International Symposium on
Nitrogen Use Efficiency in Agriculture
21 October 2020

Improving the effectiveness and efficiency of nitrogen management for maize and wheat

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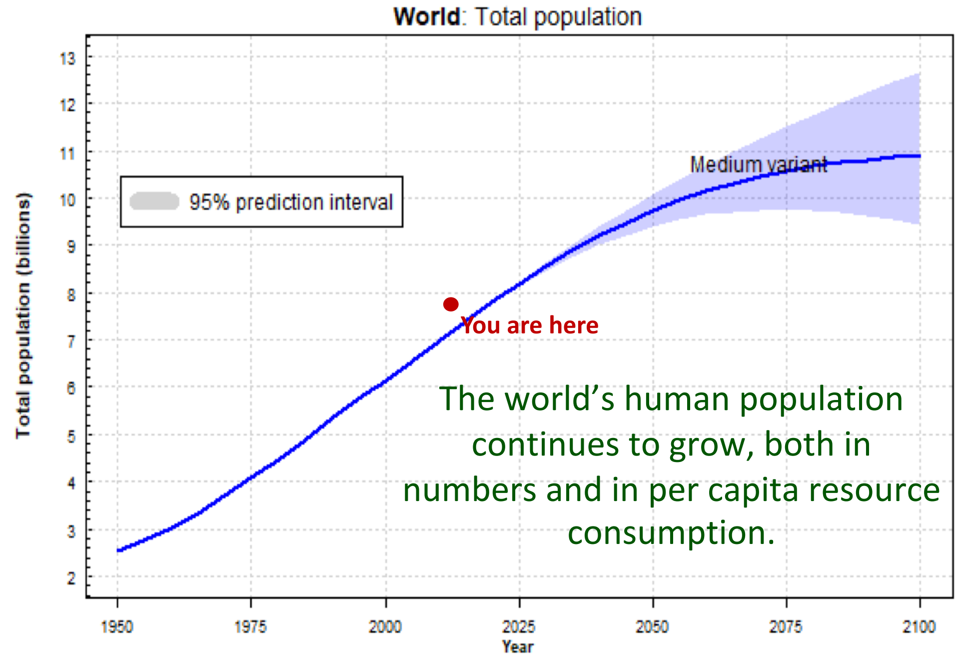
Outline – effectiveness and efficiency of N management

- Role of nitrogen in the global context
- Definitions of nitrogen use efficiency
- Efficiency versus effectiveness (impact)
- Trends in nitrogen use efficiency – global, USA, Canada and Mexico
- Stewardship systems for improvement



United Nations, DESA, Population Division. *World Population Prospects 2019*. http://population.un.org/wpp/

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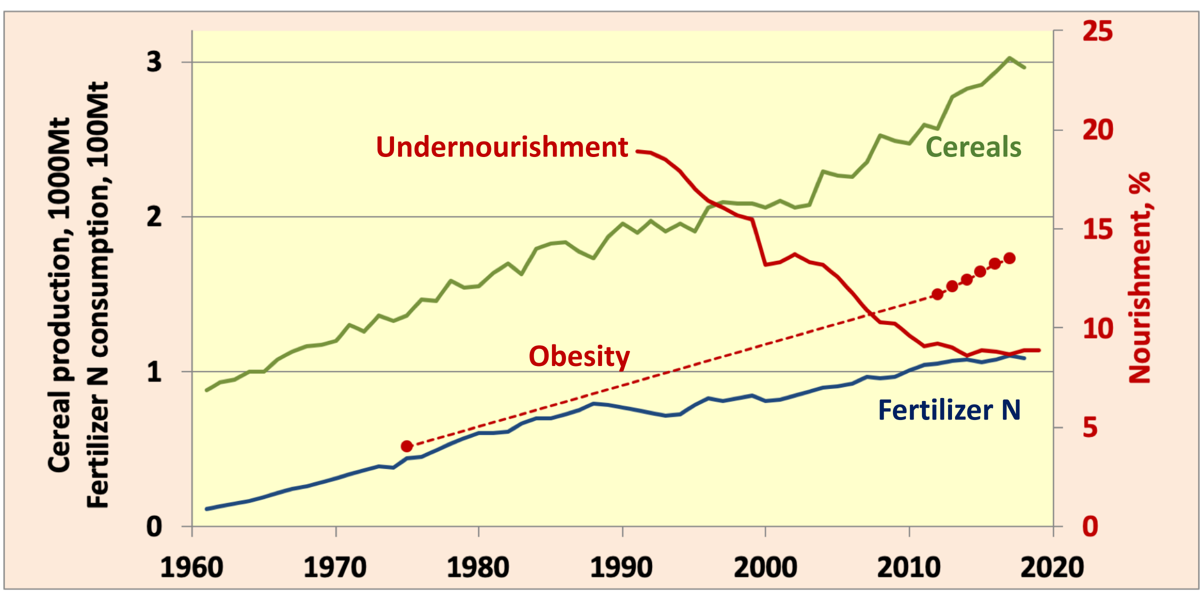
Global Trends



