

Nitrogen Use Efficiency in Responsible Plant Nutrition


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Outline

Nitrogen Use Efficiency in Responsible Plant Nutrition

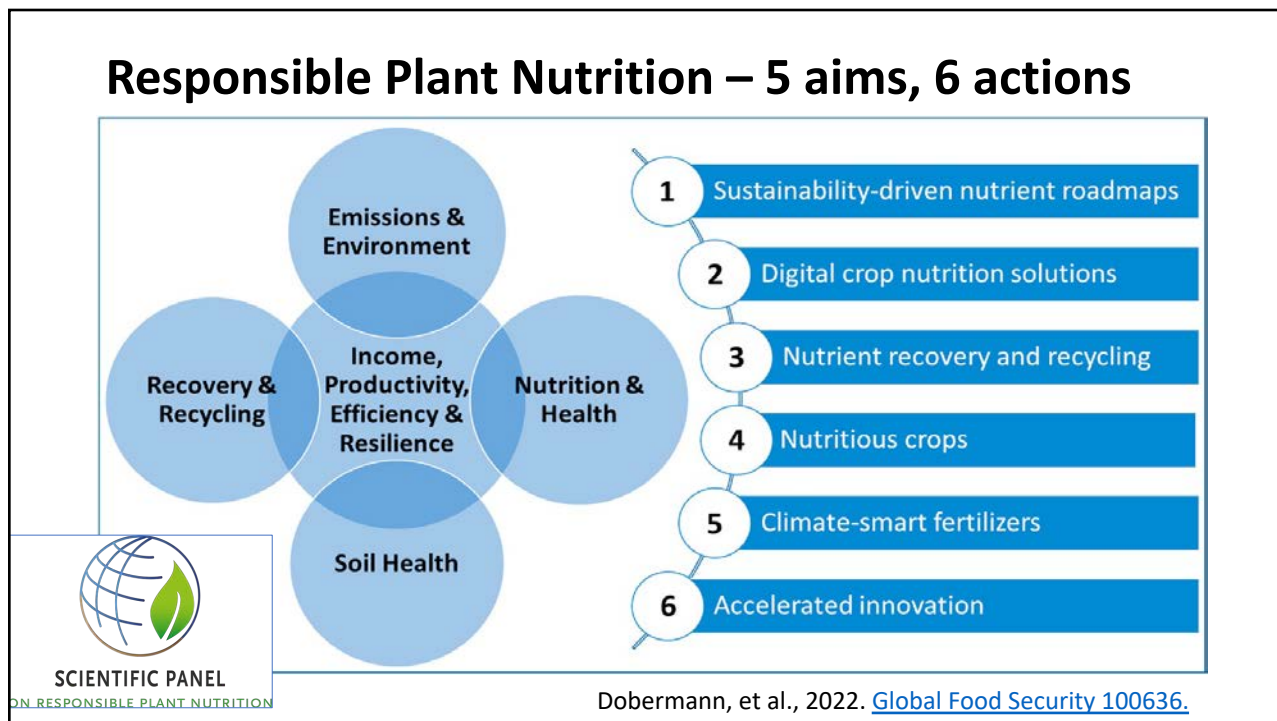
1. Responsible plant nutrition and 4R nutrient stewardship
2. Definitions and formulations of nitrogen use efficiency indicators
3. NUE indicators for the five aims of responsible plant nutrition
4. Assessing 4R nutrient stewardship programs



