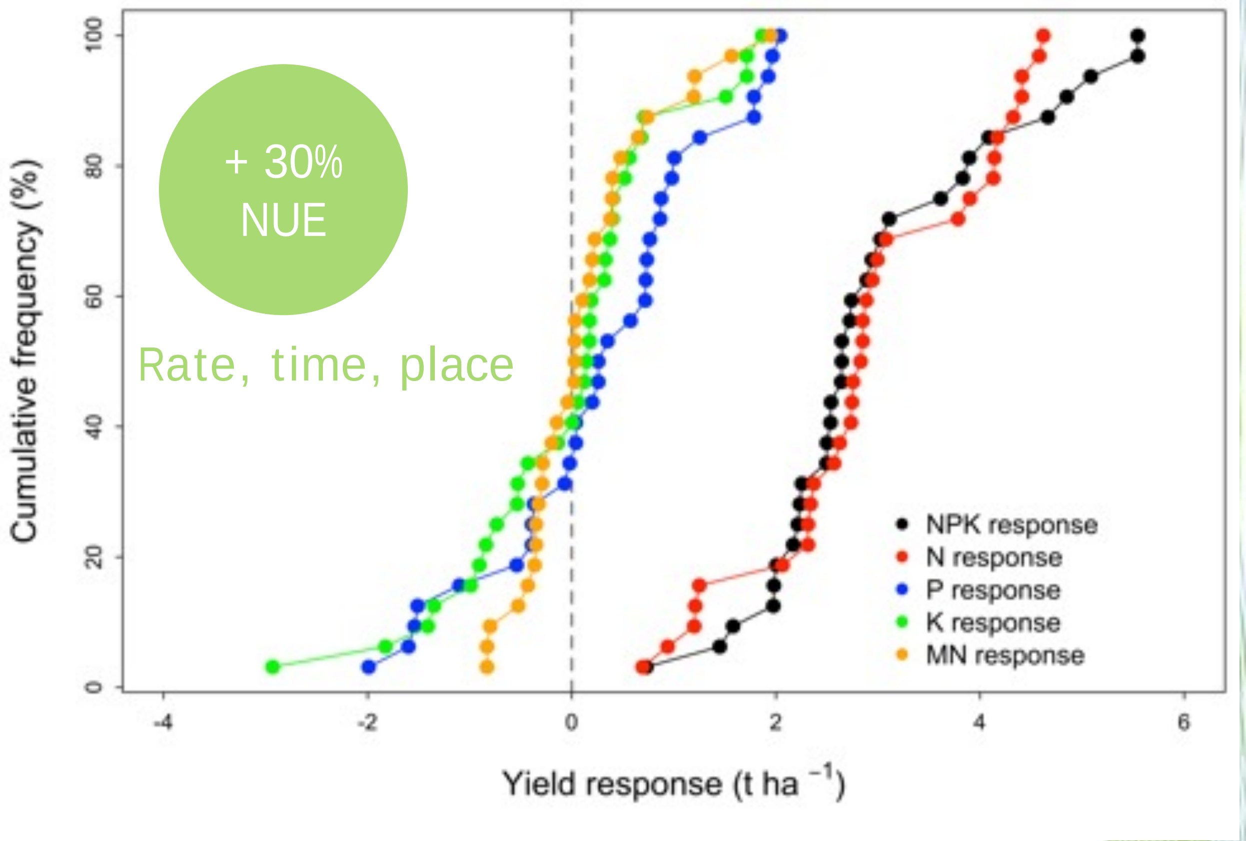


Achieving impact with 4Rs –
Optimizing urea management in N dominated wheat systems in Ethiopia

Identification of crop production constraints

Development of site-specific 4R-based solutions

Dissemination & scaling of 4R solutions

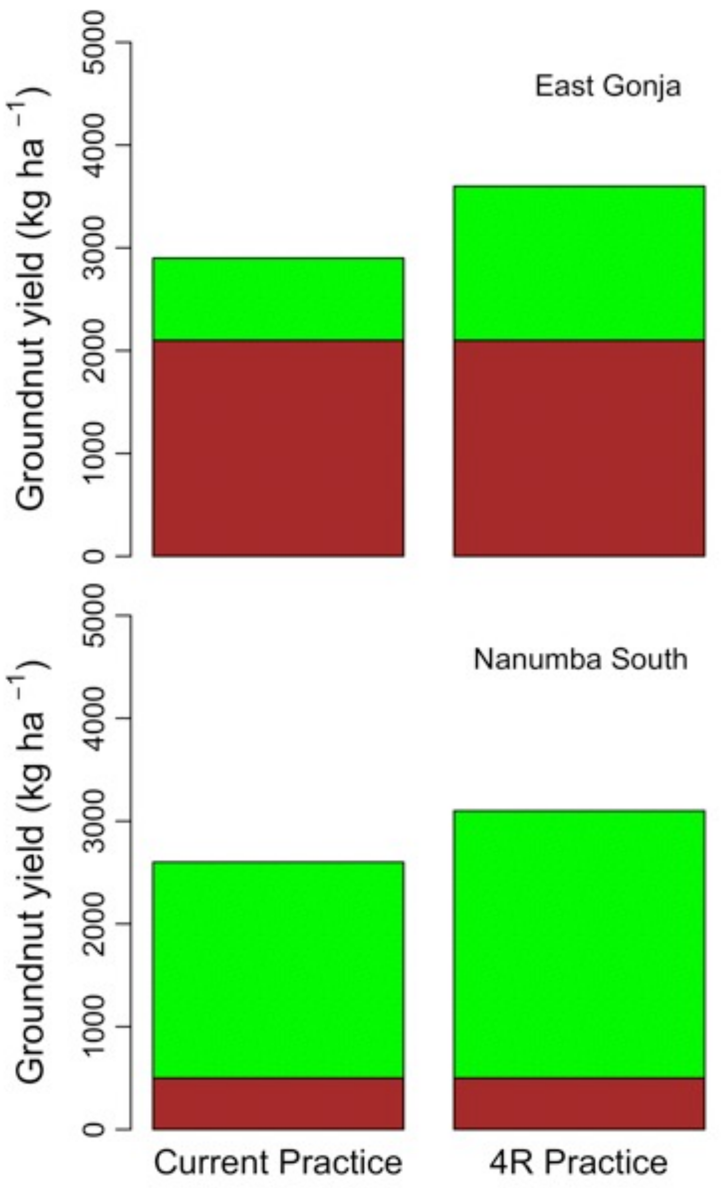


+ 30% NUE

Rate, time, place

Achieving impact with 4Rs –
Groundnut in Ghana

- Site-specific interventions
  - Optimize crop management
  - 4R Nutrient Management



Mean actual yield recorded on farmers' fields based on an agronomic survey

Additional yield attained when implementing current practice and 4R practice in the 4R learning site

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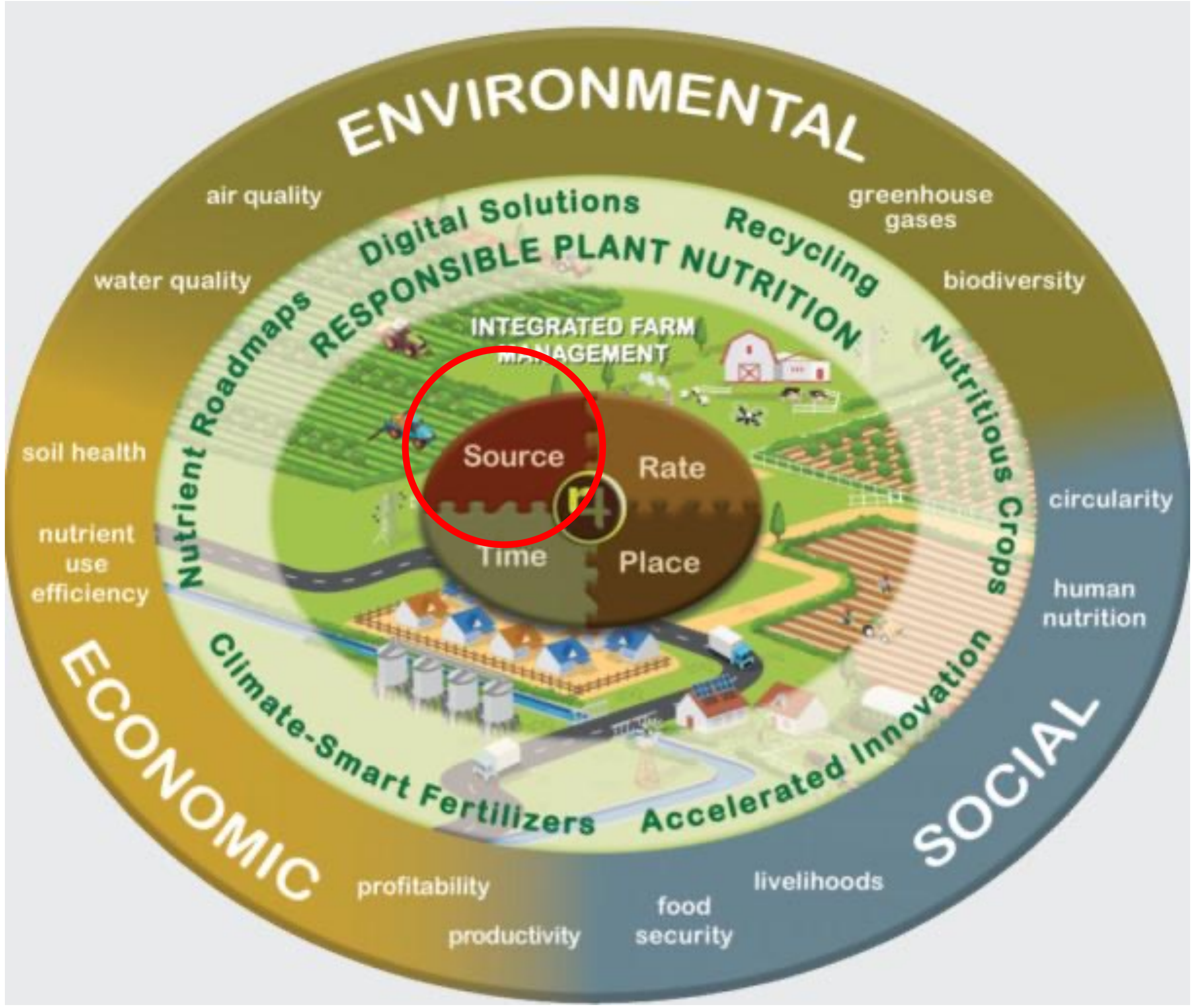
4R - Innovations in fertilizer source technologies

M.J. McLaughlin

Fertiliser Technology Research Centre, The University of Adelaide, Australia

Where fertilizer 'source' fits into the 'extended' 4R paradigm



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1. What is the ‘right’ fertilizer source

