Rebalancing Global Nitrogen Management to Address the Food-Fertilizer-Climate Crisis

Tek B Sapkota[1]

with input from

Sieglinde Snapp[1], Aditi Mukherji[2], Kaushik Majumdar[3], Tai McClellan Maaz[4], Deepak Ray[5], Upendra Singh[6], Bruno Gerard[7], Bernard Vanlauwe[8], Daniel Lapidus[9], Kai Sonder[1], Jonathan Odhong[1], and Noufa Cheerakkollil[1]

[1]International Maize and Wheat Center, [2]CGIAR System Organization, [3]African Plant Nutrition Institute,[4]University of Hawaii,[5]University of Minnesota, [6]International Fertilizer Development Center, [7]Mohammed VI Polytechnic University,[8]International Institute of Tropical Agriculture,[9]RTI International

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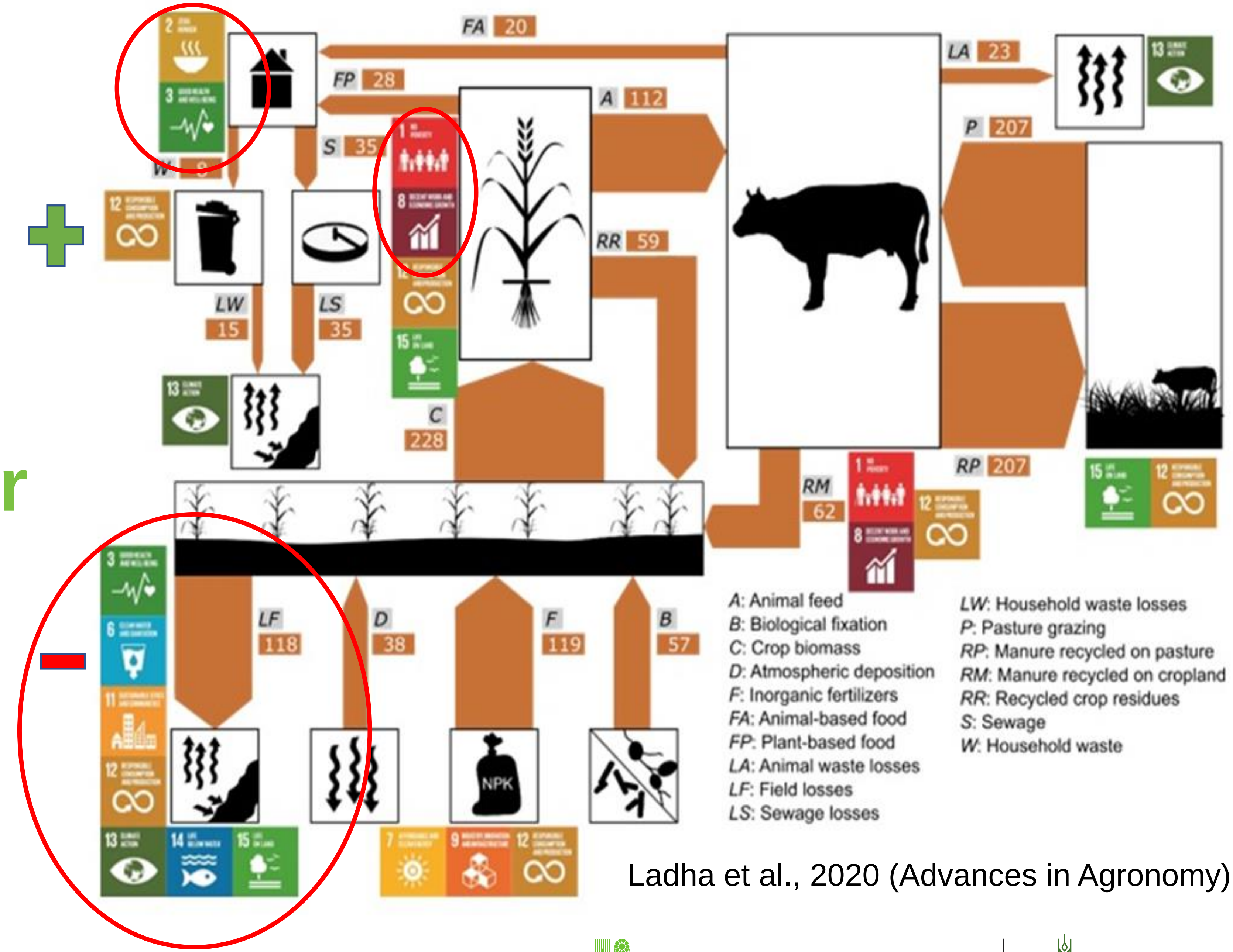
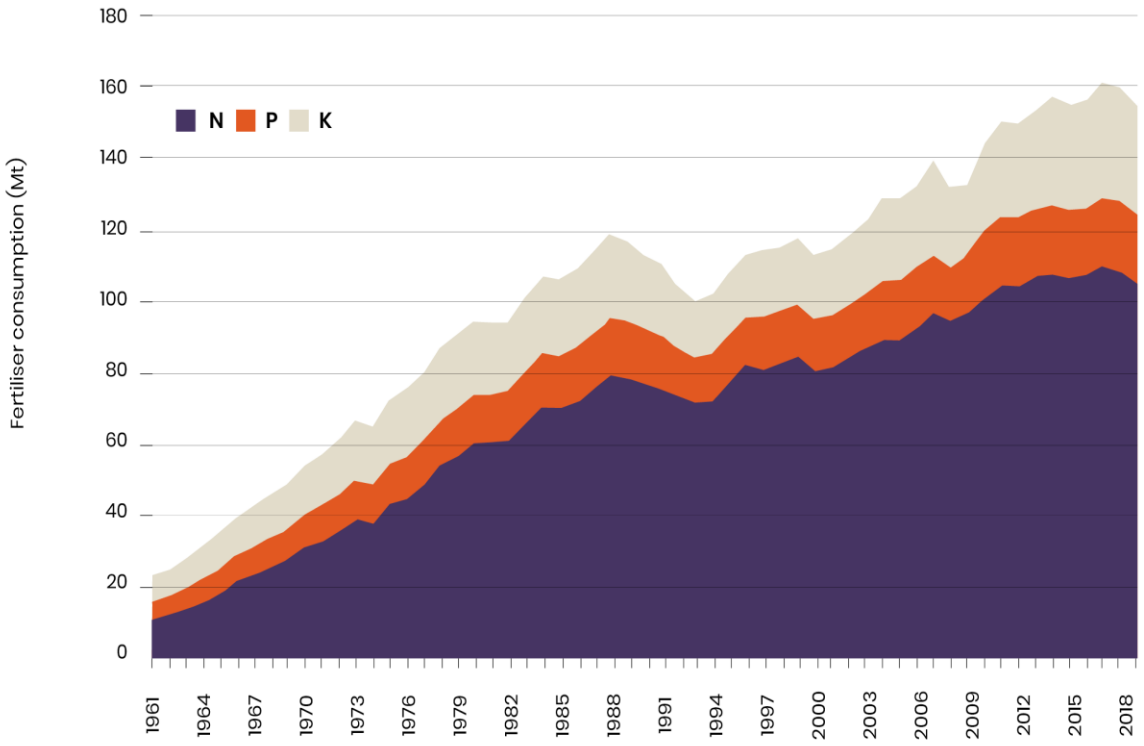
Nitrogen management contributes to food security & number of other SDGs



Ladha et al., 2020 (Advances in Agronomy)