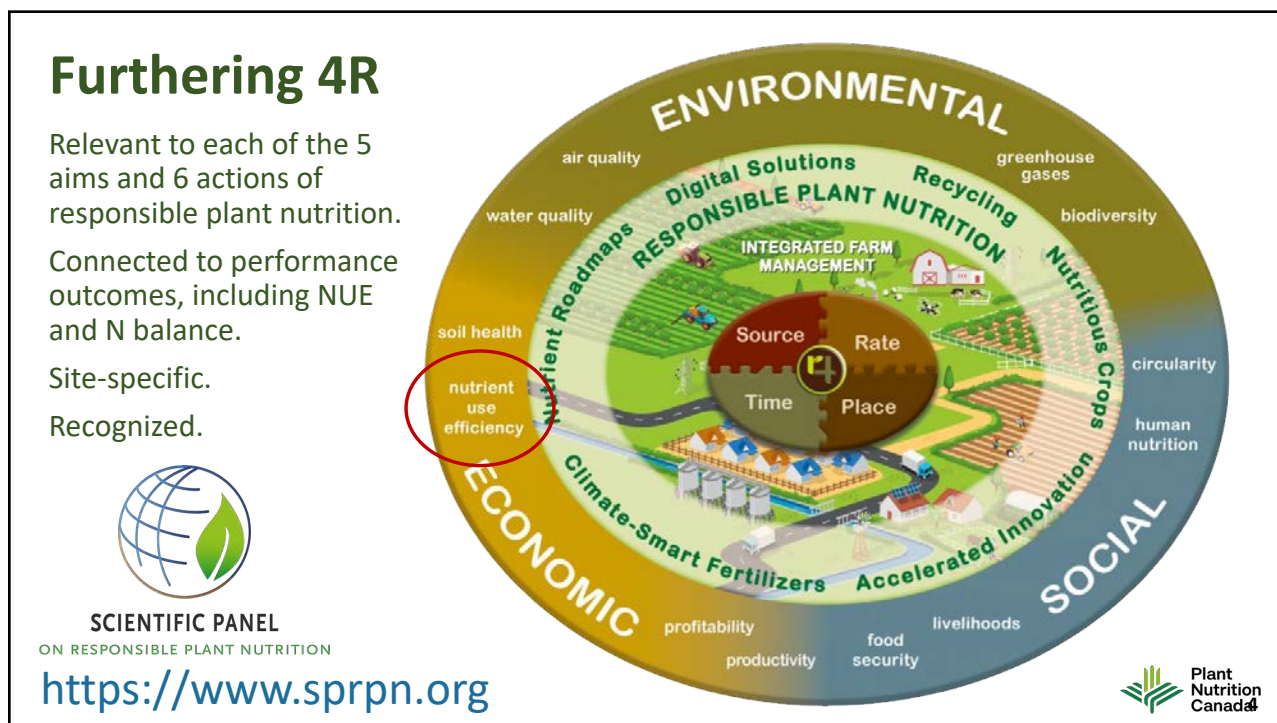
DEFINING NUTRIENT USE EFFICIENCY IN RESPONSIBLE PLANT NUTRITION
Issue Brief 04, August 2023