United Nations Food and Agriculture Organization (FAO), 2018, 2020

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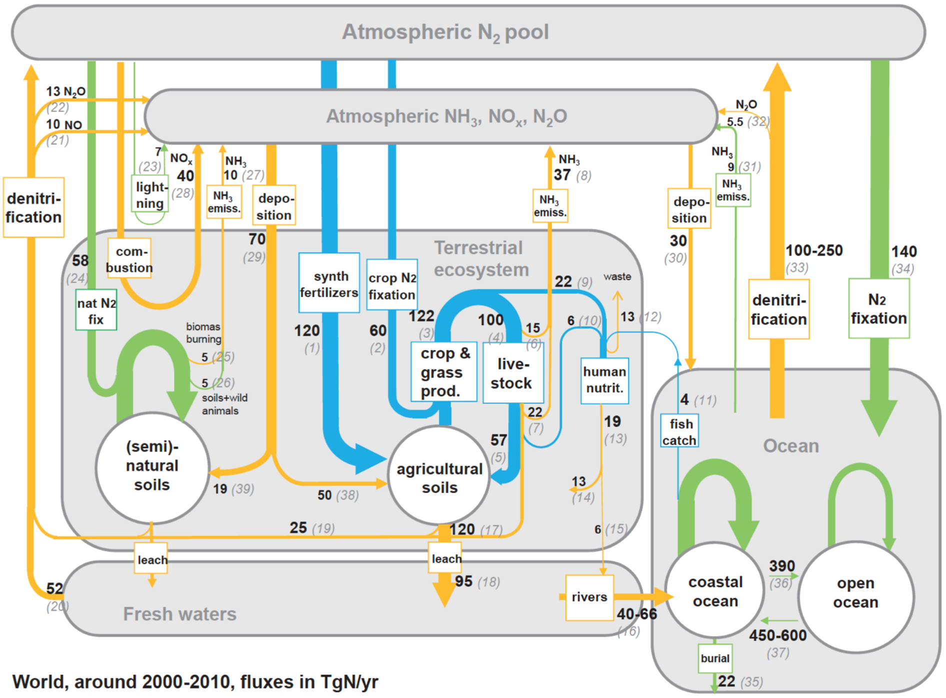

Global Nitrogen Cycle

Many efficiencies. Many pathways.

Sutton, et al., 2013. Our Nutrient World.

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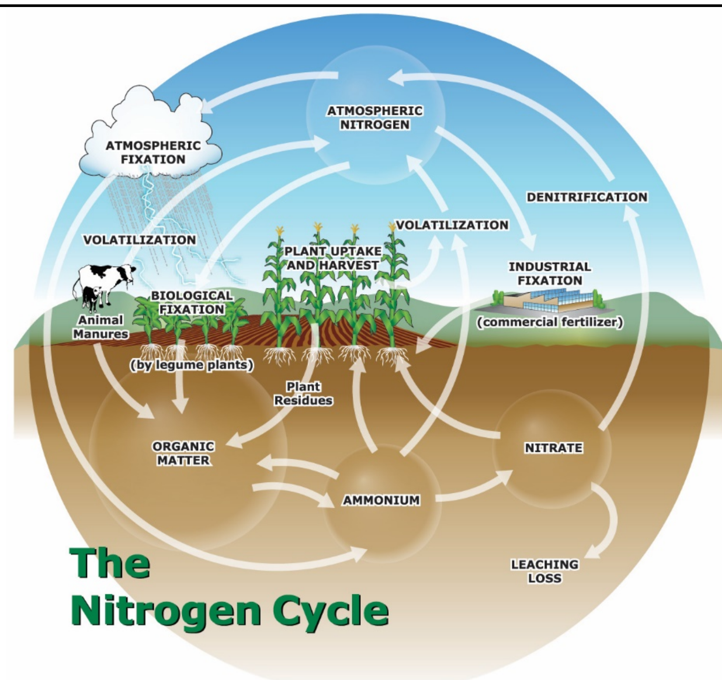

Many forms of nitrogen can be lost to air or water.

Many processes are involved in nitrogen use efficiency.

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Nutrient use efficiency can be defined and calculated in many ways

NUE term		Calculated from	Typical levels for N (maize or wheat)
Partial factor productivity	**PFP**	**Y/F**	40-90
Agronomic efficiency	**AE**	**$(Y-Y_0)/F$**	15-30
Partial nutrient balance	**PNB**	**R/F**	>90% = deficiency <70% = surplus
Recovery efficiency	**RE**	**$(U-U_0)/F$**	40-65% (whole-plant) 33% (grain only)
Internal efficiency	**IE**	**Y/U**	30-90
Physiological efficiency	**PE**	**$(Y-Y_0)/(U-U_0)$**	40-60

Y = yield, F = fertilizer, R = removal, U = uptake

After Dobermann, 2007; Fixen et al., 2014

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Example maize N response: Elora, Ontario, Canada 2013

N rate, kg/ha	**Grain yield,** t/ha	**PFP,** kg grain /kg N	**AE,** kg grain /kg N	**PNB**	**RE**	**IE,** kg grain /kg N	**PE,** kg grain /kg N	**Net return** to applied N, $/ha
0	4.7							
90	9.4	**104**	**52**	**82%**	**67%**	**87**	**78**	$ 842
150	11.4	76	45	75%	65%	79	69	$ 1,190
220	13.0	59	38	64%	65%	68	58	**$ 1,434**
260	**13.3**	51	33	56%	57%	68	58	$ 1,460

- With increasing N rate: yield increases, all forms of NUE decrease.
- Net return has an optimum rate

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Efficiency versus Productivity

- Nutrient Use Efficiency:

$$\frac{\text{output kg/}\not{\text{ha}}}{\text{input kg/}\not{\text{ha}}}$$

- ***NUE can be independent of per-hectare productivity!***
- ***Productivity, not NUE, feeds the world***
- ***Productivity with NUE feeds the world sustainably***

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Efficiency and productivity compared across cropping systems

Nitrogen balance by region (kg/ha/yr), 1997-2006			
	North China (wheat-maize double crop)	**Midwest U.S. (maize-soybean rotation)**	**Western Kenya (low input maize-based)**
Input N	588	155	7
Output N	361	145	59
Output/Input	61%	94%	840%