1. Match the fertilizer to soil physical and chemical properties – soil testing
2. Recognize synergisms among nutrient elements and sources
3. Recognise blend compatibility of materials
4. Recognize benefits and sensitivities to associated elements
5. Control effects of non-nutritive elements

Existing 4R program

6. Supply nutrients in quantifiable and available forms
7. Use climate-smart forms
8. Use recycled forms where feasible
9. Consider biological inoculants

Modified for “extended” 4R paradigm

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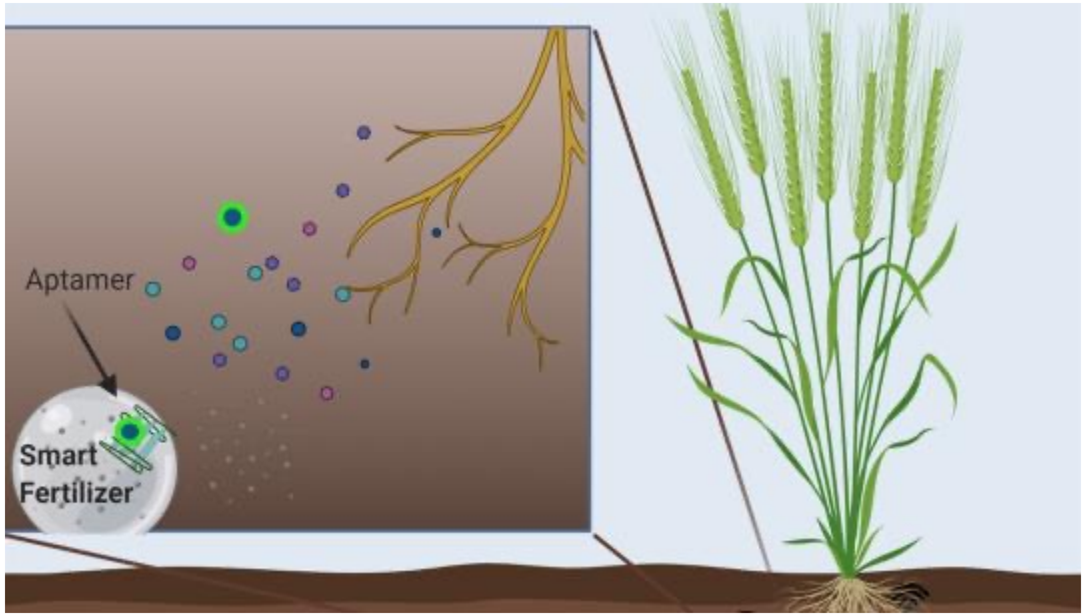
6. Supply nutrients in quantifiable and available forms

- There is a vast array of new technologies to enhance fertiliser nutrient use efficiency and/or minimise losses to the environment



Source: newsroom.carleton.ca

- New stabilised N-fertilizers
- Sulfur-polymer composites
- Zeolites
- Nanomaterials
- Hydrogels
- Layered double hydroxides
- Mechanochemical products
- Graphene-based materials
- Metal-organic frameworks
- “Smart” products

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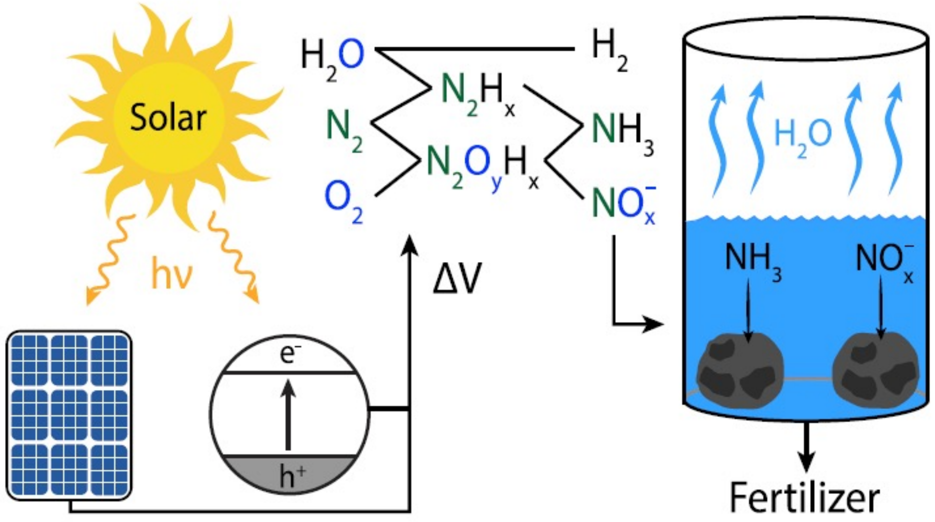
7. Use climate-smart forms

- Solar fertilizers – could decentralise and ‘green’ through the generation of NH_3- or NO_3^--based fertilizers



Comer et al. 2019 Joule 3(7): 1578-1605

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8. Use recycled forms where feasible

- Re-use of nutrients contained in waste materials
  - P recovered from waste streams
  - P, Mn and Zn from spent alkaline and lithium batteries

Source: mining.com

Sarens et al. 2021 J. Environ. Manage. Joule 280: 111743

Yue et al. (2021). *Chemical Engineering Journal 426, 131311.*

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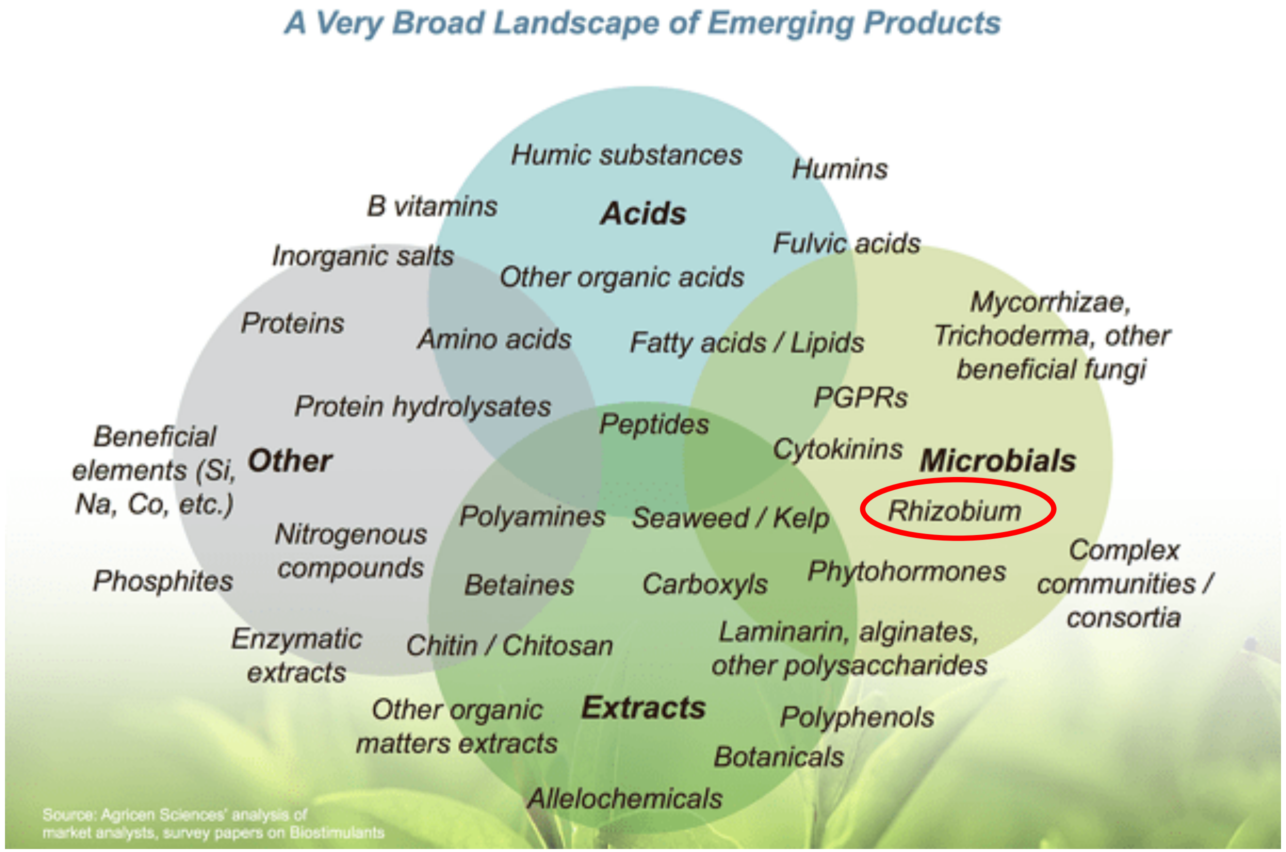
9. Consider biological inoculants

- Microbial inoculants, biostimulants and biological fertilizers are a rapidly expanding sector of the fertilizer industry/market and the range of new products is huge



Source: /www.agricen.com

Key points

- To adapt to the changing paradigm of sustainable crop nutrition, the “Right Source’ term in the 4R concept for fertilizer management needs to place increasing emphasis on

  - Use of enhanced efficiency fertilizers (slow- or controlled release) to improve agronomic efficiency and minimise losses to the environment
  - Use of climate–smart fertilizers to reduce energy footprint (manufacturing and transport) and emissions (greenhouse gases)
  - Use of recycled nutrient forms to encourage a circular economy
  - Use of non-nutrient inoculants in synergy with nutrient applications to enhance crop growth

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FURTHERING 4R NUTRIENT STEWARDSHIP

Issue Brief 03, January 2022

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Extending the 4R scope to improve agricultural sustainability around the world

Xin Zhang, Associate Professor
University of Maryland Center for Environmental Science

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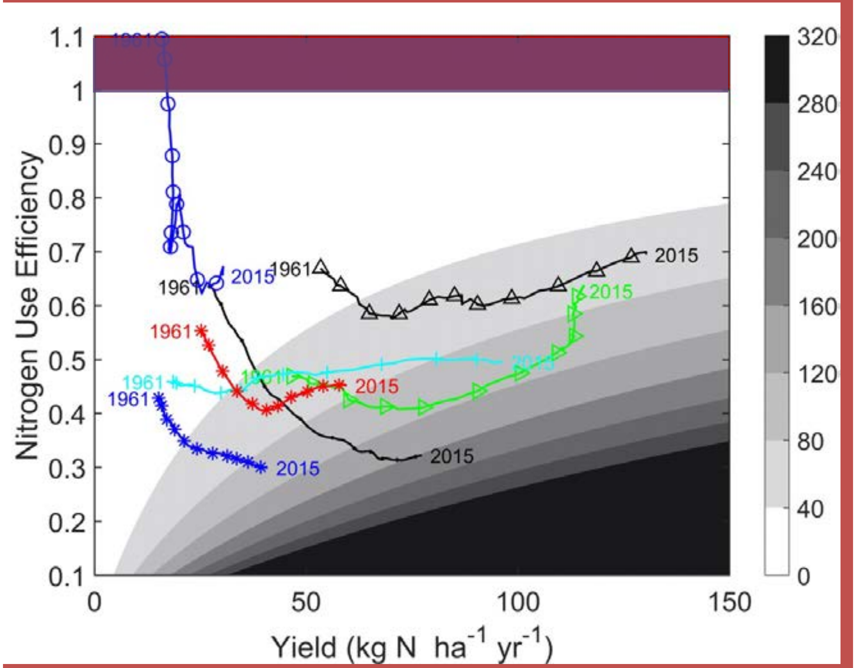
A Call for Expanding the Scope of Nutrient Management?