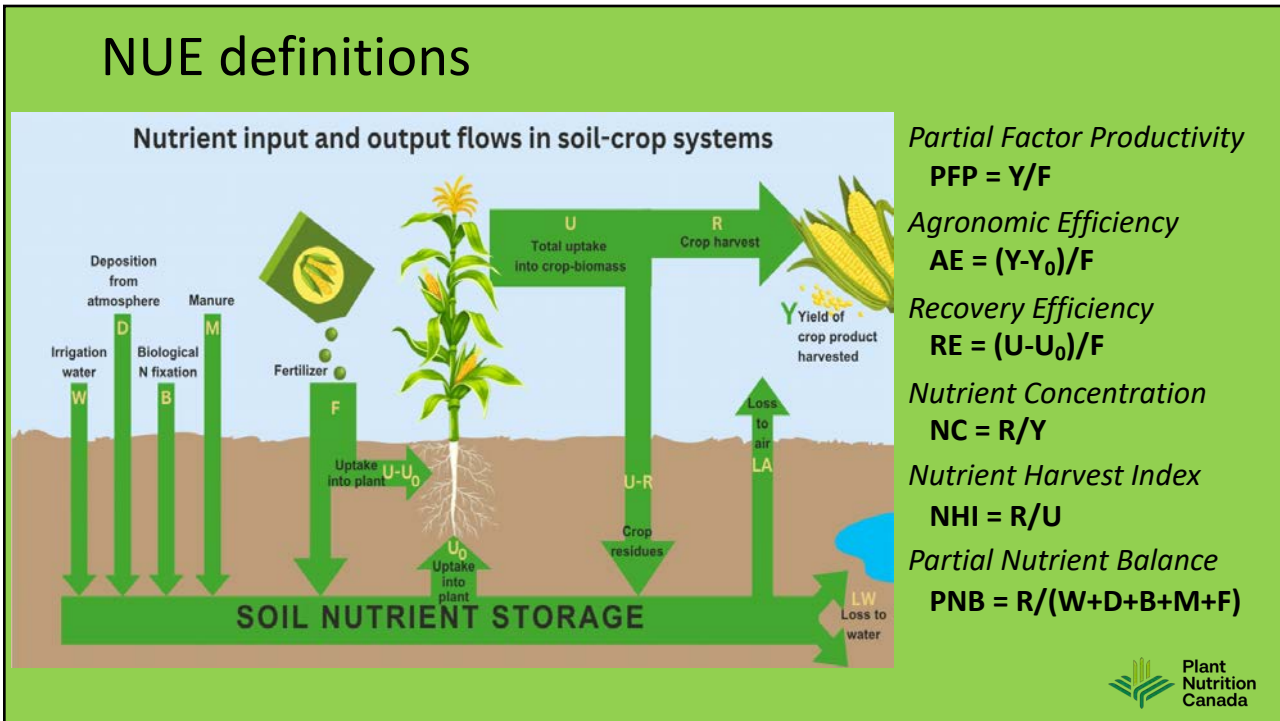
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NUE indicators for N in corn

NUE INDICATOR	CALCULATION	TYPICAL VALUES
PFP	Y/F	40-80 lb/lb
AE	(Y-Y ₀)/F	20-50 lb/lb
RE	(U-U ₀)/F	40-75%
NC	R/Y	1.1-1.5%
NHI	R/U	60-80%
PNB	R/(W+D+B+M+F)	50-90%

Plant Nutrition Canada

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NUE as performance indicator

STRENGTHS:

1. Measurable outcome of management
2. Scalable benchmark for accountability
3. Limits input use only in relation to yield
4. Relates to every loss pathway, upstream and down

LIMITATIONS:

1. Critical values vary among farming systems and regions
2. Does not prescribe practices
3. Does not guarantee reduced N pollution (lags)
4. Should be considered in context of **productivity** and **soil health** indicators



A publication of the
Global Partnership on Nutrient Management



Lead authors:
Rob Norton, Eric Davidson, and Terry Roberts

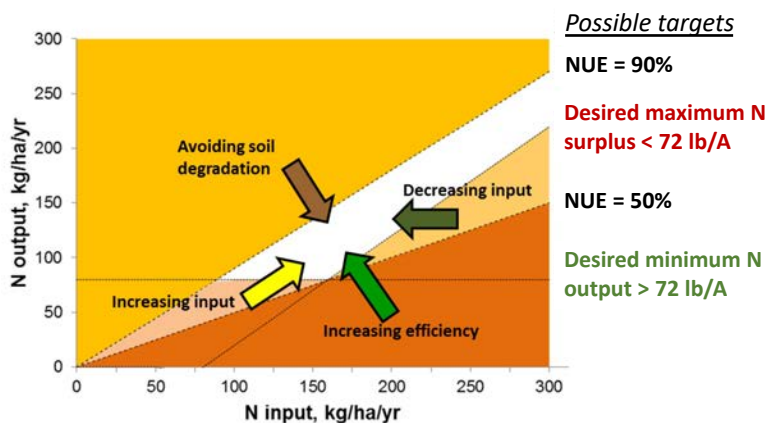
2015



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“Safe Operating Space”