Vitousek et al. 2009. Science 324:1519-1520

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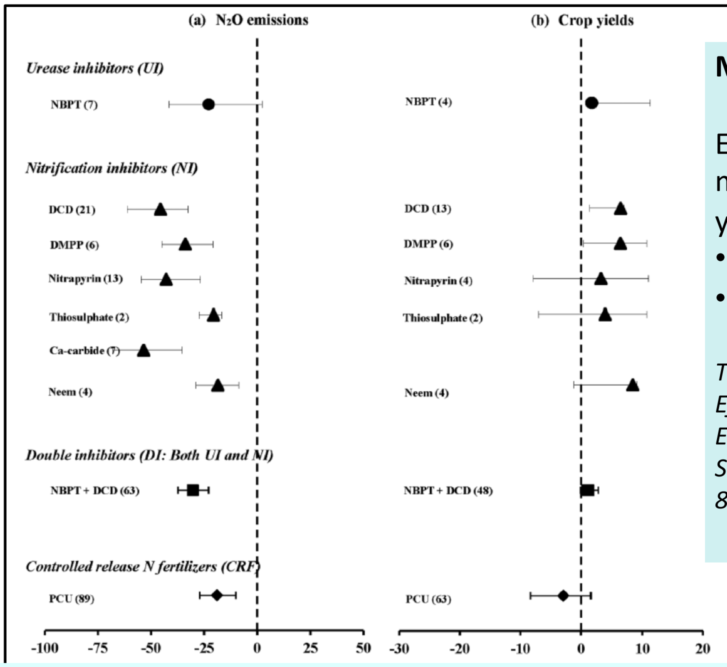

Effect of individual enhanced efficiency fertilizer (EEF) types (%)

Meta-analysis

Enhanced-efficiency fertilizers have more impact on emissions than on yield

- N_2O emission: **19-40%** reduction
- Yield: **0-10%** increase

Thapa et al. (2016). Effect of Enhanced Efficiency Fertilizers on Nitrous Oxide Emissions and Crop Yields: A Meta-analysis. Soil Science Society of America Journal 80:1121–1134

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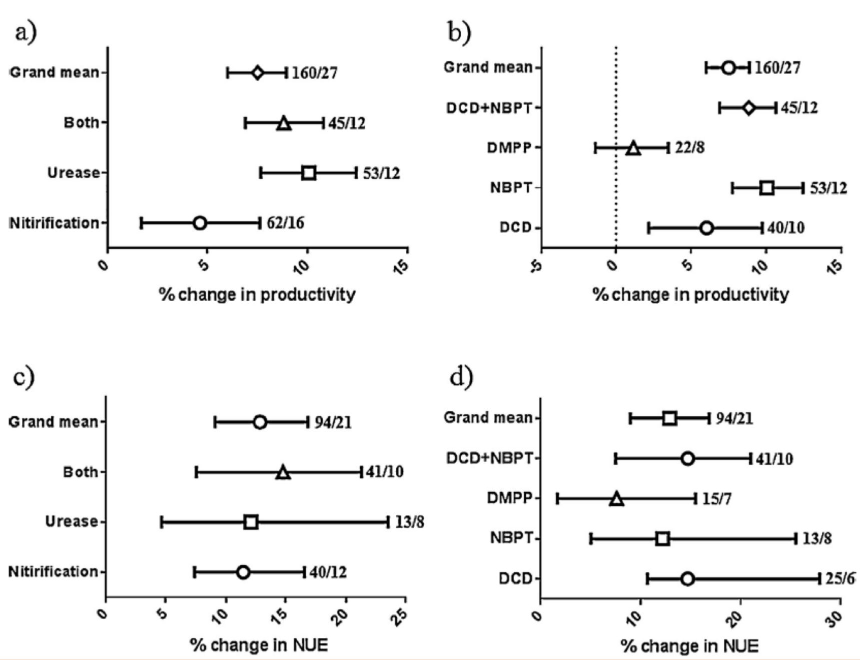

NUE= % of fertilizer N applied, taken up in the grain or above-ground biomass

Inhibitors improve Nitrogen Use Efficiency more than Yield

- **1-10% yield gain**
- **8-15% NUE gain**
- **19-40% less N_2O**

Abalos et al. (2014)
Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity and nitrogen use efficiency. Agriculture, Ecosystems and Environment 189: 136–144

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Efficiency and Effectiveness

- Nitrogen use efficiency is desirable, and contributes to sustainability.
- Trade-off with productivity requires optimizing, not maximizing, nitrogen use efficiency.
- Some nitrogen application practices may affect nitrogen losses more than use efficiency.

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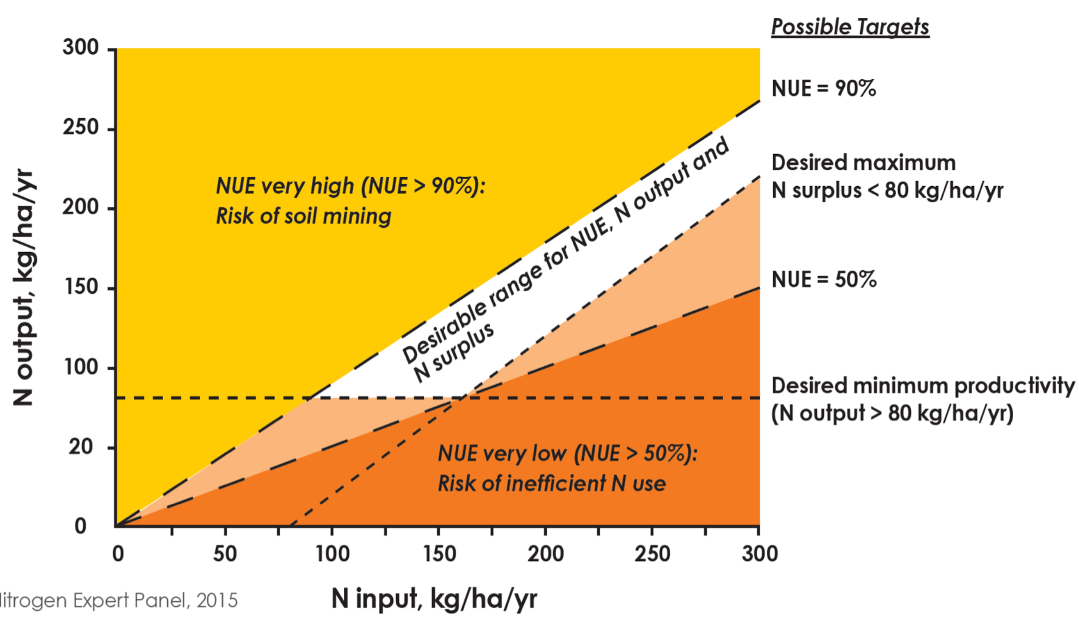