- Consider socioeconomic impacts
- Extend from a single plot to the agro-food system
- Engage stakeholders beyond farmers

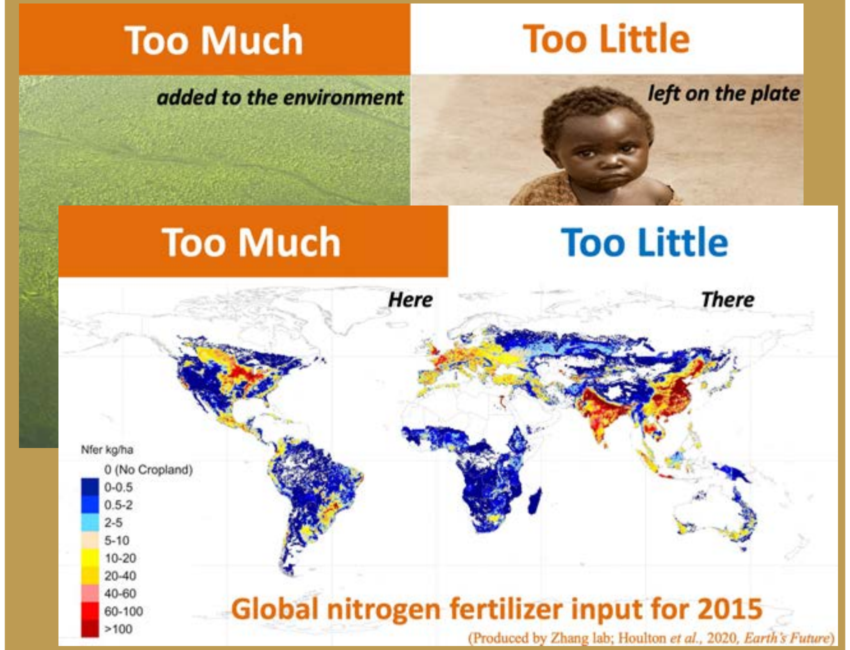
Consider socioeconomic impacts

“High-tech, low-efficiency” paradox



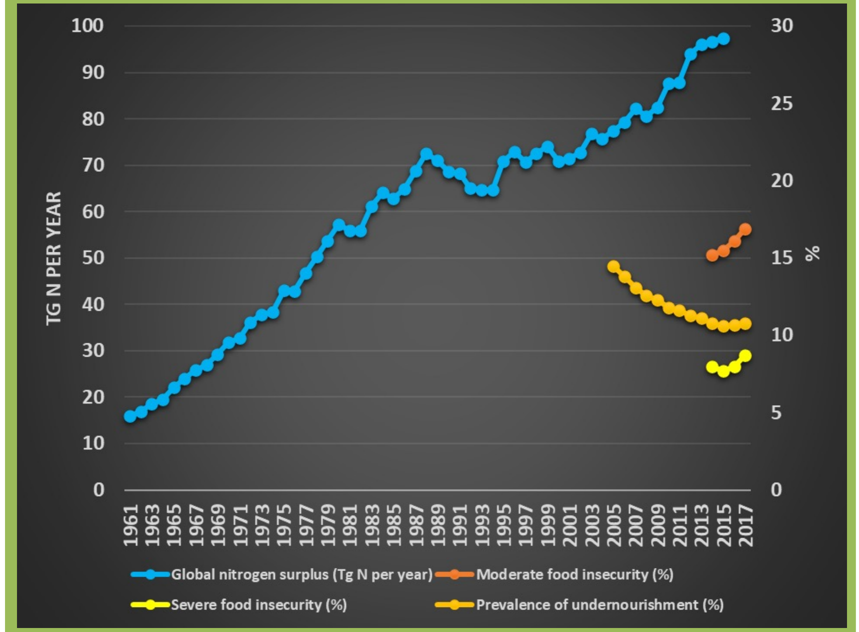
Extend from production-focused to agro-food system

“Too much, too little” paradox



Engage stakeholders beyond farmers

“High productivity, low nutrition” paradox



Consider socioeconomic impacts

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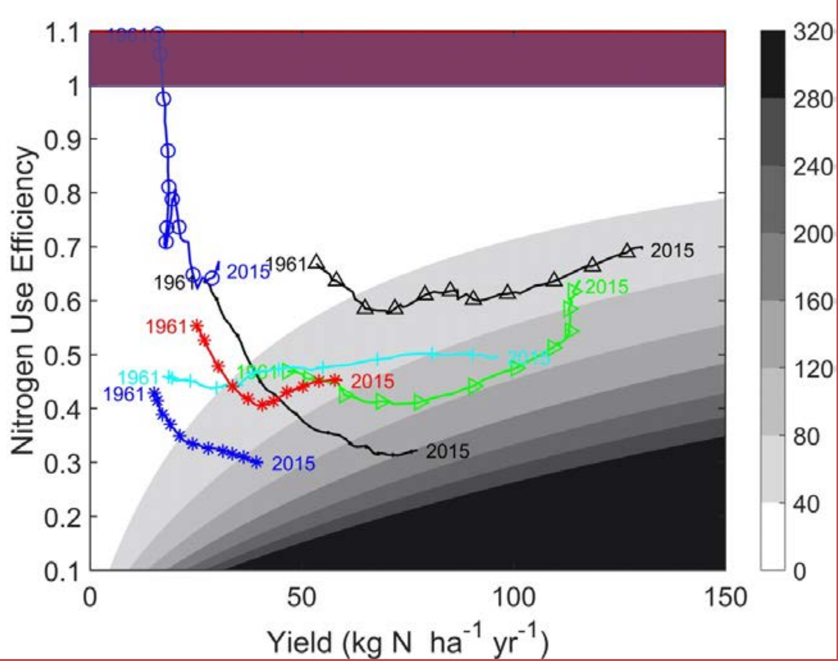
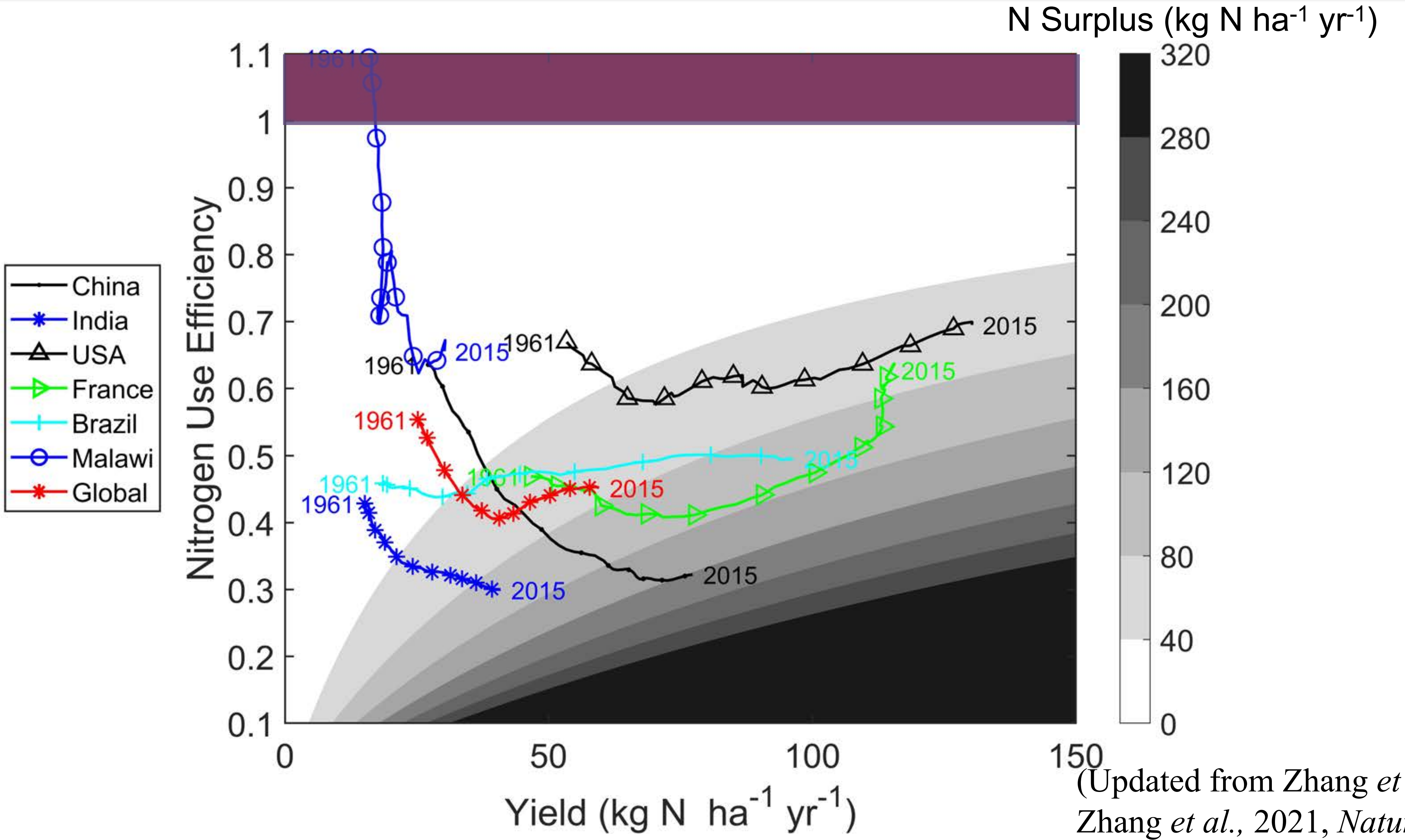


-Increasingly more available and affordable Technologies and Management Practices for Improving NUE (TMPs)