Fertilizer N use increased since 1960s

FAOSTAT



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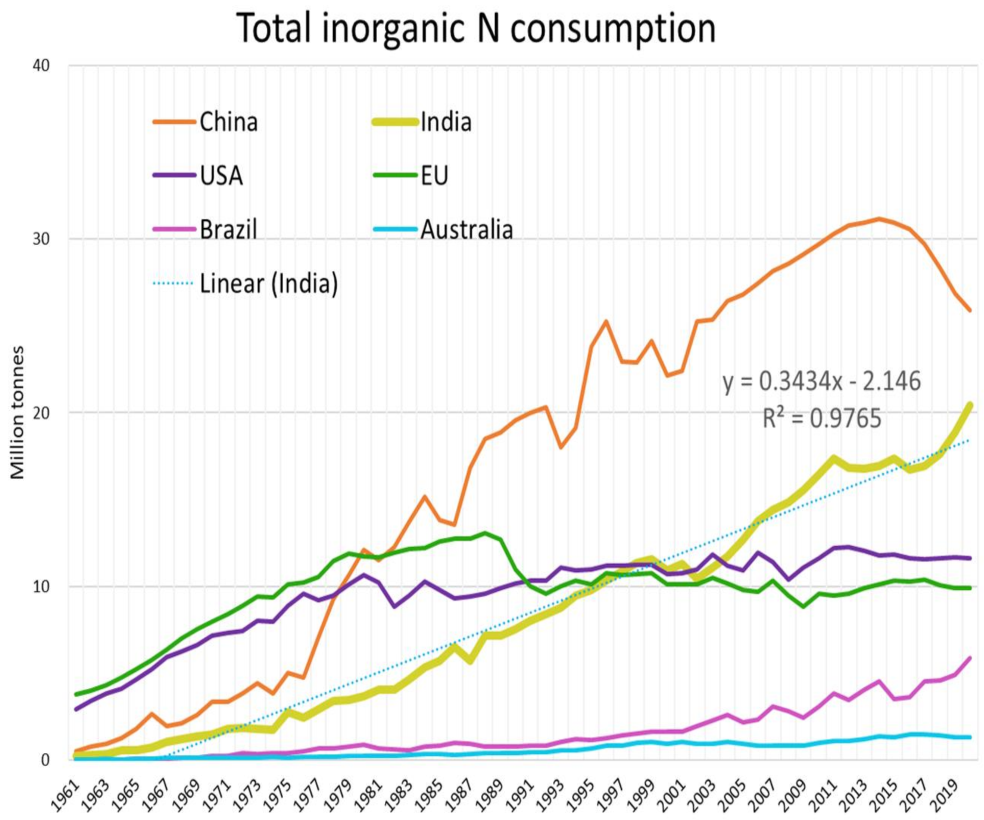
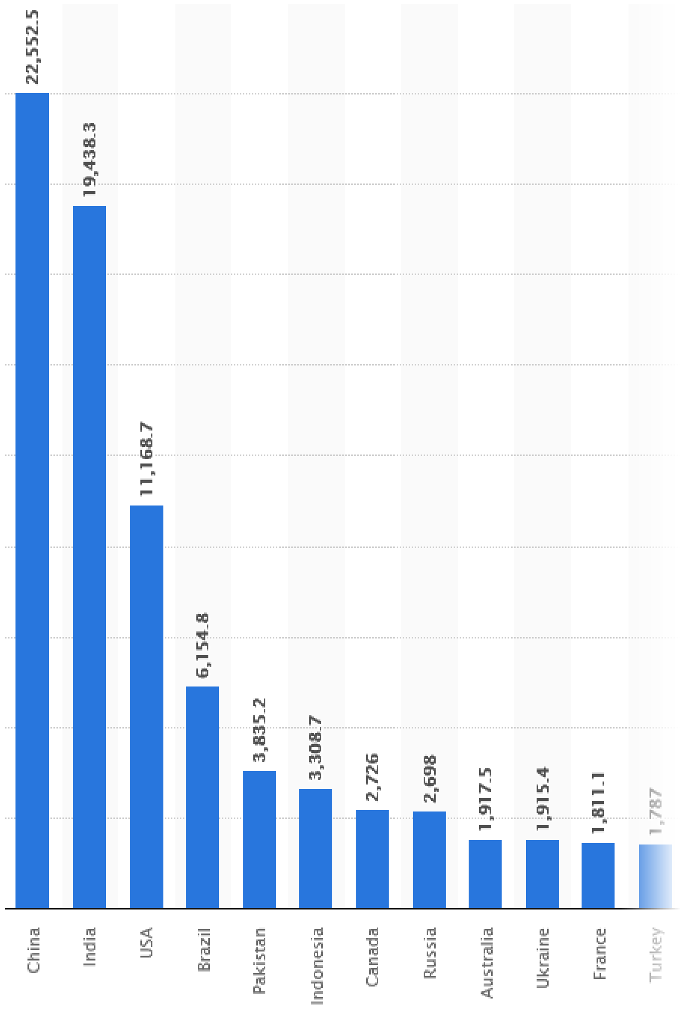
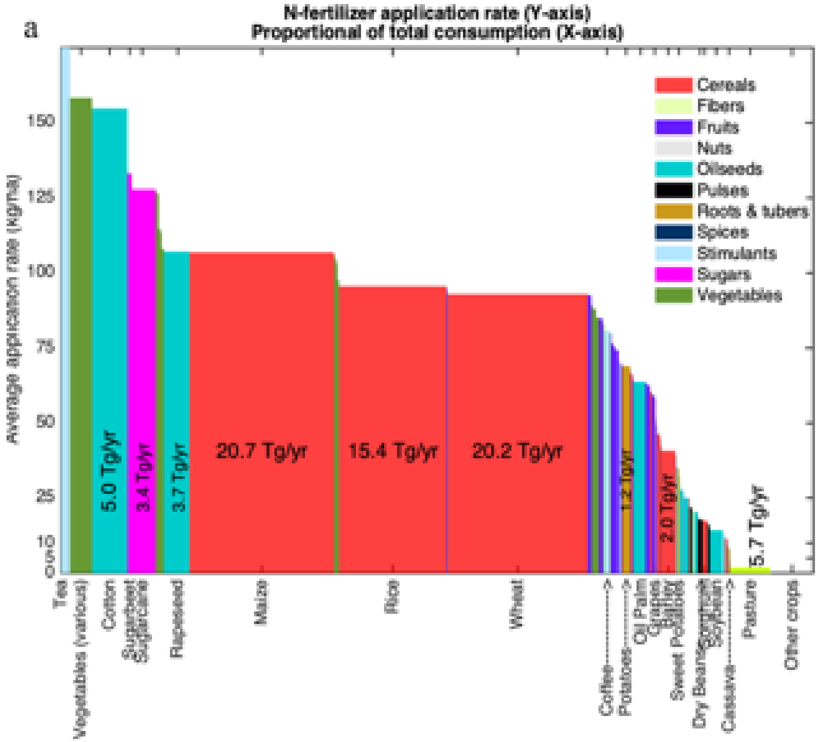


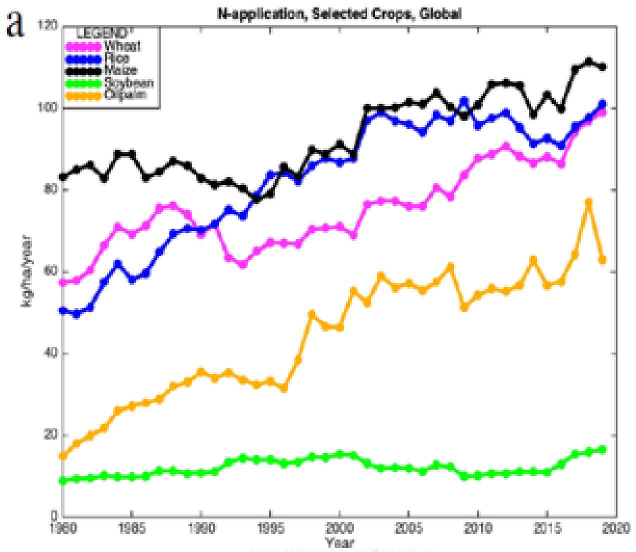
Inequality is the core of the problem

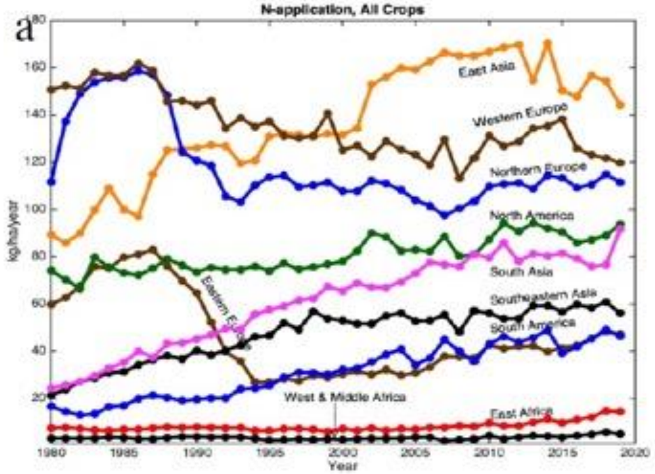
N consumption (Kt/yr)





Ray, Sapkota, and Dobermann
(Nature Communication, In Review)





Problems of under- and over-application of N

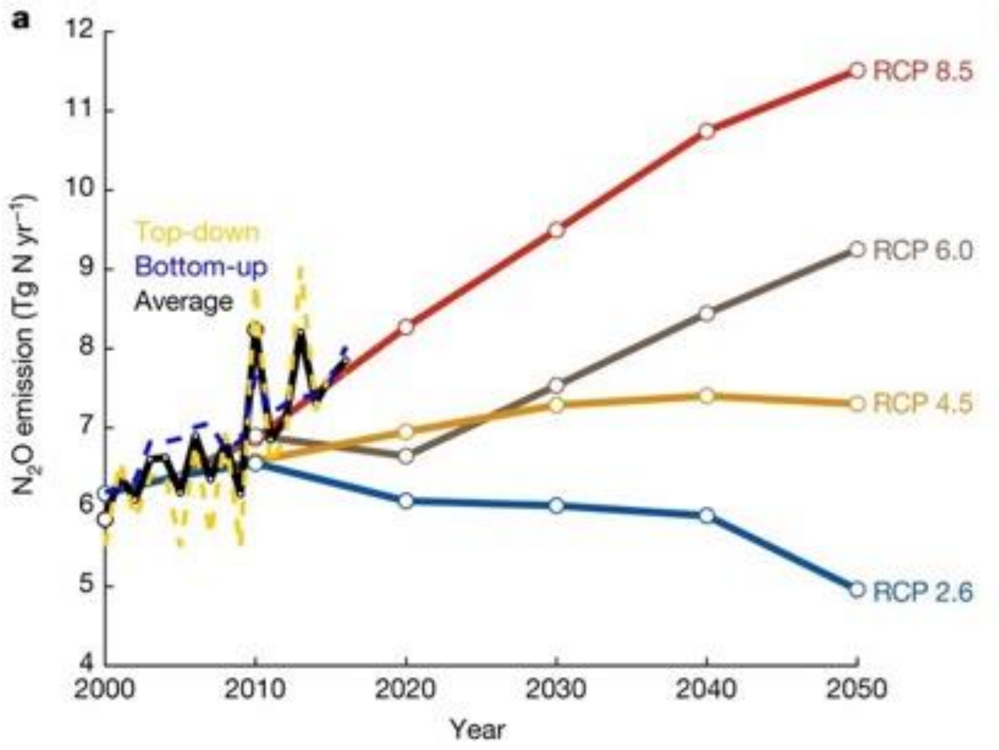
- Low yields
- Less crop residues and reduce soil C sequestration
- Nutrient mining and loss of soil fertility
- Poor Nutritional quality of harvest
- Imbalanced Nutrients
- Increased diseases and pests

- More than half of applied N is lost to the environment
- Water Pollution & Eutrophication
- Soil acidification
- Imbalanced Nutrients
- Reduced biodiversity, Crop damage
- Economic inefficiency
- Contribution to air pollution and GHG emissions

Problems Nitrogen over-application

Eutrophication

N_2O emission



Tian et al., 2020 (Nature)

Data-based approach for N management

N-inputs

- N applied from synthetic fertilizers
- Manure N deposits to the soil
- Crop residue N return to the soil
- N supply from mineralization
- Atmospheric N deposition
- N from fixation