Source: EU Nitrogen Expert Panel, 2015

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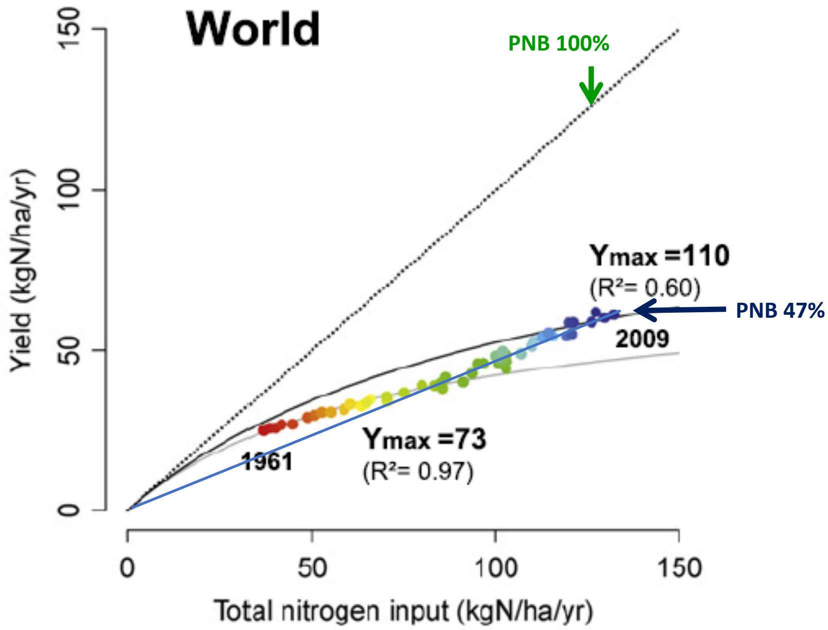
Nitrogen Use Efficiency trajectories over 49 years

increasing yield, stable partial N balance (PNB)



Lassaletta et al., 2014, Environ. Res. Lett. 9 (2014) 105011 (9pp)

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Mexico N use efficiency – low for maize, high for wheat

	Crop area, Mha	Fertilizer N use, kg/ha	Yield, t/ha	Partial factor productivity kg grain/kg N
Maize				
Mexico	7.1	125	3.4	27
Canada	1.3	153	10.4	68
USA	32.7	171	10.6	62
World	190.6	96	5.5	57
Wheat				
Mexico	0.8	100	4.5	45
Canada	9.6	81	2.9	36
USA	19.1	82	2.9	35
World	223.5	84	3.3	39

FAOSTAT, 2020; IFA, 2020

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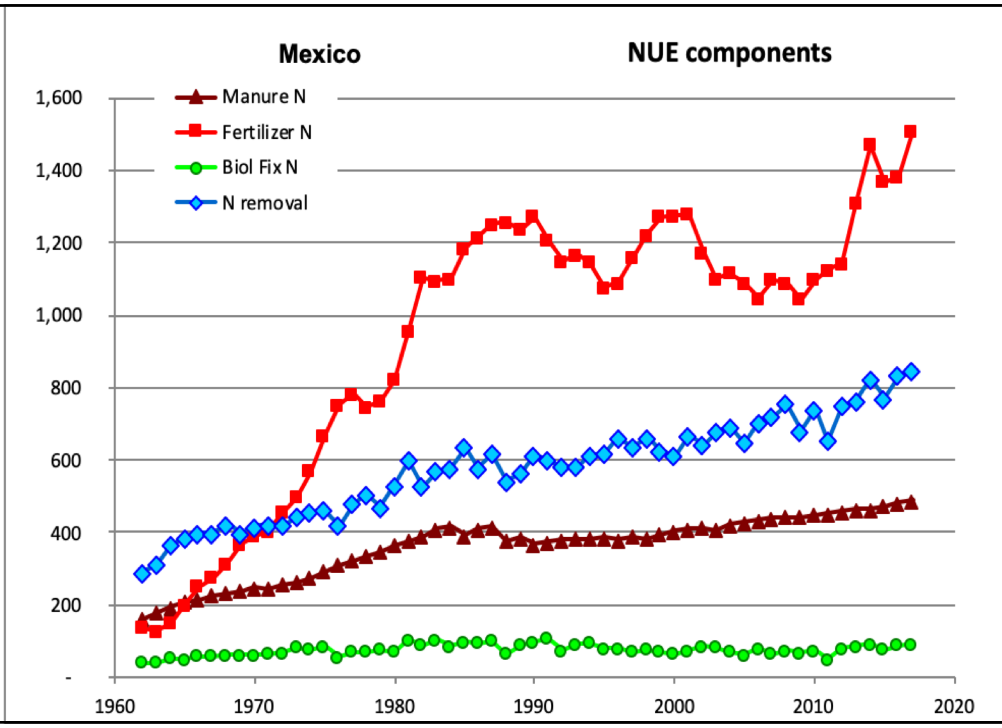
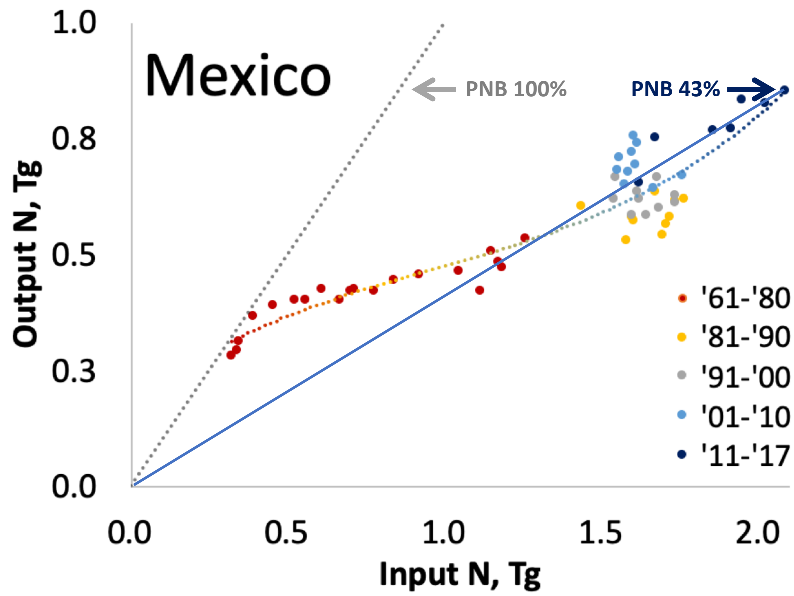