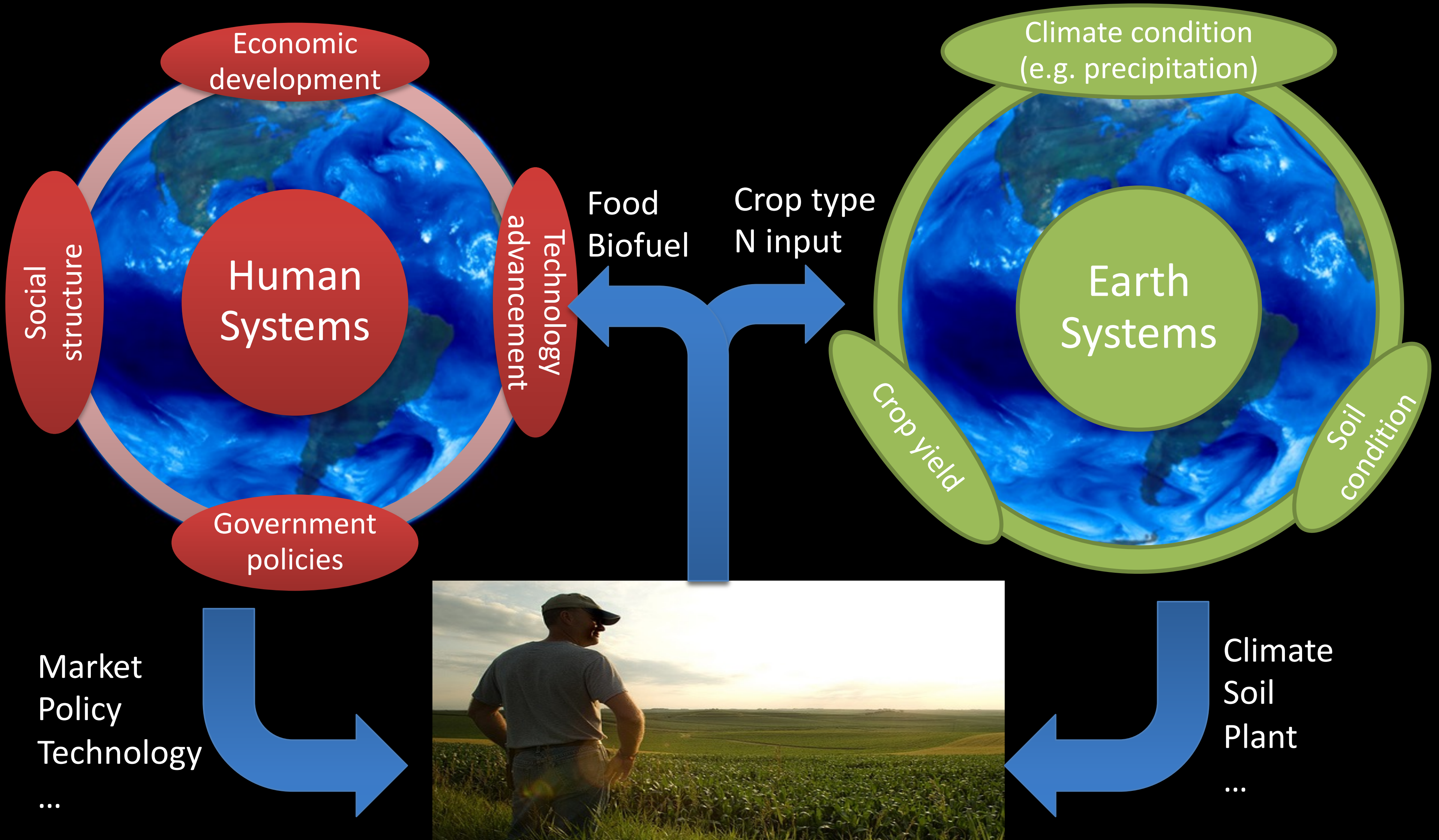
-Declining or stagnant NUE worldwide

NUE Trend for crop production



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

Converge socioeconomic and ecological processes



Extend from production-focused to agro-food system

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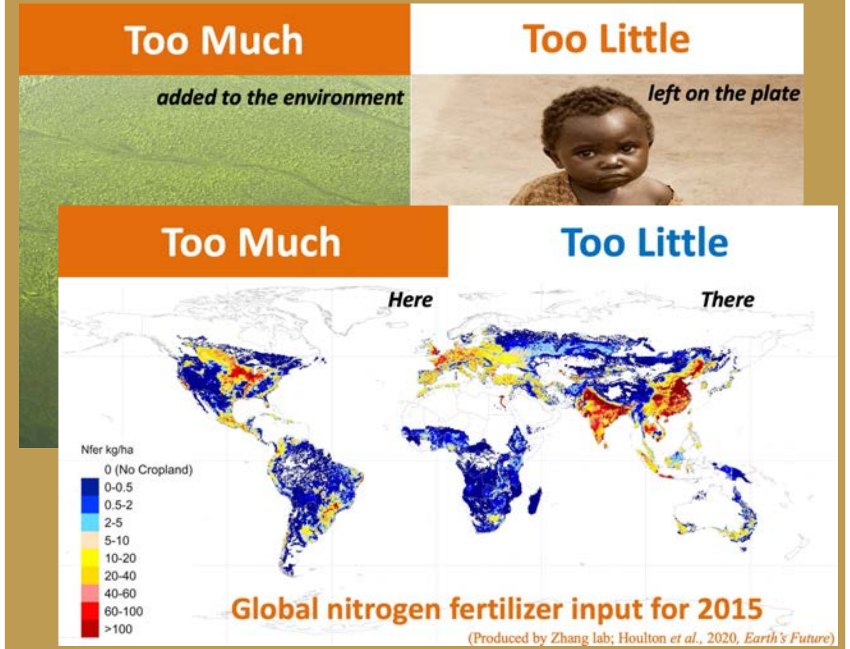
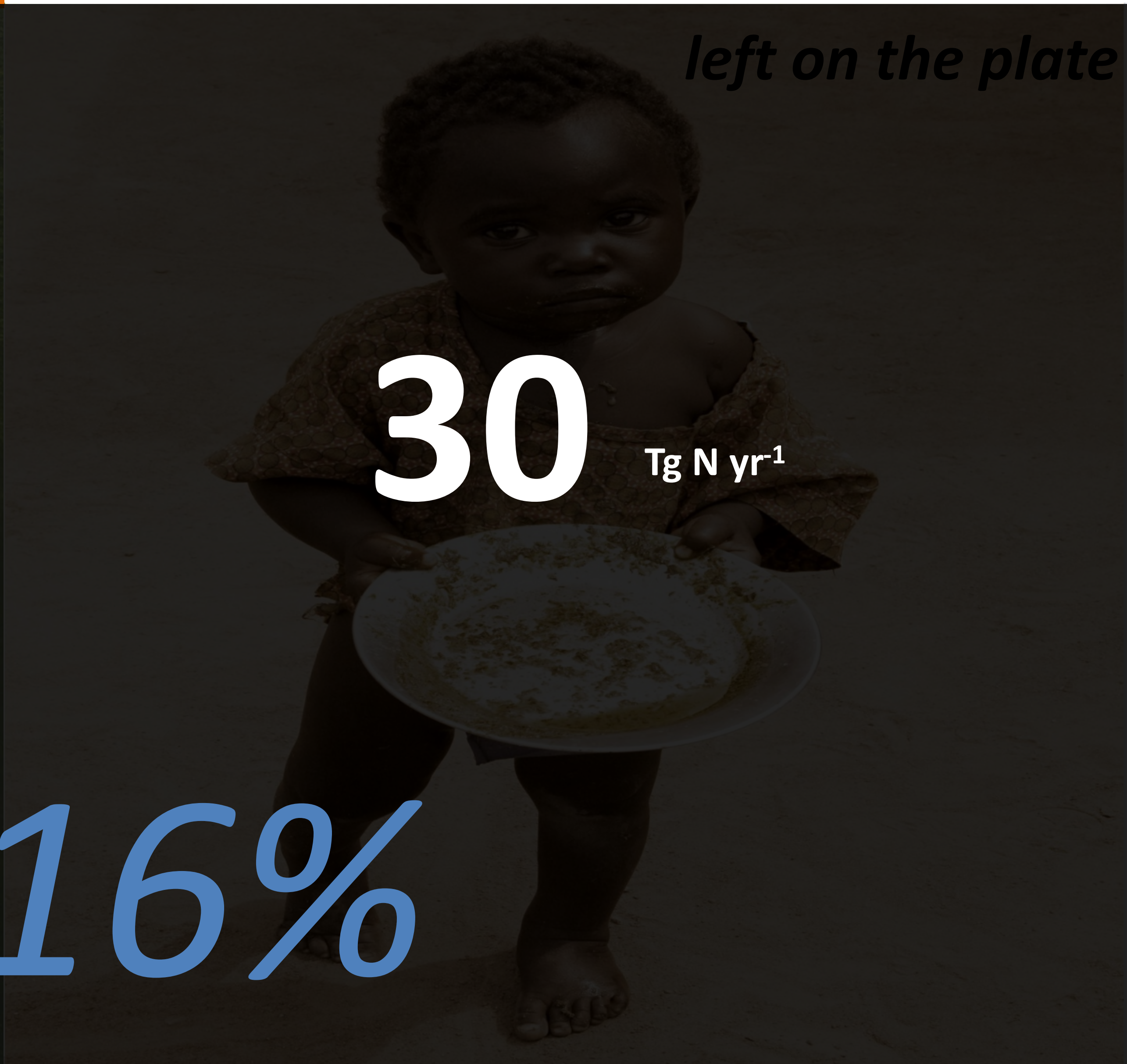