Agricultural soil system boundaries

Changes in N stock

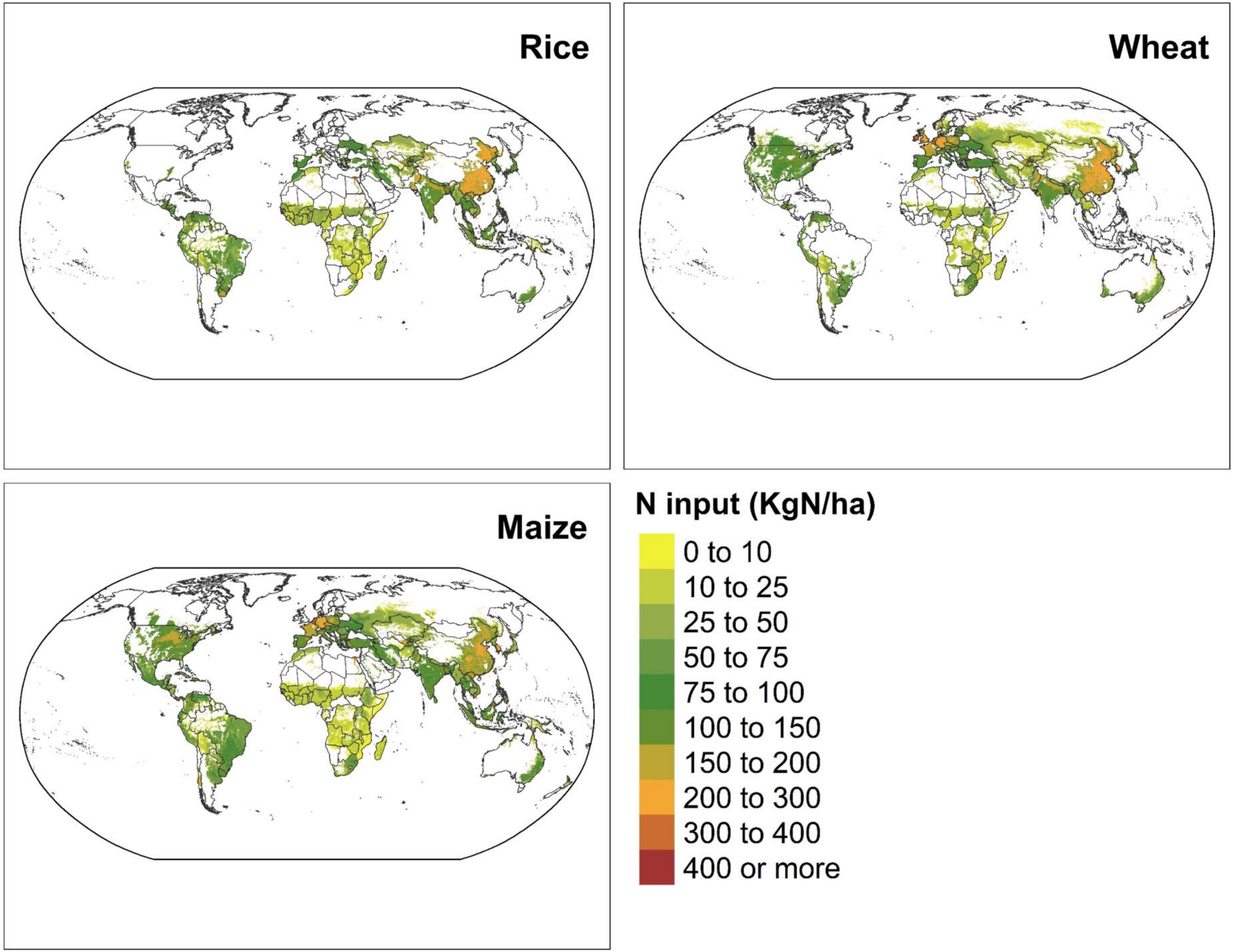
N-outputs

- N in harvested product (grain yield)