N use efficiency trajectories over **57** years (1961-2017)

increasing output, increased PNB



IFA, 2020 – Nutrient Use Efficiency database. Input = fertilizer + fixation + manure; Output = harvest

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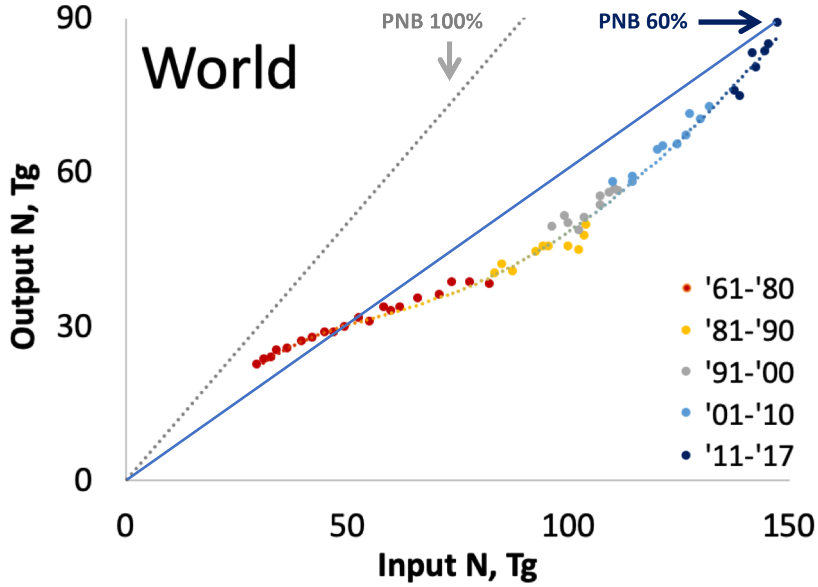

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N use efficiency trajectories over 57 years
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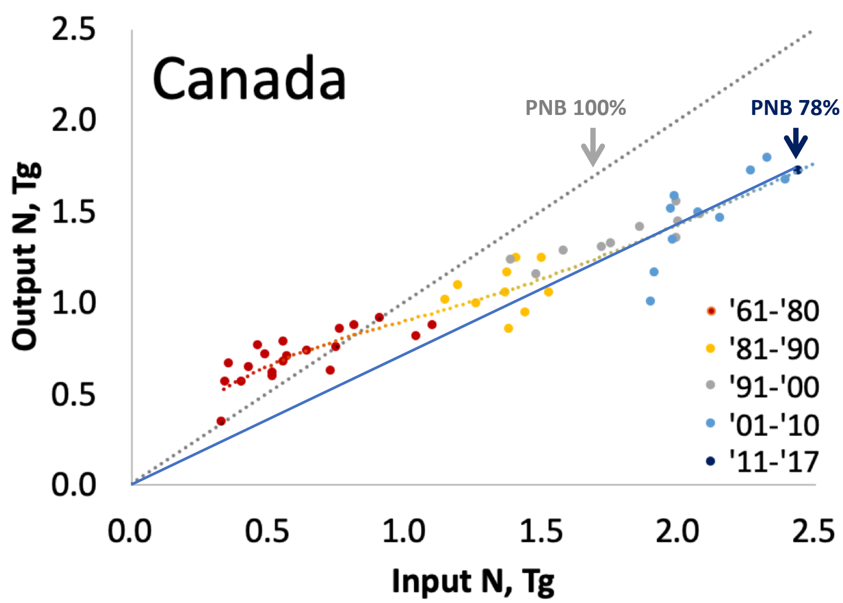
increasing output, stable PNB