Too Much

Too Little

Too Much

Too Little



added to the environment

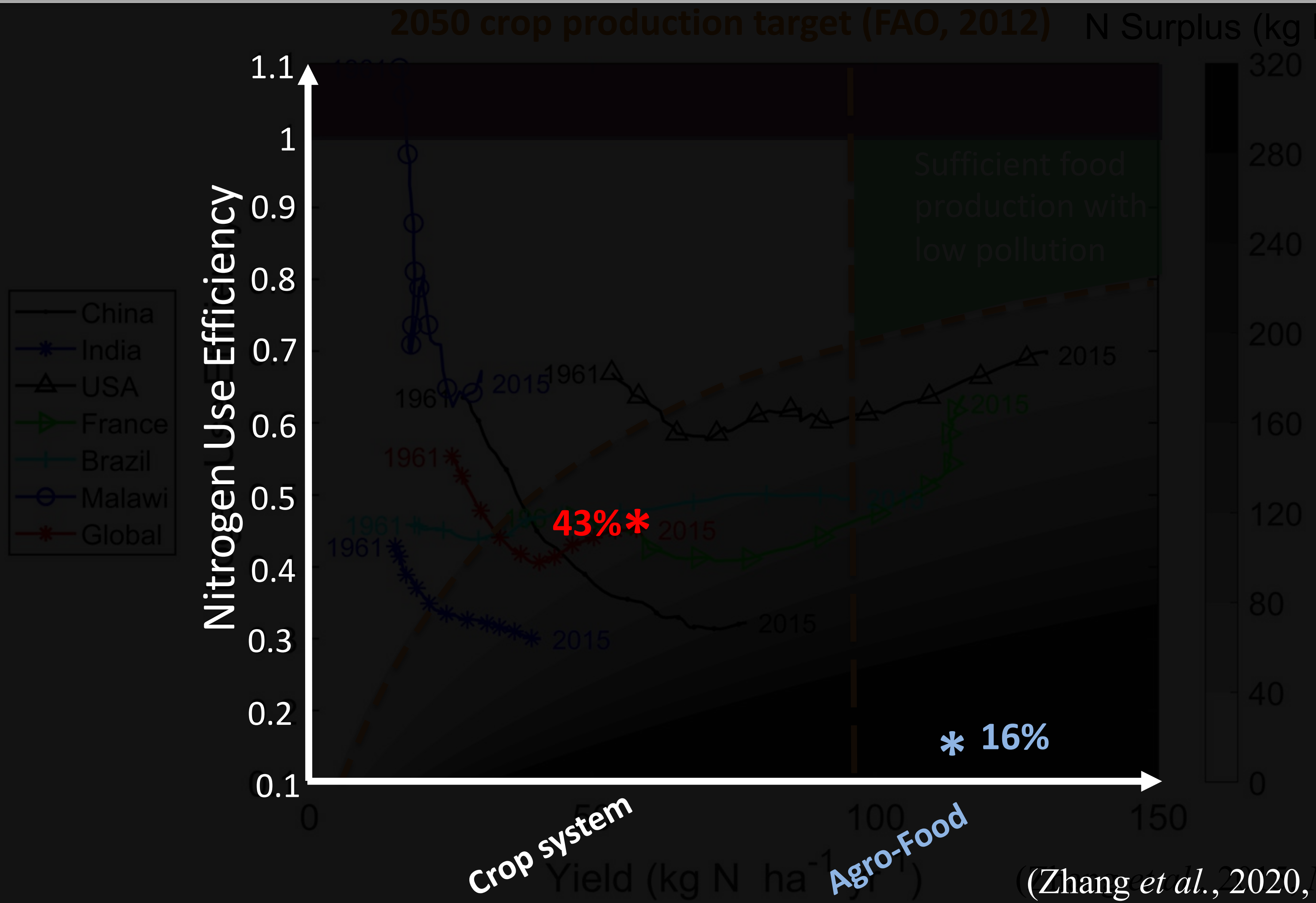
187

left on the plate

30 Tg N yr^{-1}

~16%

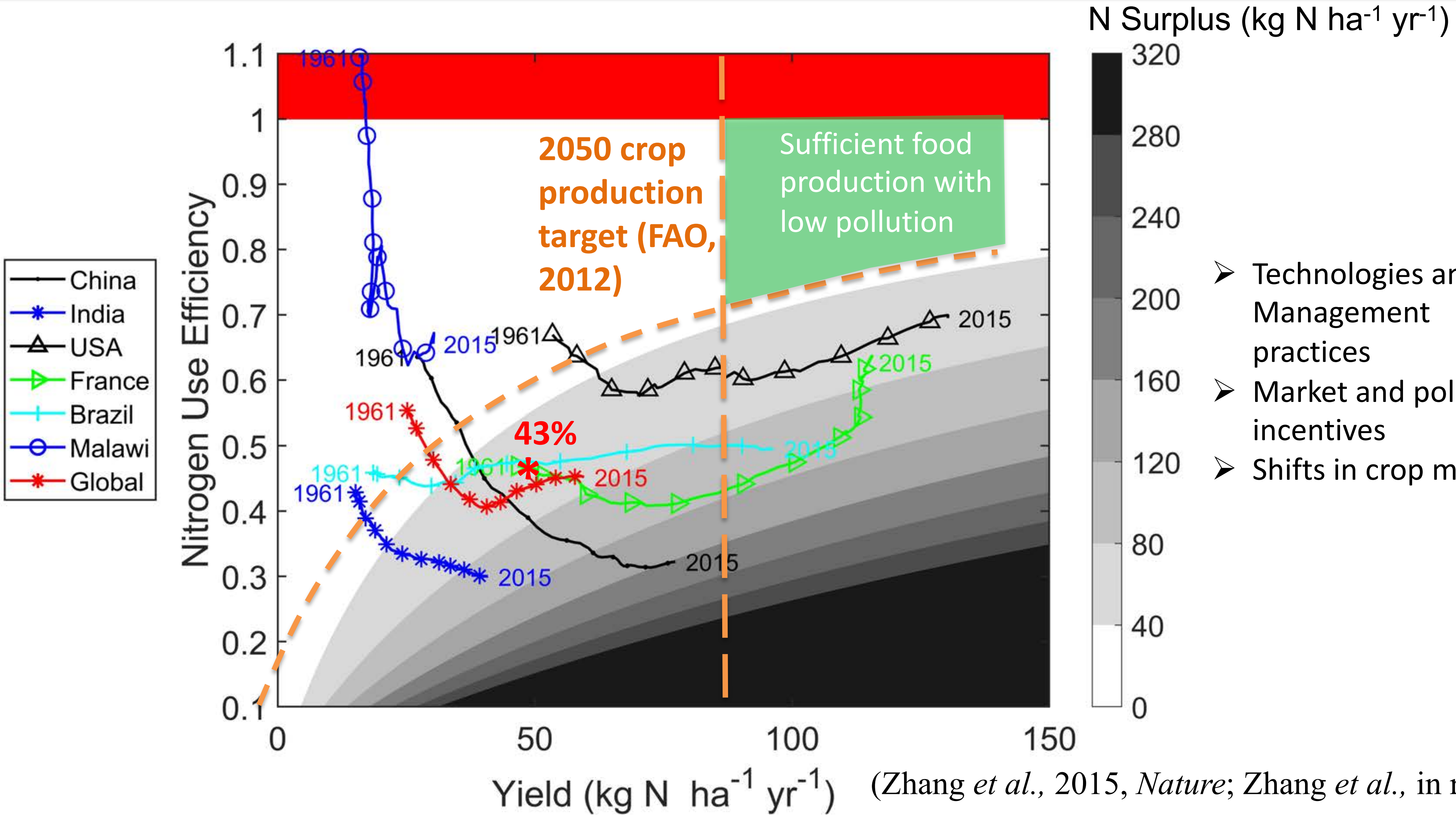
NUE beyond crop production



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

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

NUE beyond crop production



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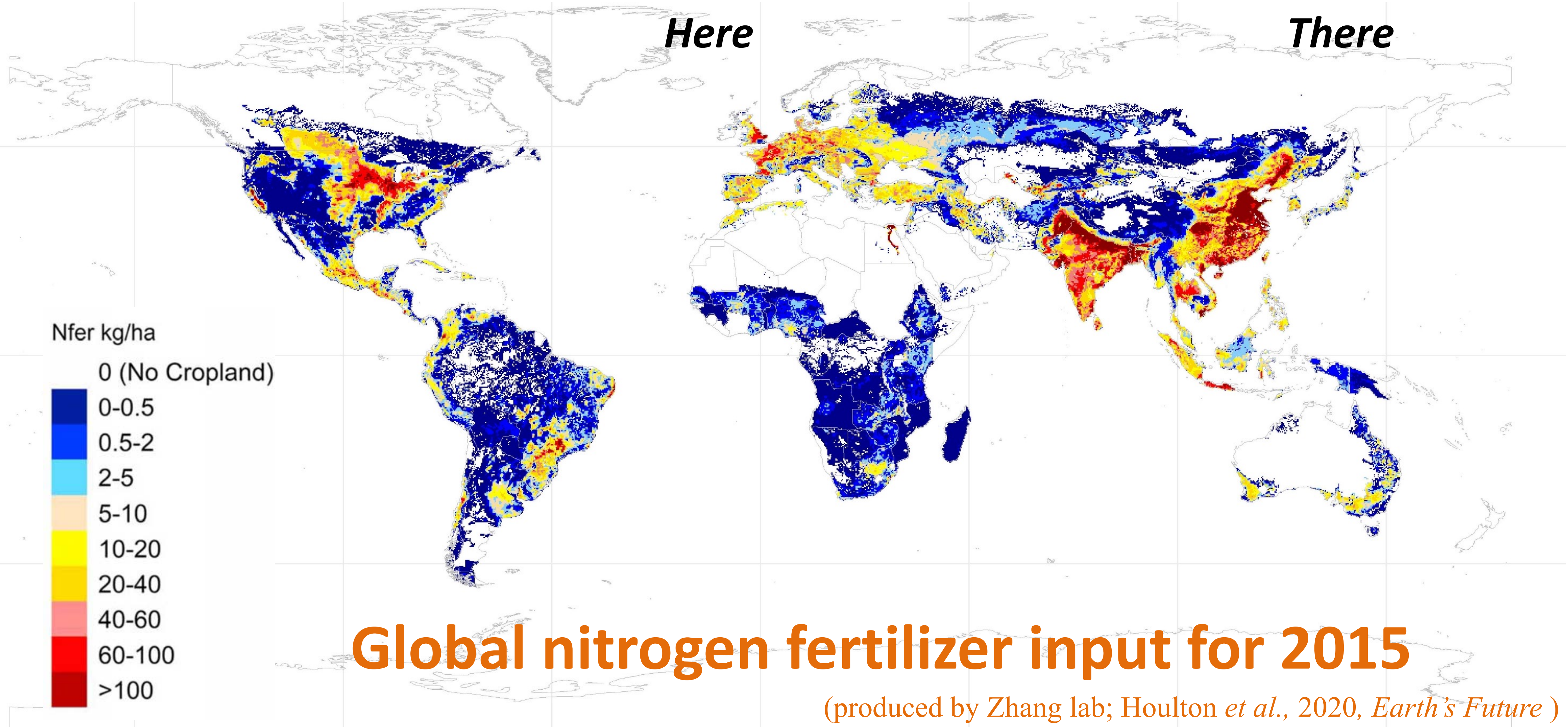
(Zhang *et al.*, 2015, *Nature*; Zhang *et al.*, in review)