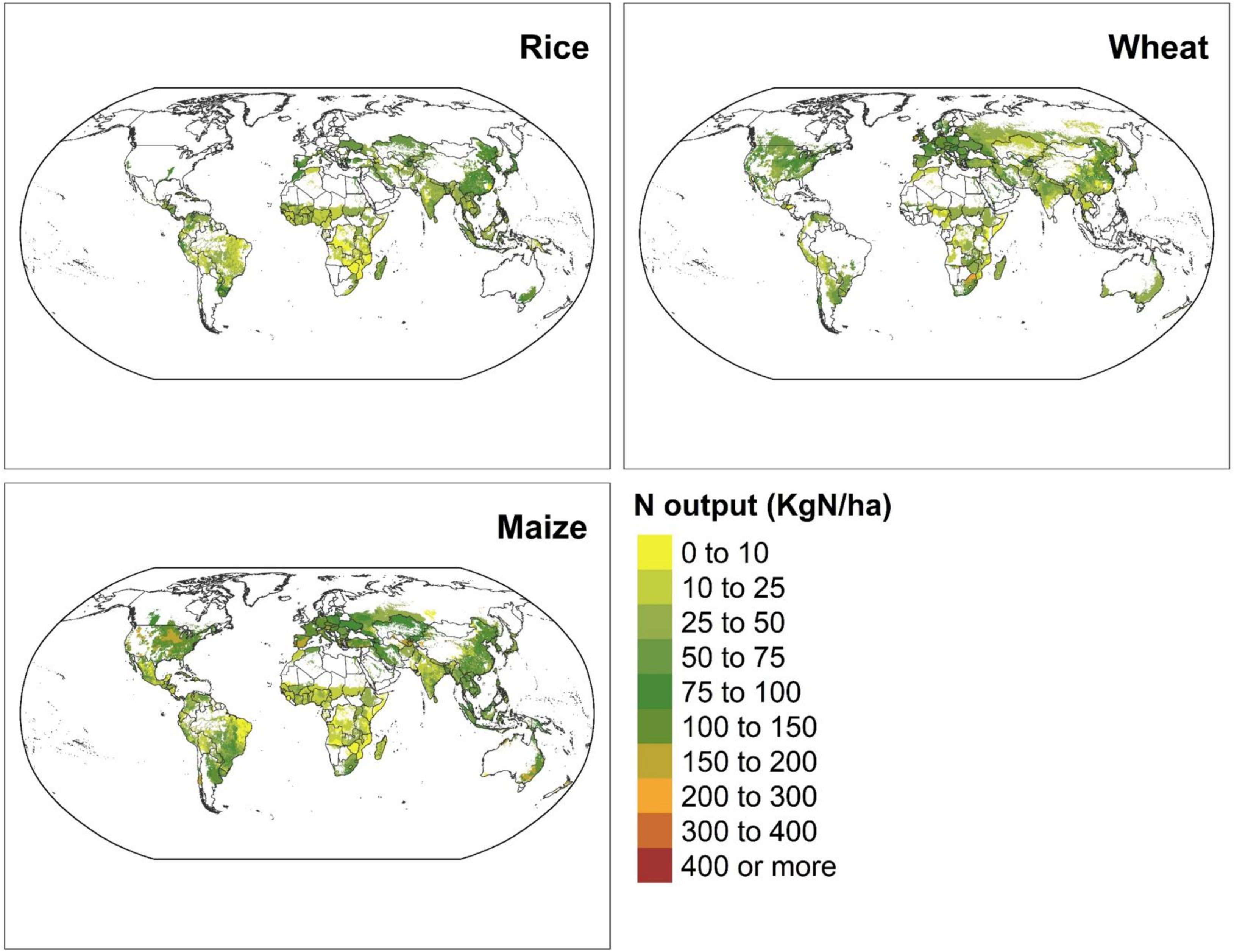
5 arc-minute

1962 - 2016

N input in rice, wheat and maize area across global cropland

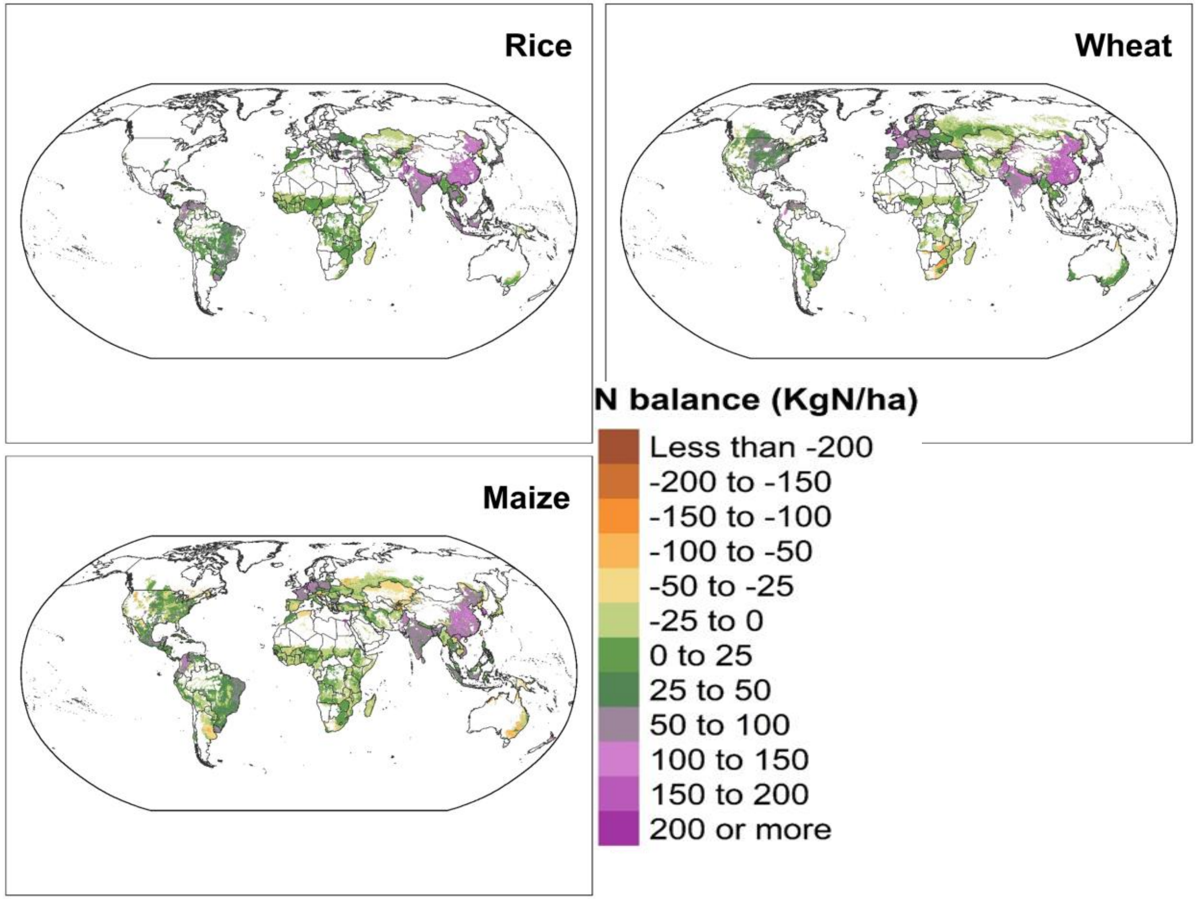


N output from Rice, Wheat and Maize area across global cropland

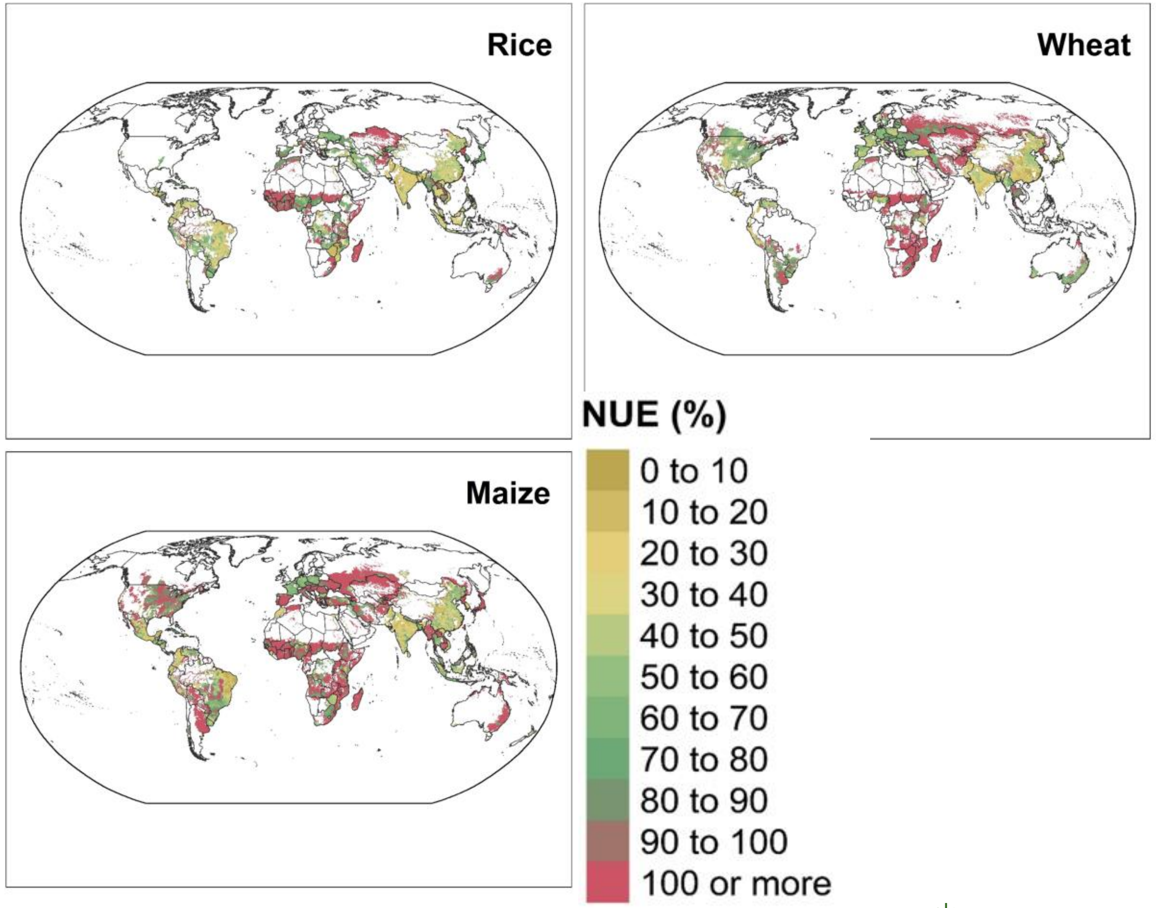


N Balance and NUE in Rice, Wheat and Maize across global cropland

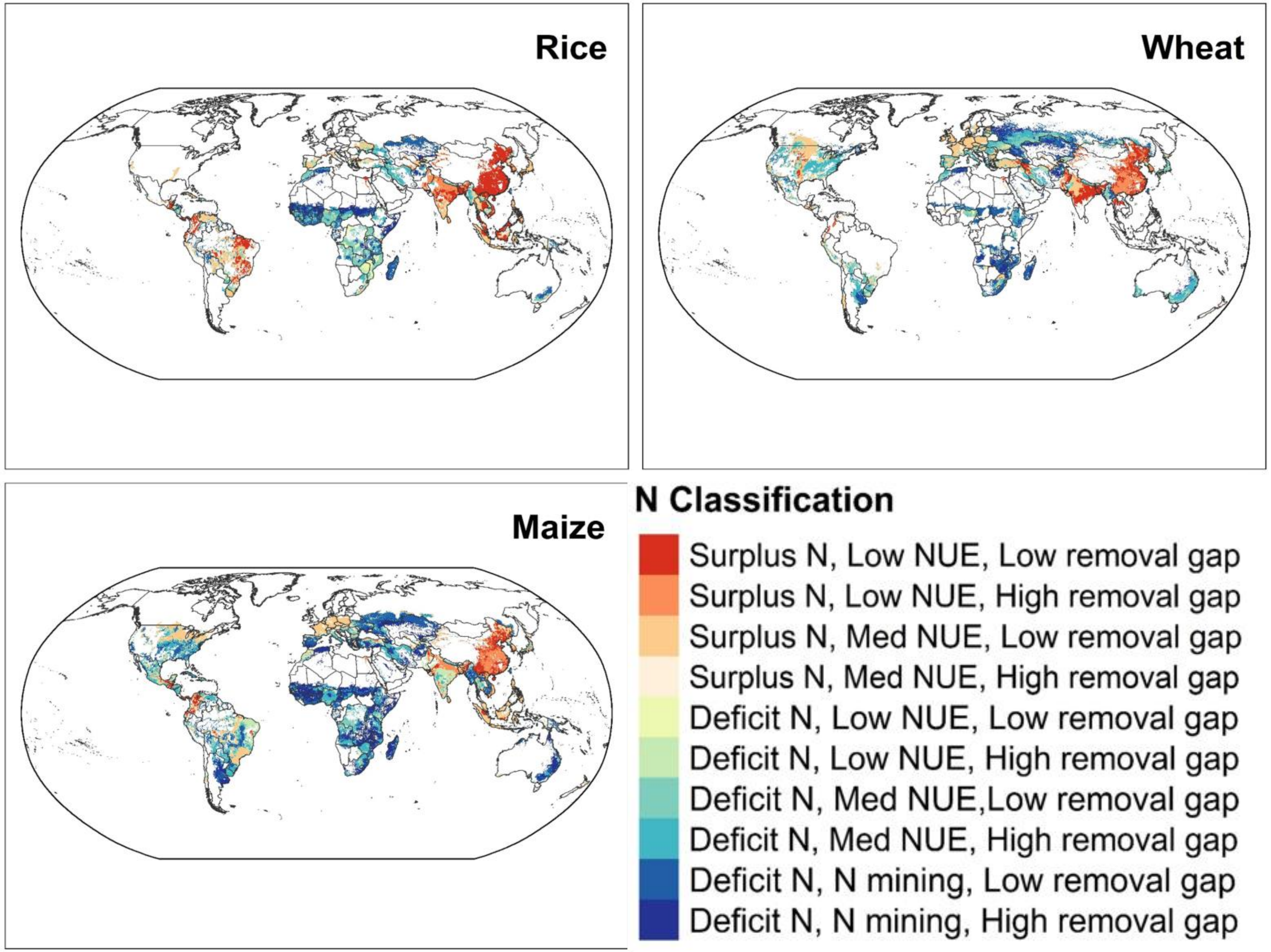
N Balance (N input – N output)



NUE (N output/N input)