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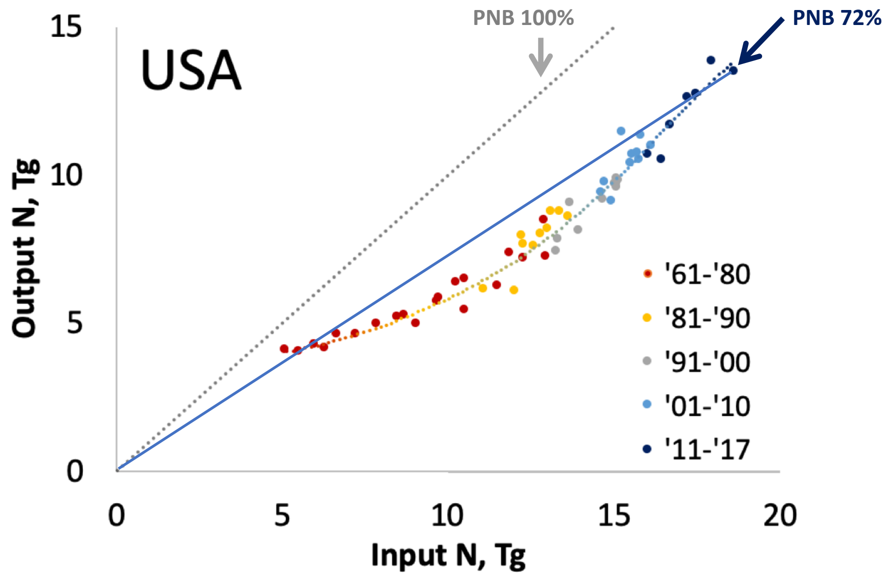

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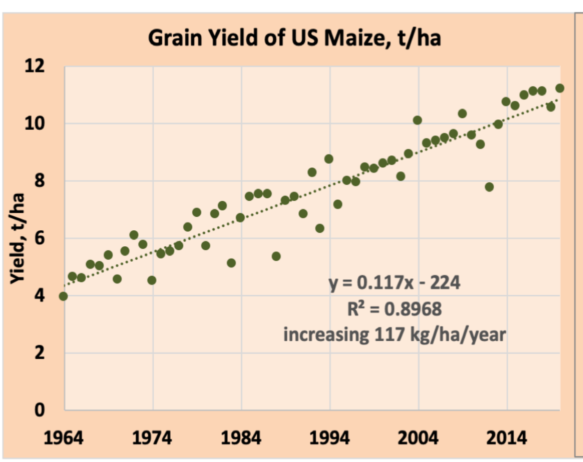
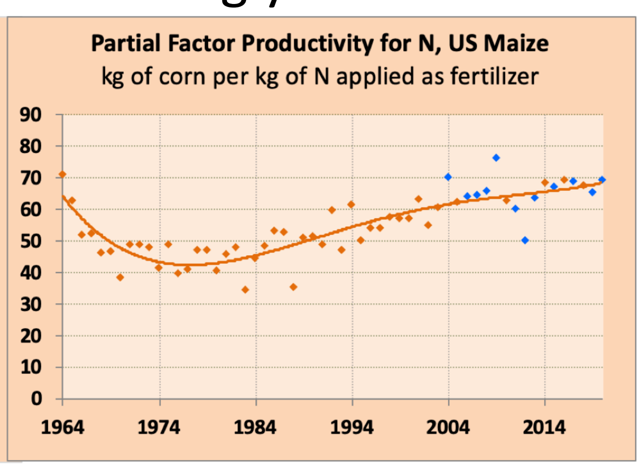
Nitrogen use efficiency improvement in US maize is associated with increasing yield





Calculated from USDA-NASS and USDA-ERS data

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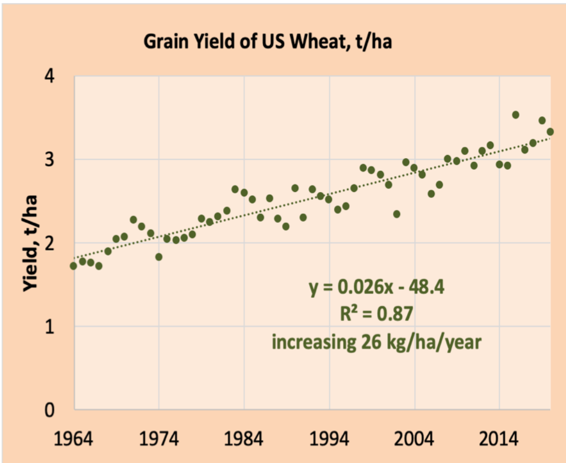
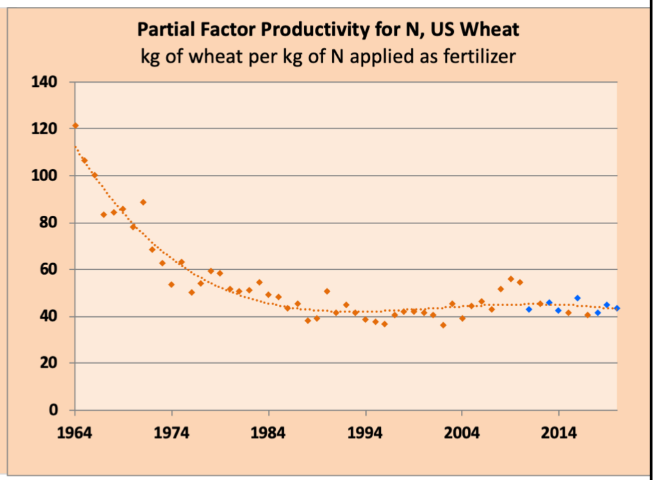
US Wheat yield improvement slower; nitrogen use efficiency stable





Calculated from USDA-NASS and USDA-ERS data

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Trends

- Productivity and efficiency generally improving
- But, is the improvement rapid enough to keep pace with growing global demand?