Too Much

Too Little

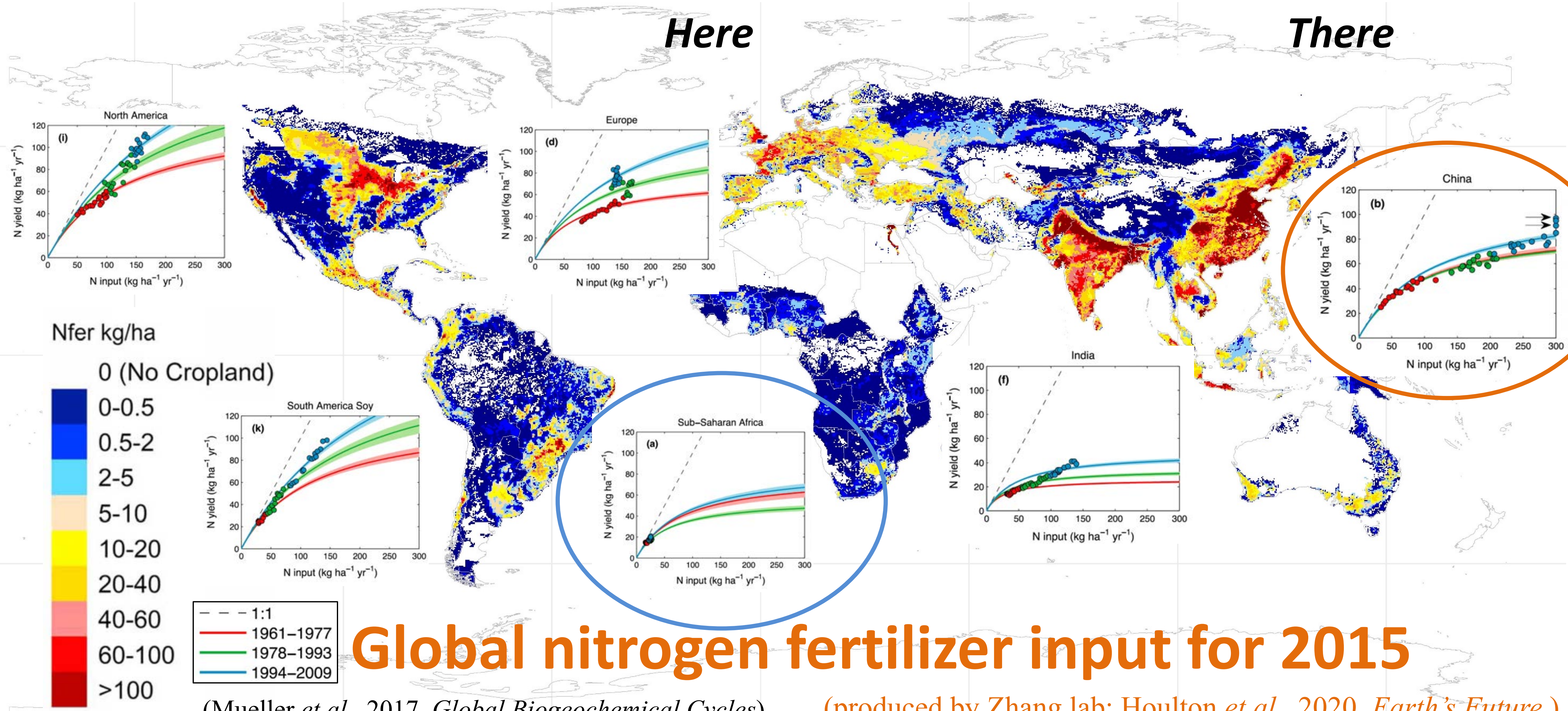


Global nitrogen fertilizer input for 2015

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

Too Much

Too Little



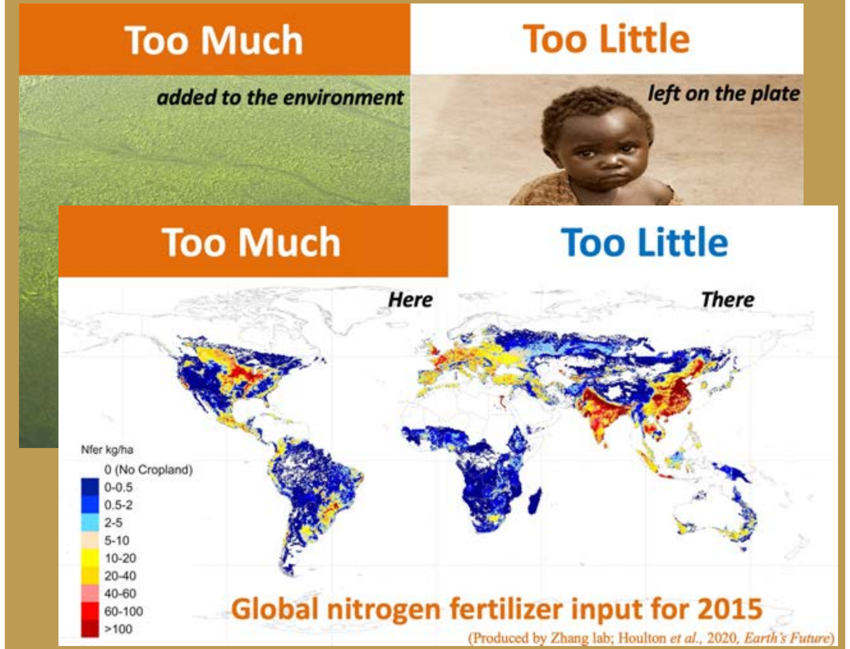
Global nitrogen fertilizer input for 2015

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

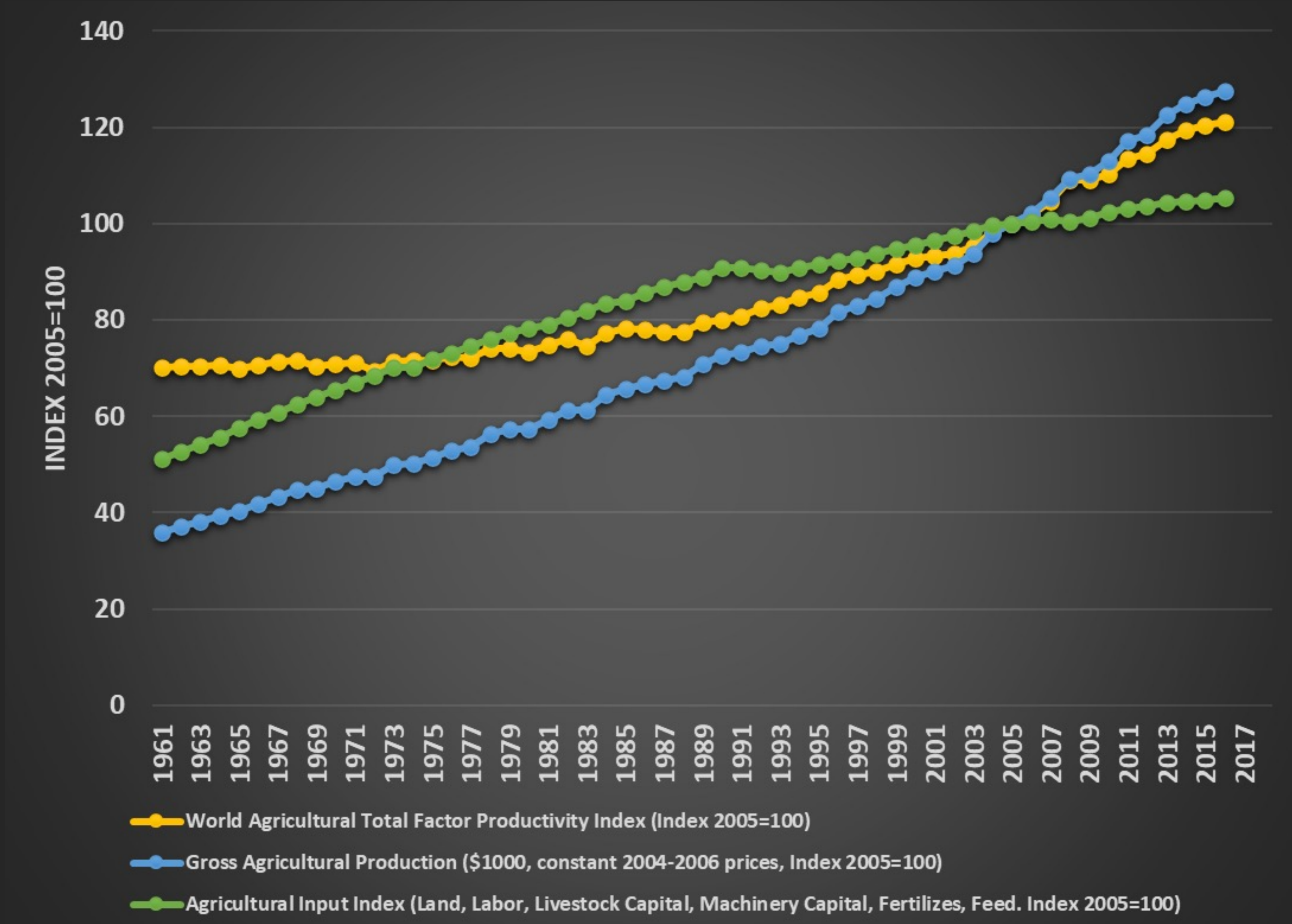
(produced by Zhang lab; Houlton *et al.*, 2020, *Earth's Future*)