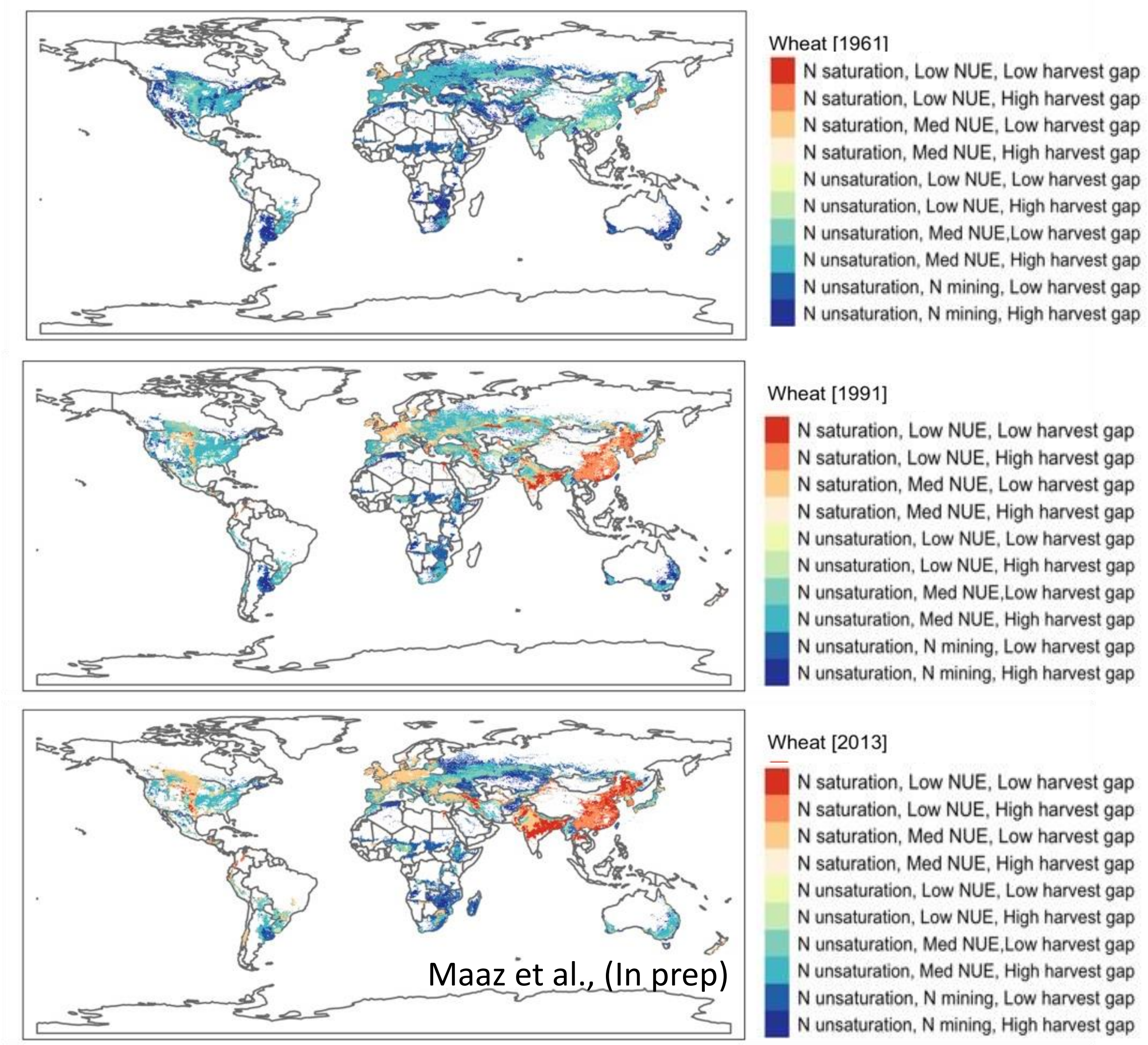
Classification of rice, wheat and maize area based on N surplus/deficit, nitrogen use efficiency, and N removal gap



Calculation

- N Surplus/deficit: N input-N output
- NUE: N output/N input (NUE≤ 30 , 30 < NUE < 90, NUE ≥ 90)
- N harvest gap: Potential N harvest-Actual N harvest

How N management challenge categories have changed over time



Maaz et al., (In prep)

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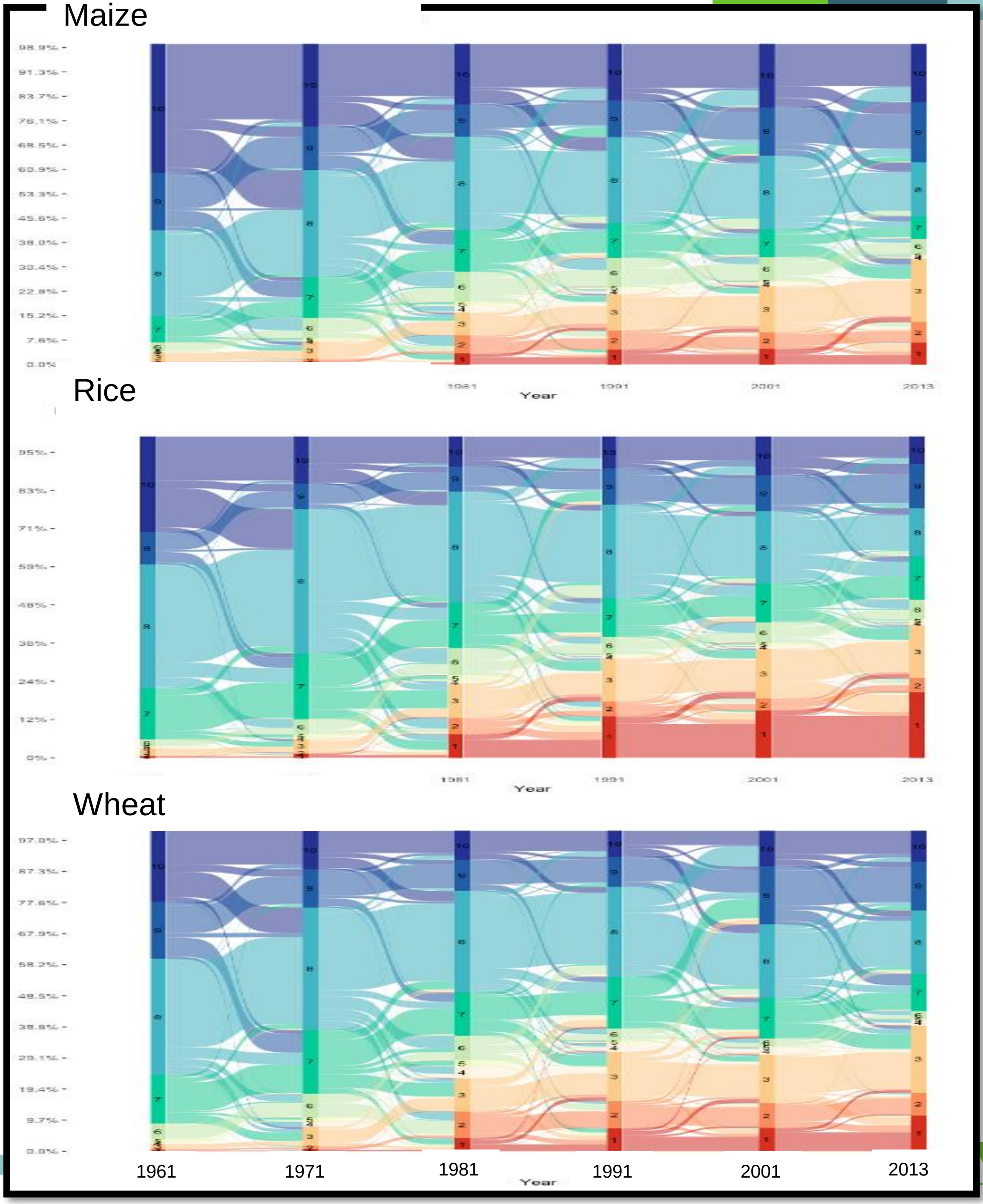
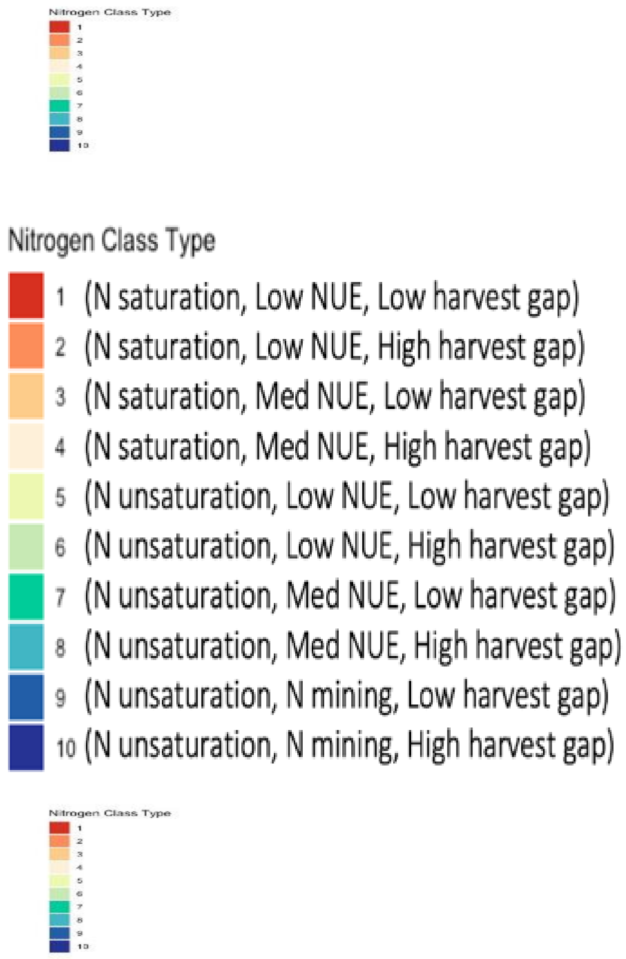
Decadal shift in N problem categories





Maaz et al., (In prep)