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How to improve efficiency and effectiveness

- Crop genetics
- Nutrient management
- Cropping system management
- Stewardship
- Sustainability

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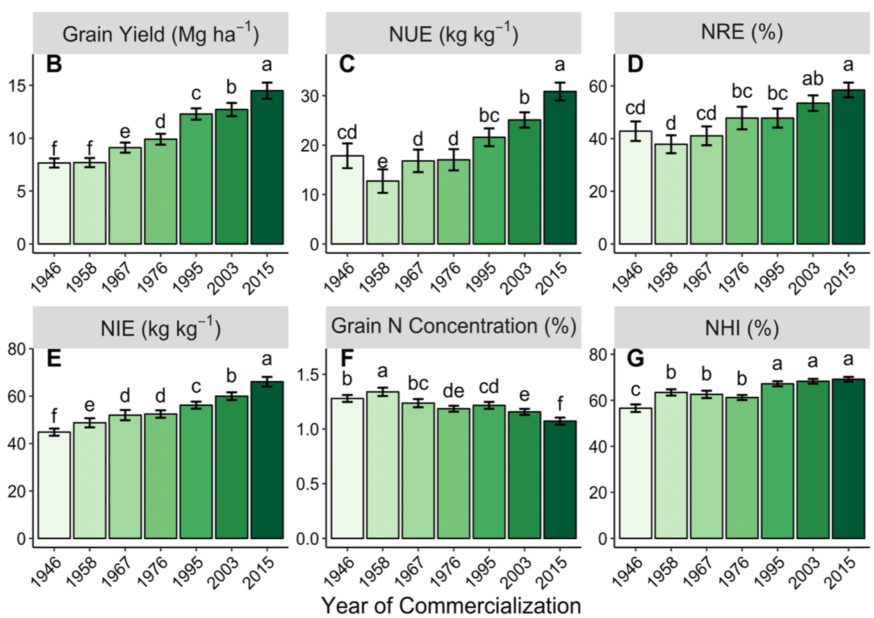

Genetics

Maize hybrids in USA show increasing yield and N use efficiency, decreasing grain N

Mueller, Messina, & Vyn. 2019. Nature Scientific Reports 9:9095 https://doi.org/10.1038/s41598-019-45485-5

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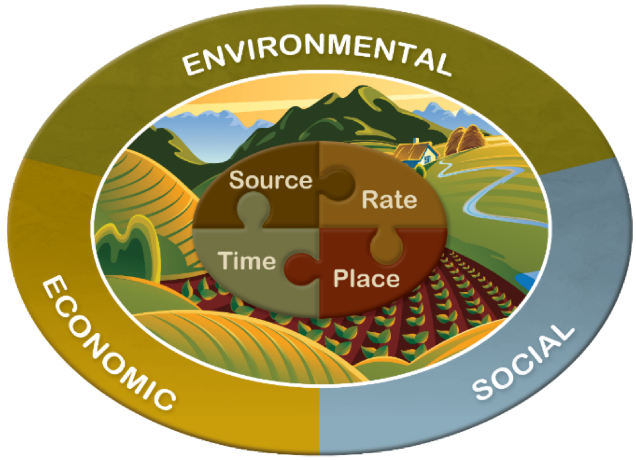
4R Nutrient Stewardship

Right Source
Right Rate
Right Time
Right Place



Right =
a more sustainable cropping system

nutrient stewardship

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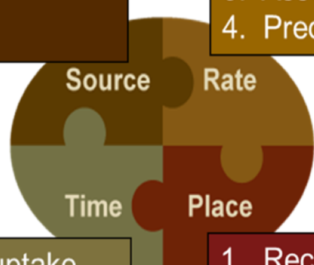
Source

1. Diagnose nutrient deficiencies
2. Supply in plant available forms
2. Suit soil properties
3. Recognize synergisms among elements
4. Blend compatibility

Rate

1. Appropriately assess soil nutrient supply
2. Assess all available indigenous nutrient sources
3. Assess plant demand
4. Predict fertilizer use efficiency



Time

1. Assess timing of crop uptake
2. Assess dynamics of soil nutrient supply
3. Recognize timing of weather factors
4. Evaluate logistics of operations

Place

1. Recognize root-soil dynamics
2. Manage spatial variability
3. Fit needs of tillage system
4. Limit potential off-field transport

4R principles are the starting point for improving use efficiency of **applied nitrogen**

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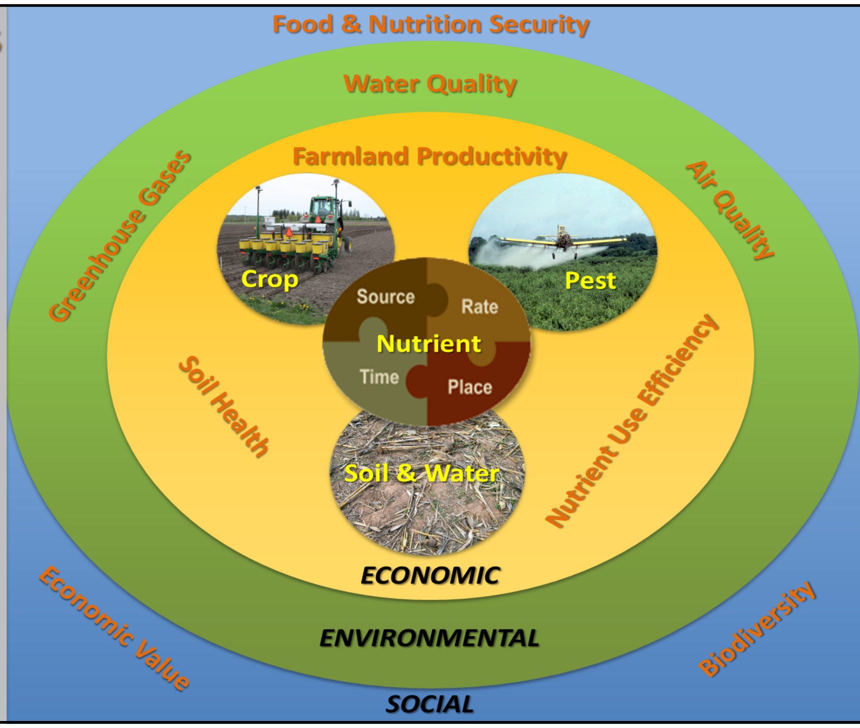
OUTCOMES

of 4R nutrient stewardship are influenced by **crop and pest management,** and by **soil and water conservation practices** in the context of changing **weather and climate.**