Extend from production-focused to agro-food system

"Too much, too little" paradox

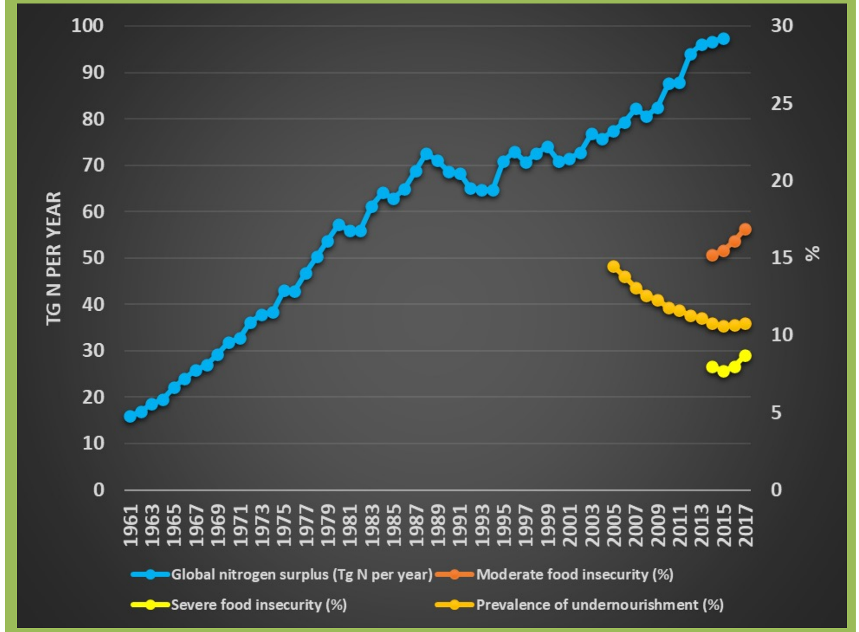


Increasing agricultural productivity



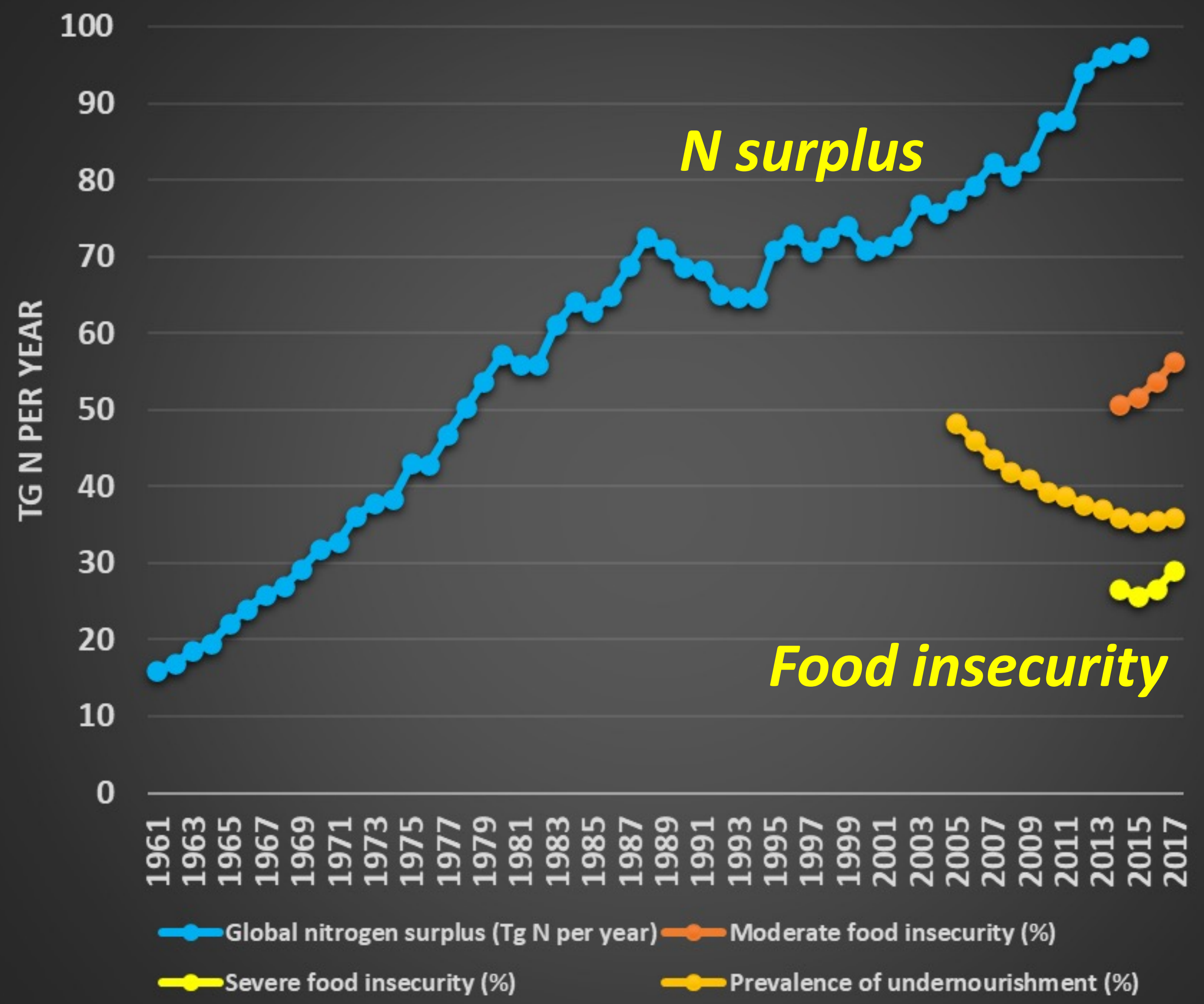
Engage stakeholders beyond farmers

"High productivity, low nutrition" paradox



(Zou & Zhang *et al.*, report to FAO)

Increasing agricultural productivity, but…



Engage stakeholders beyond farmers

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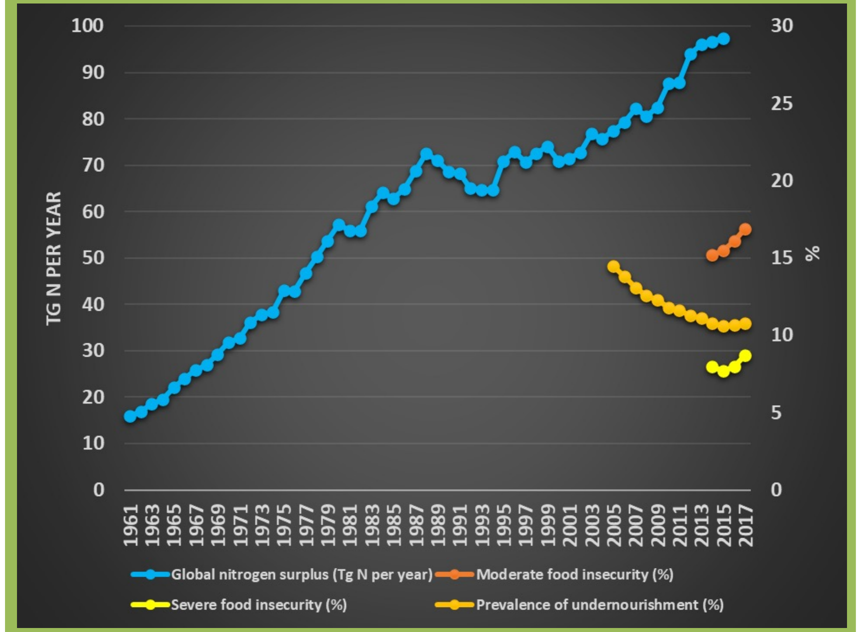

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Consider socioeconomic impacts

"High-tech, low-efficiency" paradox

Extend from production-focused to agro-food system

"Too much, too little" paradox

Engage stakeholders beyond farmers

"High productivity, low nutrition" paradox

How to get it right?

4R Framework & Principles: What needs to change?

Tom Bruulsema, Chief Scientist,
Plant Nutrition Canada

1. FUTURE FARMING SYSTEMS INTEGRATION
   - Integrate with farming systems in transition
   - Use data-driven digital solutions to support decisions
   - Innovate using adaptive management
2. NEW CORE PRINCIPLES
   - Source, rate, time, and place
3. CONTRIBUTE TO SUSTAINABILITY PERFORMANCE REPORTING
   - Track practices and economic performance at the farm level
   - Share tracked data to report performance

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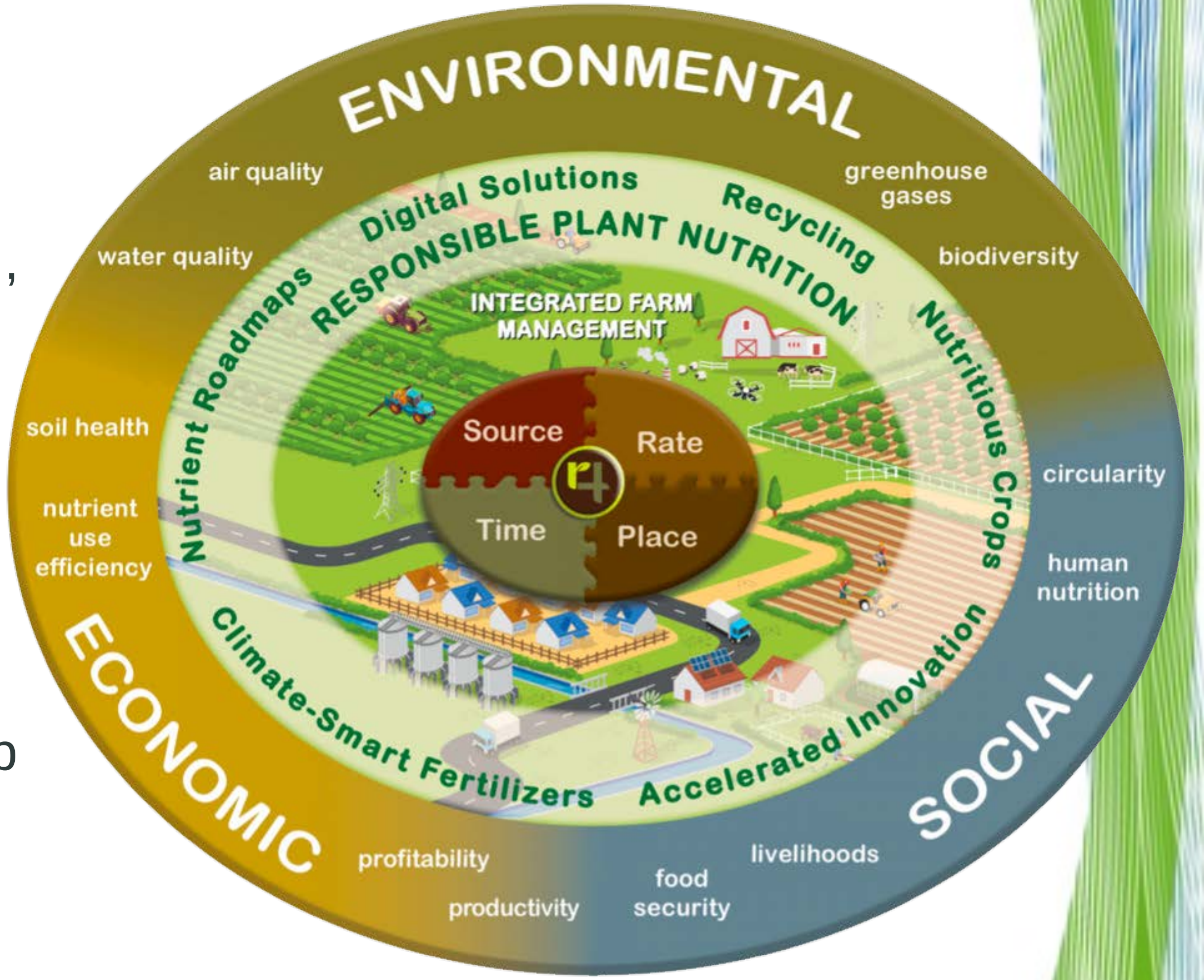
Future Farming Systems Integration

- Farming systems in transition – regenerative, circular, nature-based
  - Soil conservation
  - Integration with livestock
  - Mechanization, irrigation, fertigation → sustainable intensification
  - Better human nutrition → biofortification, better diets
- Data-driven digital solutions
  - GPS guidance
  - Decision support tools
- Adaptive management for accelerated innovation
  - Weather-responsive sensing tools and crop models



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New Core Principles

RIGHT SOURCE

- Supply nutrients in quantifiable available forms
- Use climate-smart forms
- Use recycled forms where feasible
- Consider biological inoculants

RIGHT RATE

- Address variability in crop response

RIGHT TIME

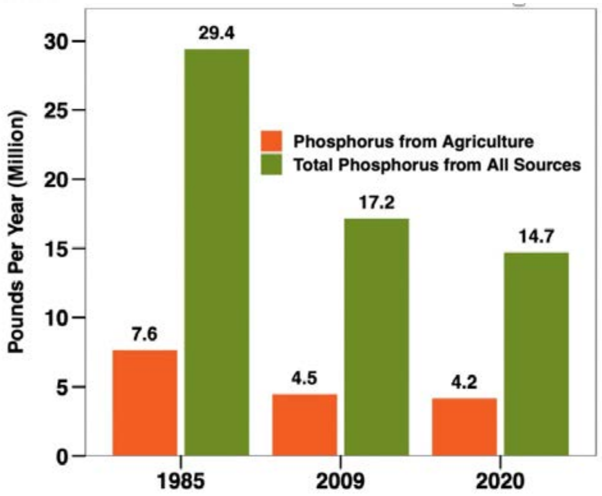
- Address changes in nutrient need through the growing season