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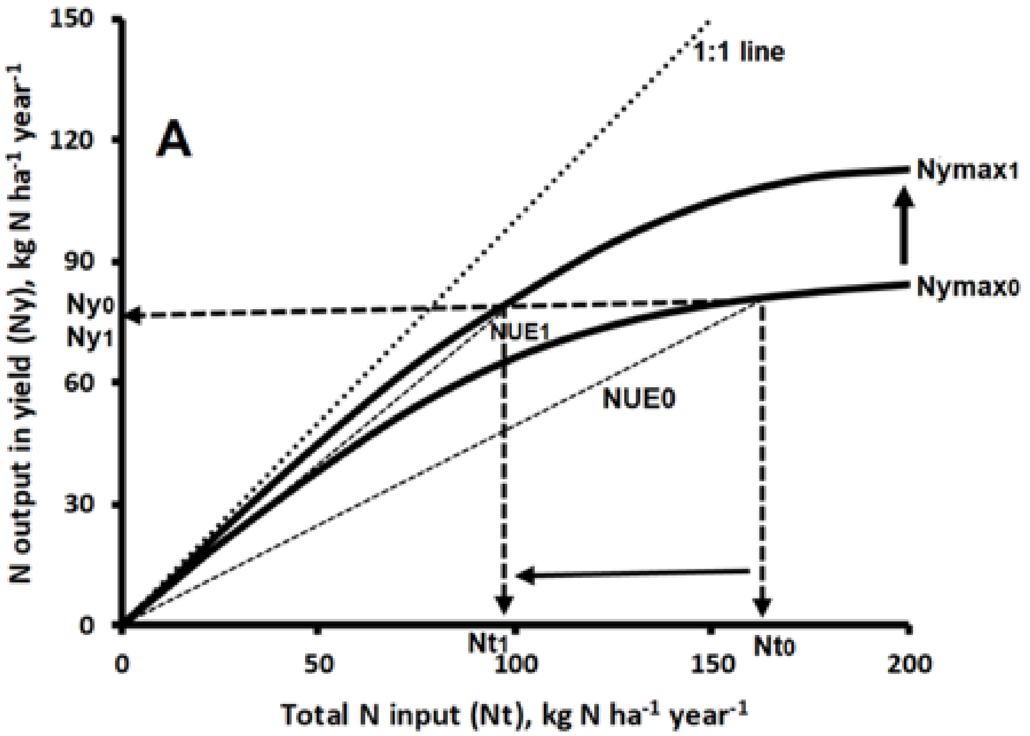
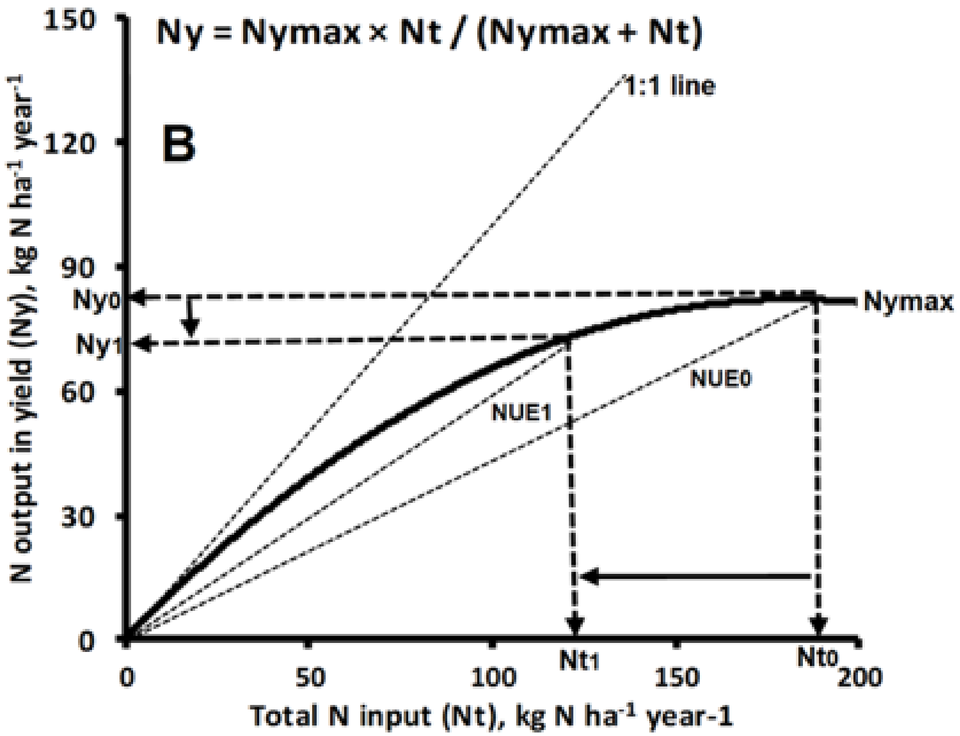
Improving NUE is the Key

Either by increasing yield or by reducing N or both



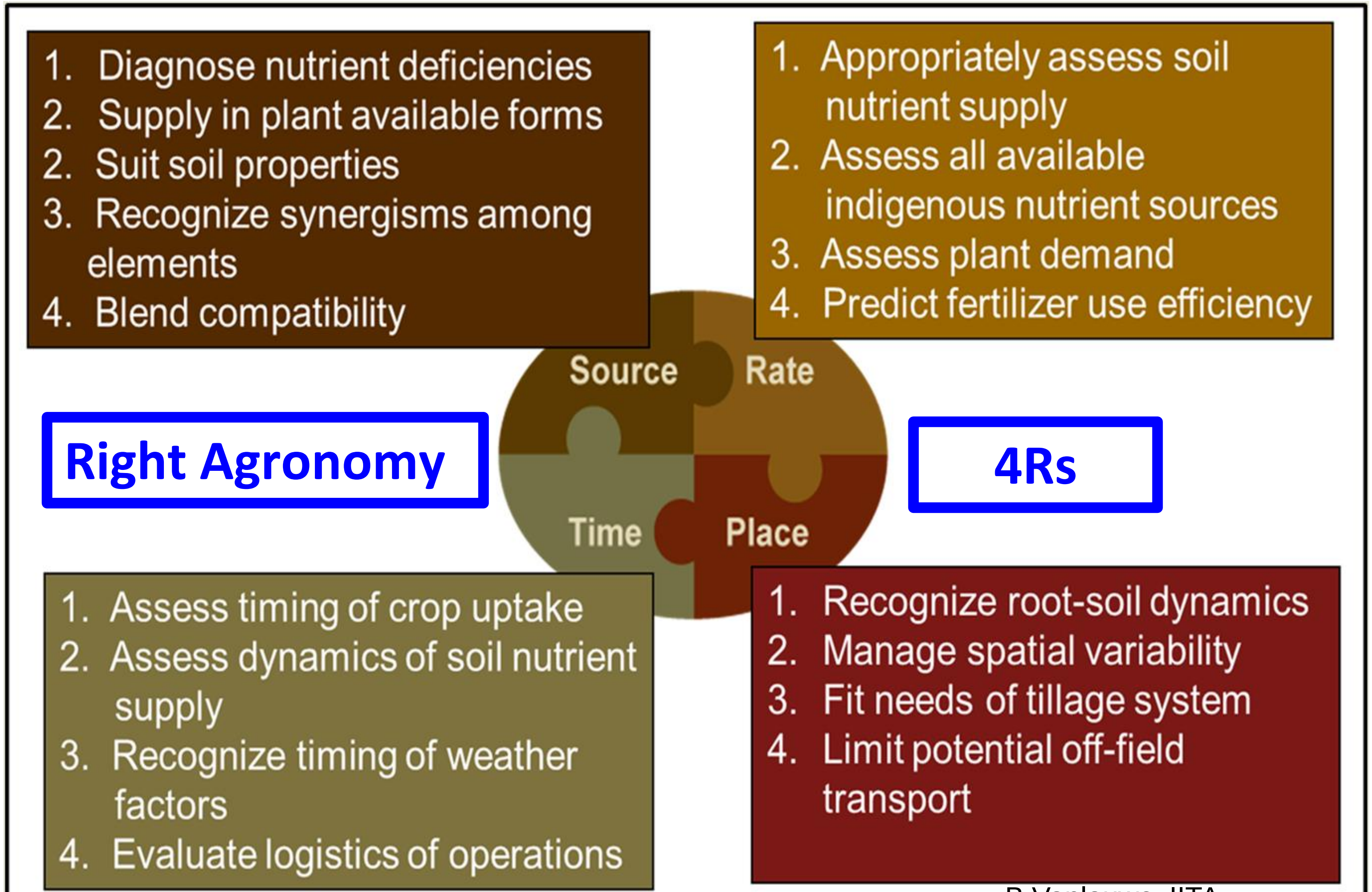


Sapkota et al., 2022 (Advances in Agronomy)

Some Examples of NM Strategies

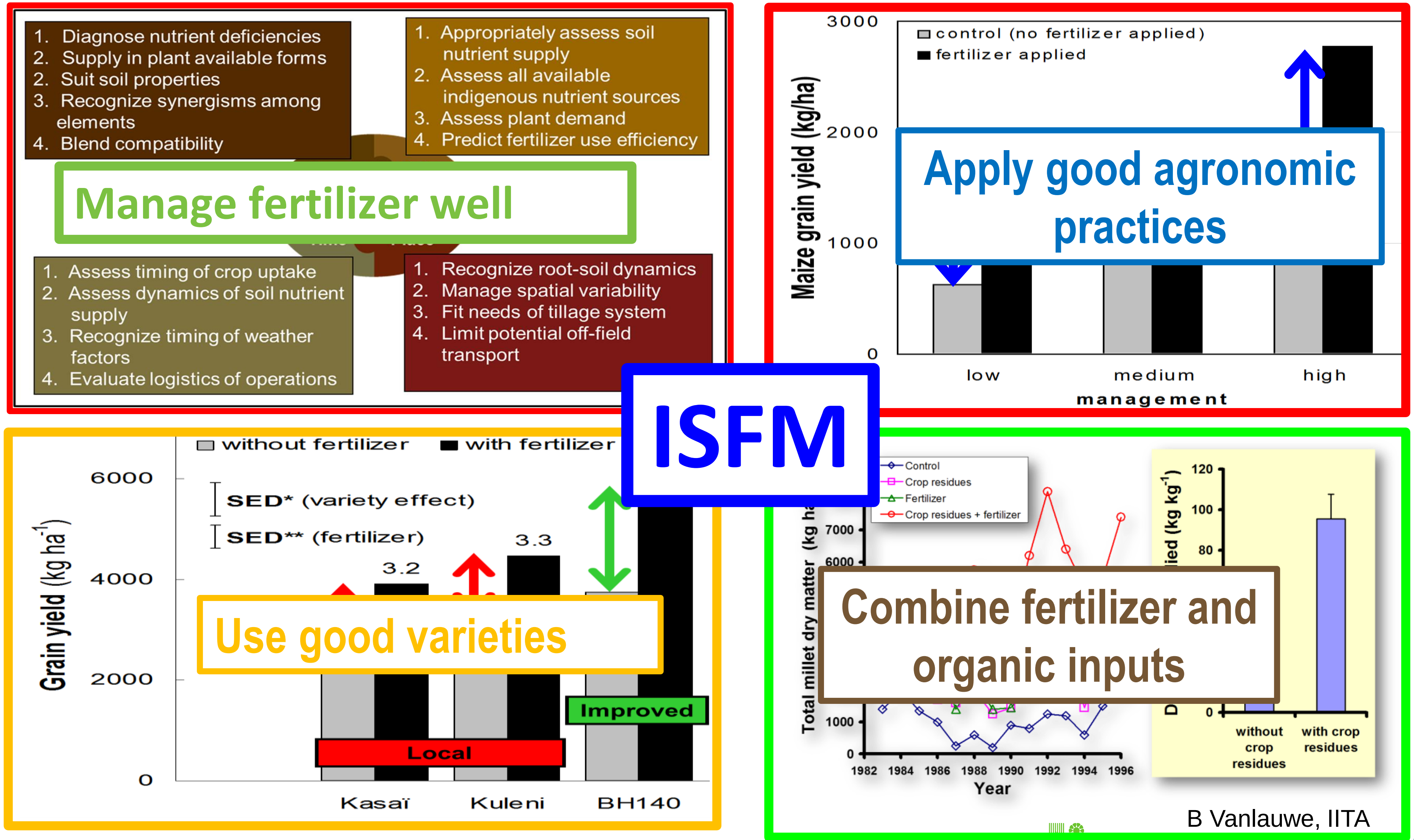
- Precision nutrient management (4Rs, SSNM)
- Decision support systems (Nutrient Experts, Crop Manager etc)
- In-season N management (e.g using sensors in hand, drone etc)
- Integrated soil fertility management (ISFM)
- Nitrification inhibitors (chemical and biological)
- Low Emission fertilizer including slow/controlled release fertilizers
- Biological sources of N (legumes, biofertilizers and genetic engineering)
- Organic inorganic integration
- Using high N-containing fertilizer
- Repurposing public subsidies