- N output vs N input
- N output represents productivity
- Slope from any point to origin represents NUE
- **N surplus (F-R)** can also be plotted as a line
- Excessive NUE can degrade soil



EU Nitrogen Expert Panel, 2015

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NUE indicators for the 5 aims of RPN

AIM	NUE INDICATORS	USES
1. Improve income, productivity, efficiency & resilience of farmers	a) PFP & PNB (on farm) b) AE & RE (in research)	Assess efficacy of practices and efficiency of cultivars & products
2. Increase nutrient recovery & recycling from waste	a) PNB – farm gate b) AE & RE	a) Opportunity b) Nutrient availability
3. Lift & sustain soil health & soil carbon	PNB (NHI)	Potential change in soil nutrient storage
4. Enhance human health through nutrition-sensitive agriculture	NC & NHI	Transfer of nutrient to nutritional quality
5. Minimize losses (GHG, pollution, biodiversity)	PNB (RE)	Potential for nutrient losses

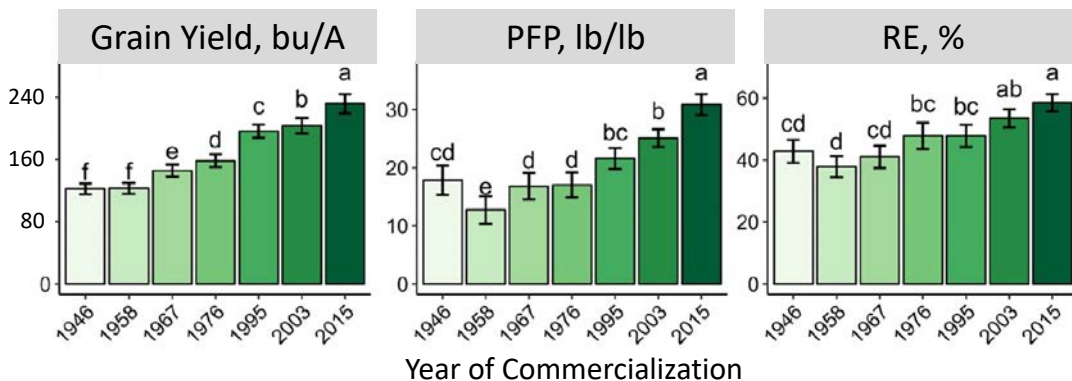
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RPN Aim #1. Improve income, productivity, efficiency & resilience of farmers

NUE INDICATORS	USES
a) PFP & PNB (on farm) b) AE & RE (in research)	Assess efficacy of practices and efficiency of cultivars & products

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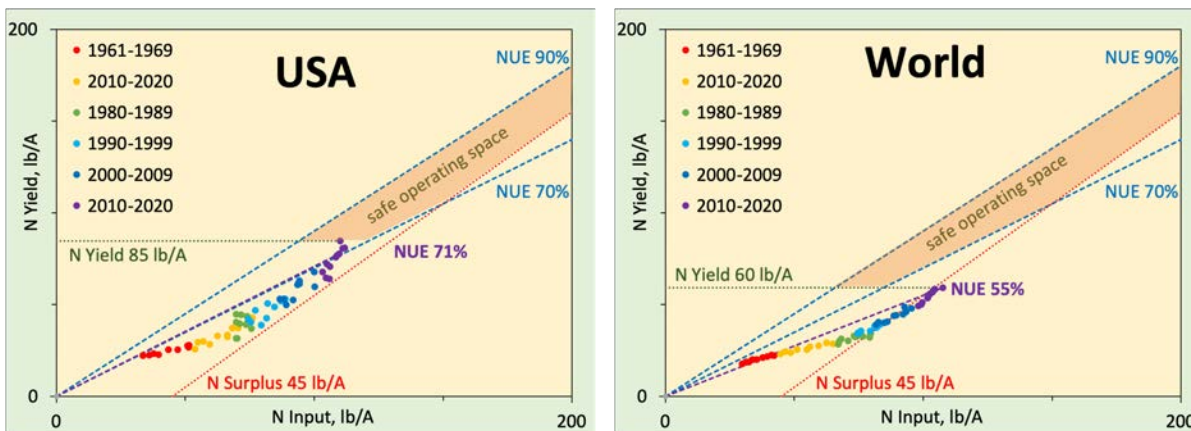
Genetic improvement in corn hybrids has increased yield & NUE