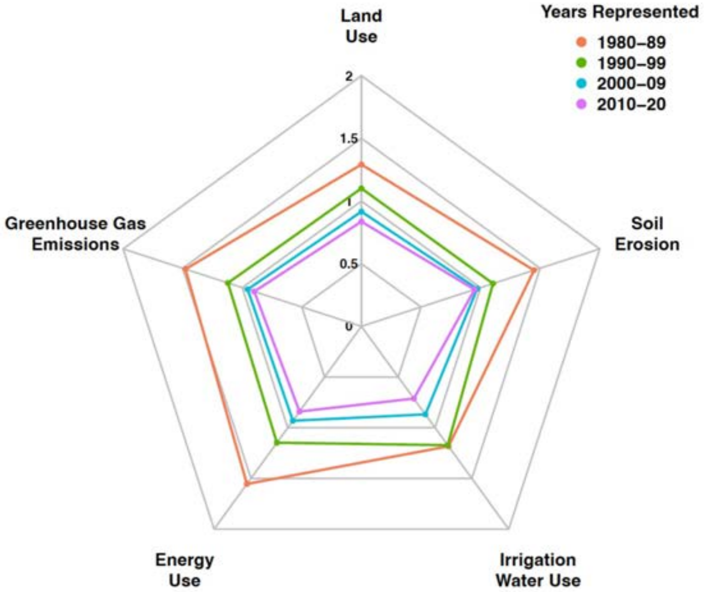
RIGHT PLACE

- Place nutrients to avoid loss

Sustainability Performance Reporting

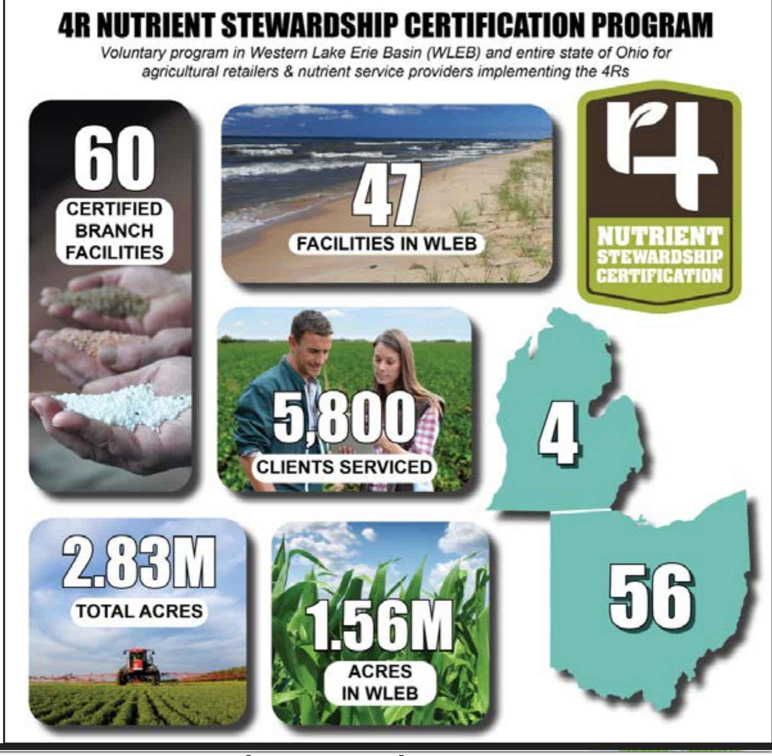
- Track practices at farm level
- Share tracked data to report performance
- Economic, environmental and social sustainability

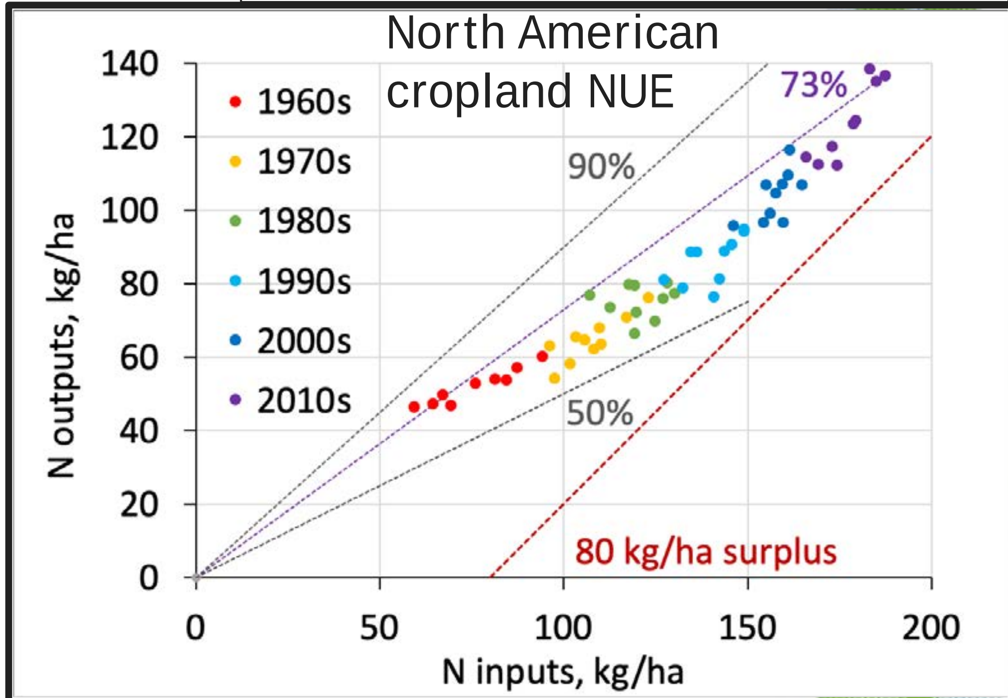




Chesapeake Bay Water Quality   Corn for grain

-------Field to Market 2021 Indicators Report-------





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Summary. Who needs to do what?

- Fertilizer industry
  - Implement 4R programs, deliver products, provide footprints, collaborate, innovate
- Fertilizer retailers, agri-service providers, and crop advisers
  - Provide recommendations, collaborate in adaptive management, meet 4R standards
- Farmers
  - Use adaptive management, share data, use local nutrient resources appropriately
- Scientists
  - Define and describe 4R practices, develop methods to link practices to performance
- Governments
  - Recognize 4R practice adoption, support data collection, and incentivize innovation
- Food traders, processors and retailers: Include 4R metrics in sustainability standards
- Civil society organizations: Advocate and communicate 4R adoption and outcomes
- Investors: invest in technologies and entities that support evidence-based 4R

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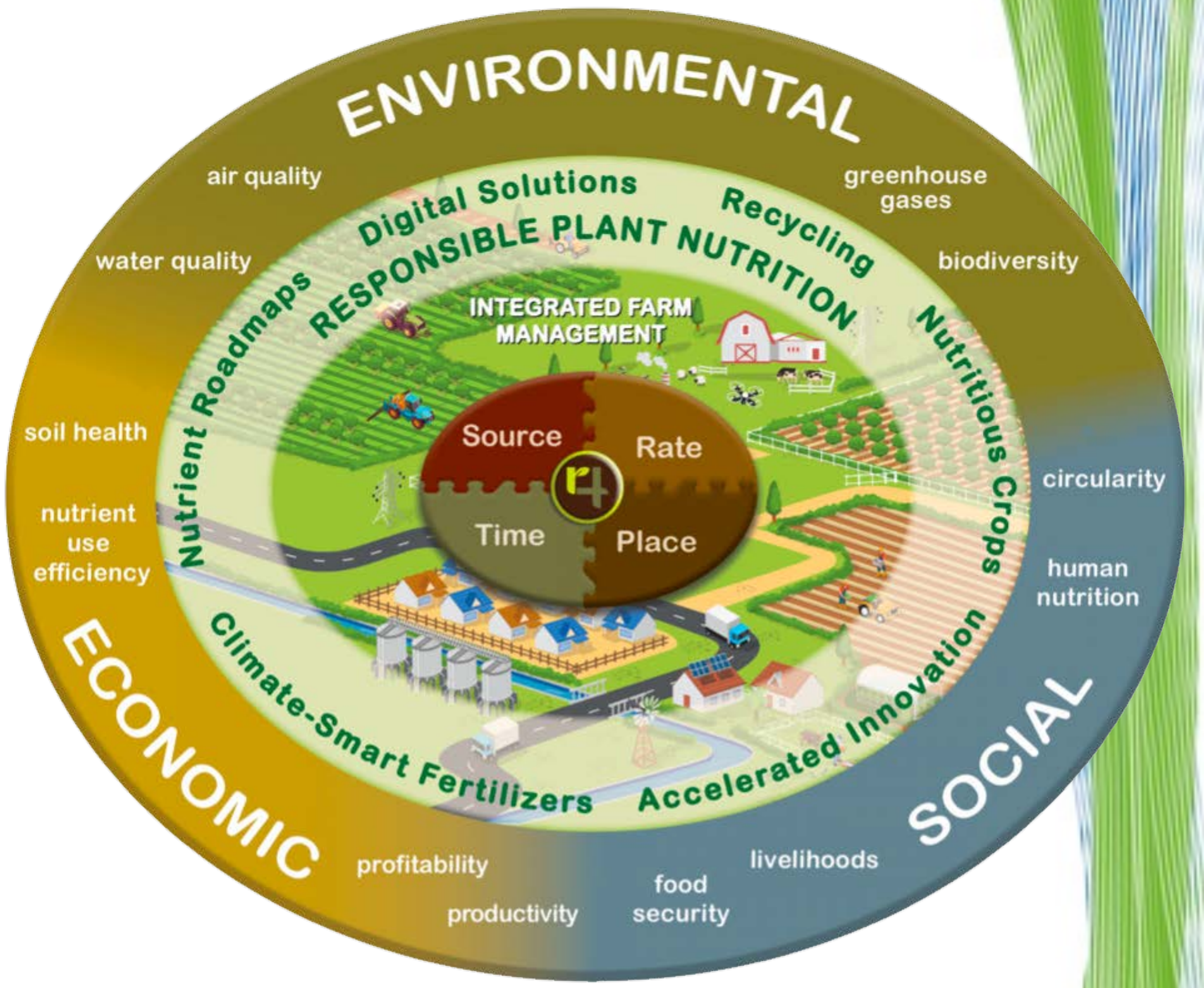
What will success look like?

1. Farmers willing to share data.
2. Collaboratively developed 4R practice standards.
3. Digital technology use increasing.
4. A green label recognizes 4R standards.
5. Nutrients from manure just like fertilizer.
6. Regenerative cropping systems use 4R.
7. Standards to assess nutrient stewardship.
8. 4R standards recognized by buyers of agricultural commodities.

By 2030?



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