Maximizing NUE through 4+1Rs



B Vanlauwe, IITA

Maximizing NUE through 4+1Rs (ISFM)



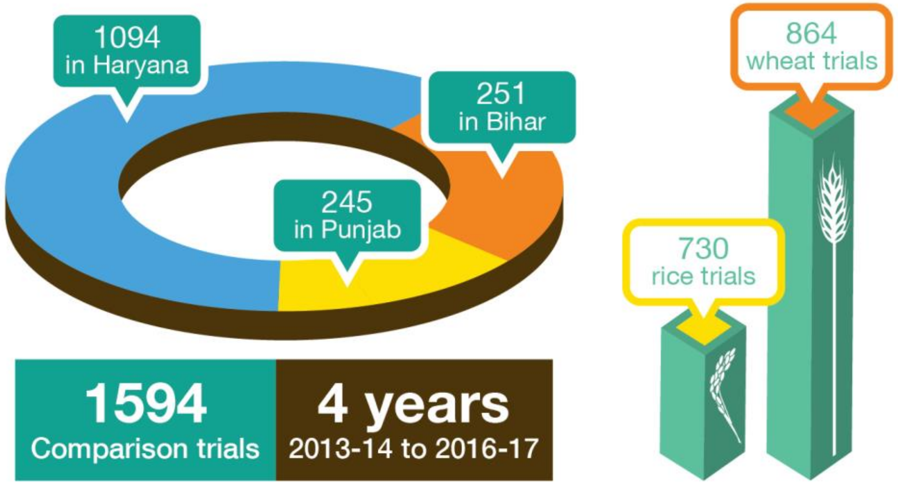
B Vanlauwe, IITA

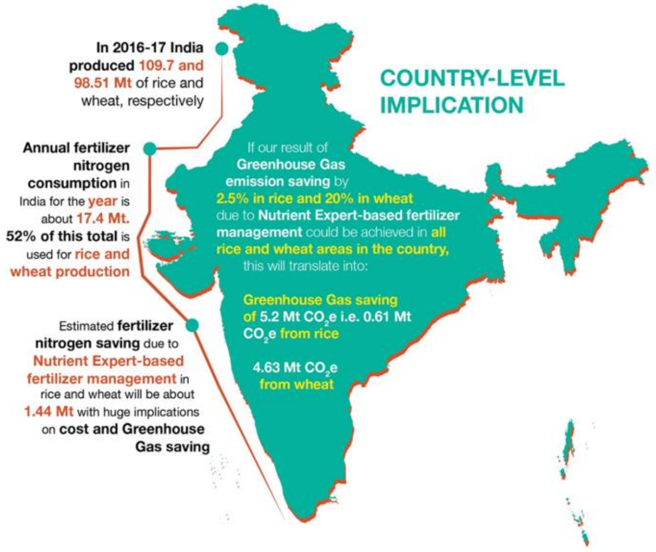
Legume integration

B Vanlauwe, IITA

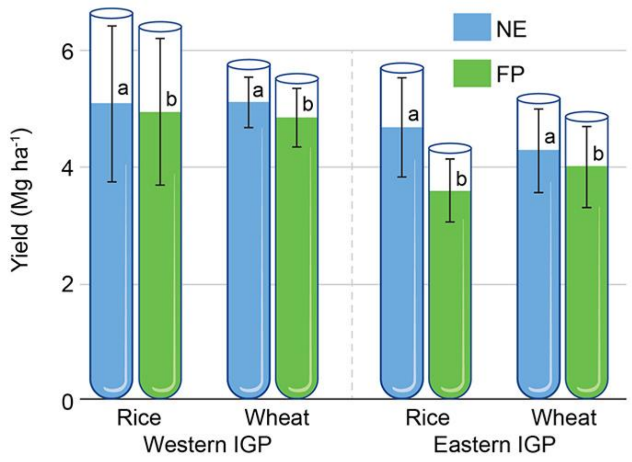
N_2Africa (http://www.n2africa.org) has extended legume benefits to more than 800,000 farmers in 11 countries.

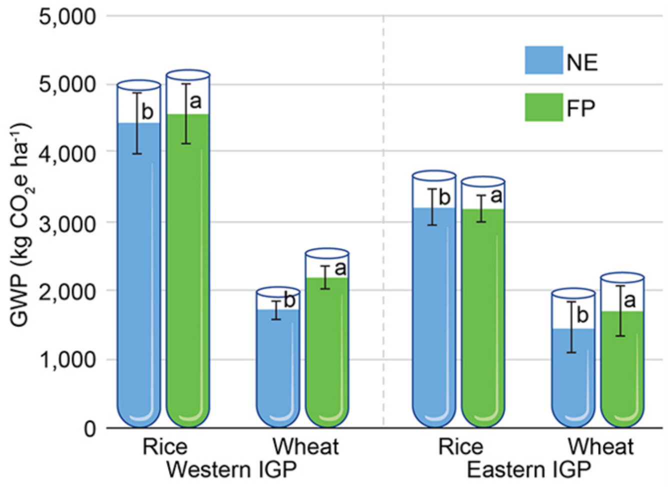
Impact of Nutrient Expert: Evidence from India





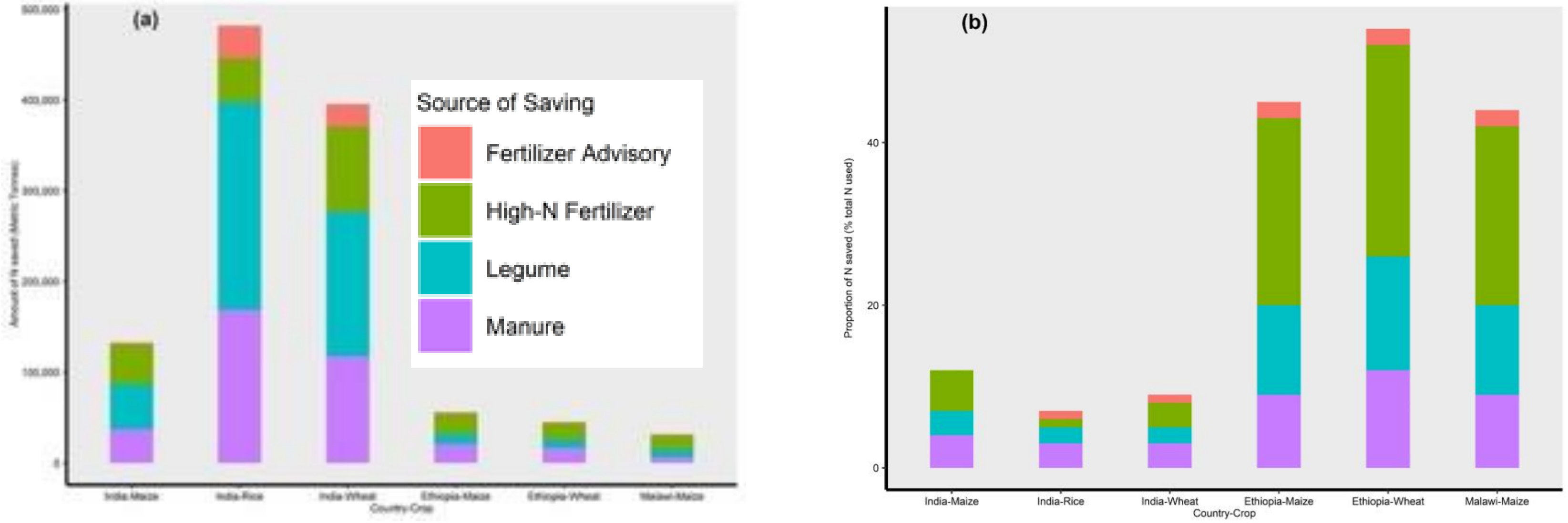
NE adoption in Indian RW systems provides 14 Mt extra grain with 5.34 Mt less CO_2eq Emission (eq 1.2 M passenger car)





Sapkota et al., 2021 (Nature Sc. Rep)

Differentiated Strategies is key



- Supply of fertilizer and food is highly sensitive to international disruptions
- Smallholder farmers suffer most from climate change
- Integrated management of organic and inorganic nitrogen fertilizers to target N-deficient regions can bolster global food security
- N-deficient/low-yield systems: Supply of high-N fertilizer
- High-yield systems: balanced fertilization

Snapp et al., 2023 (Nature Sustainability)

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Rebalancing fertilizer use

Global reallocation of excess N fertilizers from regions with over-application to regions with low application could increase global crop yield by 30% and reduce GHG emissions from synthetic fertilizers.

Check for updates

Nitrogen solutions for food security amid fertilizer shortages and climate change

Nitrogen requirements and usage vary across maize, wheat and rice systems in Ethiopia, Malawi and India. Analysis of these systems indicates that targeted nutrient management strategies could increase the efficiency of nitrogen usage, helping to address fertilizer shortages and reduce the negative environmental impacts of excess nitrogen.