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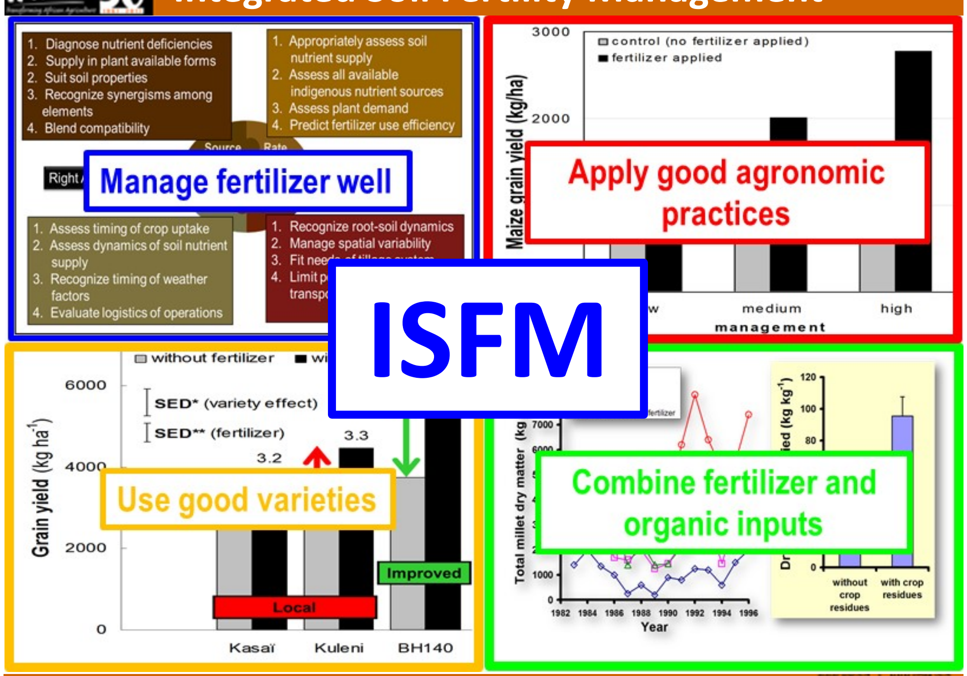
Integrated Soil Fertility Management



4R Nutrient Stewardship is an important component of **Integrated Soil Fertility Management**

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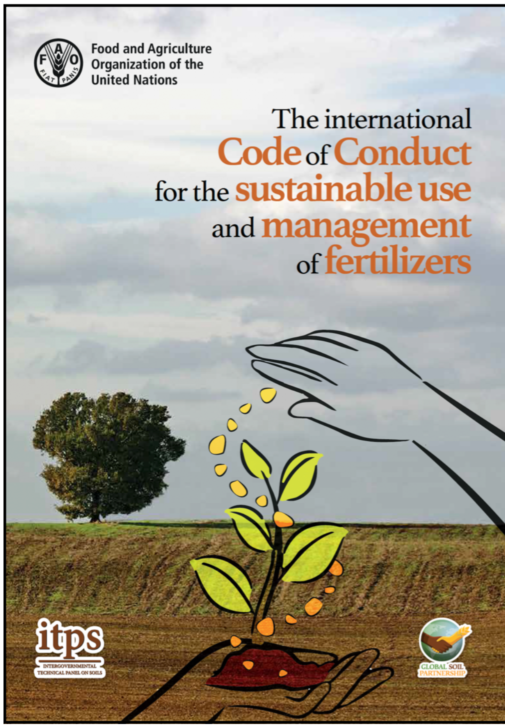

Principles of 4R Nutrient Stewardship and Integrated Soil Fertility Management are embedded in the FAO Code.

Responsibilities for:
- governments
- research institutions
- fertilizer industry
- fertilizer users
- retailers
- laboratories

Articles on:
- Soil fertility and plant nutrition
- Fertilizer use and management
- Nutrient reuse and recycling
- Composition, limits and testing
- Access, distribution and labelling
- Information, extension and outreach
- Implementation, dissemination, use and evaluation

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HOME VISION & MISSION WHO WE ARE VIEW POINTS ISSUE BRIEFS RESOURCES CONTACT

The Panel's mission is to provide a sound scientific basis for principles and practices of responsible plant nutrition in farming systems.

Responsible plant nutrition nourishes plants in a sustainable manner, enhancing earth's capacity to support healthy life. As a Scientific Panel on Responsible Plant Nutrition, we seek to better understand the links between plant nutrition practices and sustainability outcomes, and to provide the scientific evidence to support a transition in practices to achieve these outcomes. Here we outline this vision.

In agricultural systems, nutrient inputs are needed to replenish those removed by crop harvests, to build fertility in degraded soils,

Conclusions

Continuing improvement in nitrogen use efficiency and effectiveness requires:

- Attention to the principles of 4R nutrient stewardship and definition of region-specific 4R practices
- Integration of 4R practices with improvement in crop genetics, and management of soils, crops, and pests.
- Attention to impacts on productivity, soil health, and specific loss pathways affecting air, water, climate, biodiversity, and socioeconomics
- Collaboration: science, practitioners, farmers, NGOs, government, universities

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