The problem

Food production is dependent on a sufficient supply of nutrients; these nutrients are often provided by synthetic nitrogen fertilizers, which are produced using fossil fuels as the feedstocks. This global fuel–fertilizer–food nexus is highly vulnerable to geopolitical conflicts that cause abrupt disruptions in the supply chain and subsequently increase the price of fertilizers[1]. There are both access and environmental problems associated with fertilizers. These problems are driven by inequality: over-fertilization in certain regions and under-fertilization in others. More than half of the fertilizer applied in over-fertilized areas is lost to the environment, contaminating aquatic, terrestrial and atmospheric environments[2], whereas under-fertilized areas have poor plant growth, low yield and nitrogen deficiencies caused by soil mining[3]. Together with the challenges associated with climate change, this inequality poses a serious threat to agricultural productivity and therefore could increase food prices, resulting in reduced food access and diminished food security in vulnerable populations. Large-scale durable solutions to address these challenges are urgently needed.

The solution

We calculated the nitrogen status in Ethiopia, Malawi and India for three staple cereals using a mass balance approach (subtracting nitrogen outputs from nitrogen inputs), based on existing data. Analysis of these results revealed variations in nitrogen surplus and deficiency, nitrogen-use efficiency and nitrogen harvest gaps (that is, the difference between the potential and actual amount of nitrogen harvested in grain yield) across maize, wheat and rice systems. We quantified the nitrogen management challenges in each geolocation. These results varied along an intensity gradient, from predominantly high nitrogen input cropping systems in India to mixed intensity in Ethiopia to low nitrogen input systems in Malawi. We then calculated the nitrogen savings that can be achieved by adopting innovations and explored which technologies and management interventions were most effective in each geolocation.

In regions where soils are nitrogen deficient and have limited nitrogen inputs, cost-effective methods should be used to enhance the nitrogen supply[4], such as using organic nitrogen and replacing low-nitrogen fertilizers with high-nitrogen fertilizers. In nitrogen-surplus regions, the efficiency of nitrogen usage can be increased through the integrated management of organic and inorganic nitrogen sources; cropping system diversification with crops that enhance nitrogen fertility such as legumes; fertilizer advisories to prescribe more efficient fertilizer management strategies; and other site-specific nutrient management strategies[5]. We found that these short-term targeted interventions in maize, wheat and rice production can lead to nitrogen savings of 7–11% in India and 45–55% in Ethiopia and Malawi (Fig. 1). Additionally, countries such as India and Ethiopia, which display diverse nitrogen-use patterns, can stabilize crop productivity and profitability during crises by redirecting high-nitrogen fertilizers from nitrogen-surplus areas to nitrogen-deficient regions.

The implications

Our findings suggest that during a fertilizer supply crisis, targeting nitrogen supplies from inorganic and organic sources to farms with minimal access to nitrogen inputs can improve nitrogen-use efficiency and help maintain crop yields. Additionally, increasing the efficiency of the use of nitrogen fertilizer on high-yield farms is essential to minimize the environmental impacts of nitrogen usage. Global reallocation of excess fertilizers from regions with over-application to regions with low application could increase global crop yield by 30% and reduce greenhouse gas emissions from synthetic fertilizers.

However, present government policies offer subsidies that often encourage the use of excess nitrogen to boost crop yields. To avoid the negative environmental consequences of increased fertilizer use it is necessary to reform subsidies, introduce location-specific policies and invest in government extension systems that provide farmer education. Together, these investments will support improved nitrogen awareness, farmer knowledge and monitoring of management practices. Therefore, policy reforms are needed with a focus on integrating organic and inorganic nitrogen and new technologies into nitrogen management strategies. Digital advisories and locally relevant decision support systems offer opportunities for farmers to adapt and adopt targeted fertilizer and soil health recommendations. Implementing these cost-effective solutions and prioritizing targeted nitrogen management could help to ensure global food security amidst challenging fertilizer and climate crises.

Sieglinde Snapp & Tek B. Sapkota
International Maize and Wheat Improvement Center (CIMMYT), El Batán, Texcoco, Mexico.

This is a summary of:
Snapp, S. et al. Spatially differentiated nitrogen supply is key in a global food–fertilizer price crisis. *Nat. Sustain.* https://doi.org/10.1038/s41893-023-01166-w (2023).

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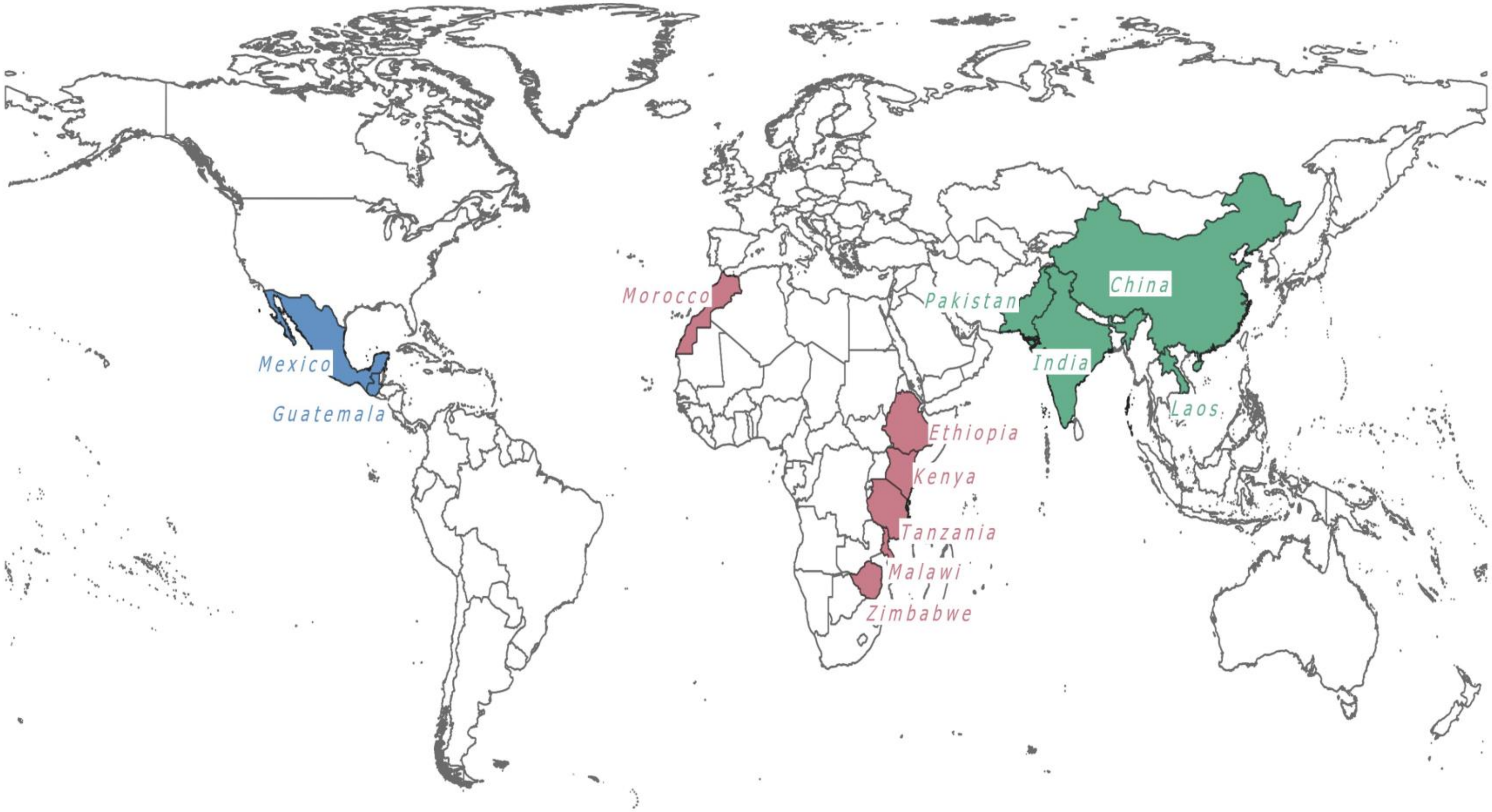
AIM for Climate Innovation Sprint

Implement and scale-up range of climate robust nutrient management strategies in 12 countries to reach millions of smallholder farmers



Increasing the uptake of tried and tested N management practices (e.g. living lab, digital extension, citizen science, ICT and decision support systems.

Continuous R4D on cutting-edge nature-based solutions for managing N, C and GHG, simultaneously for net zero farming e.g. BNF, BNI, ISFM

Market and Policy: Connecting farmers with carbon credit and ecosystem services markets and repurposing subsidies.

AIM4C sprint on Climate-resilient fertility management

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Recommended actions

- Improve **fertilizer recommendations** in developing countries through actions by NARES and private sector
- Support **cutting-edge research** such as breeding for NUE, BNF, BNI and other aspects ISFM
- **Develop and maintain data infrastructure** and sharing for informed decision
- **Enhance international collaborations and knowledge sharing** to upscale scale-ready technologies,
- Involve the **Private Sector** (both supply side and demand side) to invest in research and promote sustainable N management through RS, CSR
- Implement **targeted subsidies and financial incentives** for farmers adopting ISFM practices
- **Collaborate** with NGOs and CBOs to promote ISFM at grassroots level
- **Consumers** could help make informed choices to promote ISFM
- International development agencies should **prioritize financial support** for promoting ISFM

Take home message

- N Fertilizers play a significant role to address **food security, climate crisis and many SDGs**
- **Inequality is the core** of the problem in fertilizer management: some regions apply more than required amount contaminating aquatic, terrestrial, and atmospheric systems whereas in some regions fertilizer application is insufficient for plant needs leading to low yield and soil mining
- **N saving from high application areas and shifting it to deficient areas:** increase global crop yield by 30% while reducing N_2O emission
- **Data-based approach helps identify nutrient management challenges:** Surplus, inefficiencies, or deficits for targeted nutrient management
- 4R should be combined with the **right varieties, right agronomy** and other aspects of **ISFM**
- **Research** on cutting-edge science and scaling already tested/validated technology should go hands-in-hand

Thank you for your interest!

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