Mueller, S.M., C.D. Messina, and T.J. Vyn. 2019. Simultaneous gains in grain yield and nitrogen efficiency over 70 years of maize genetic improvement. Scientific Reports 9(1): 9095. doi: [10.1038/s41598-019-45485-5](https://doi.org/10.1038/s41598-019-45485-5).

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Cropland NUE is increasing with productivity



NUE = N outputs/ N inputs

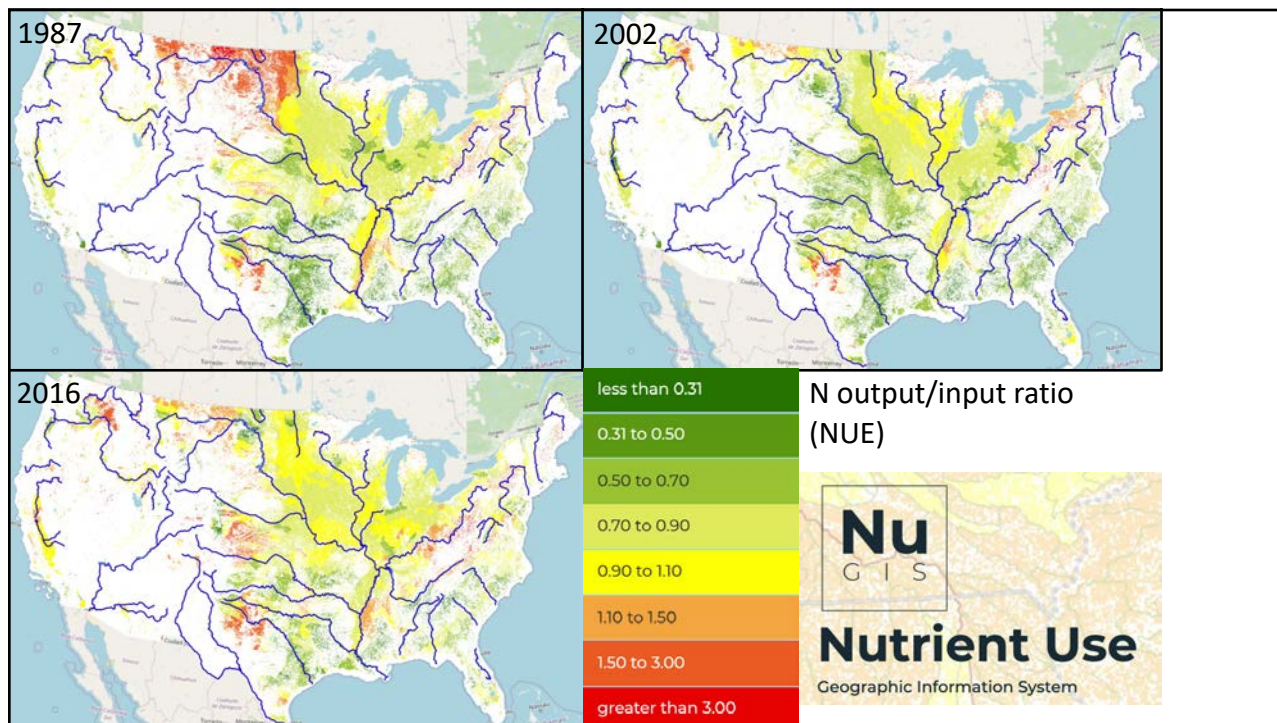
N Outputs: Crop removal.

N Inputs: Fertilizer + manure applied + biological fixation + atmospheric deposition

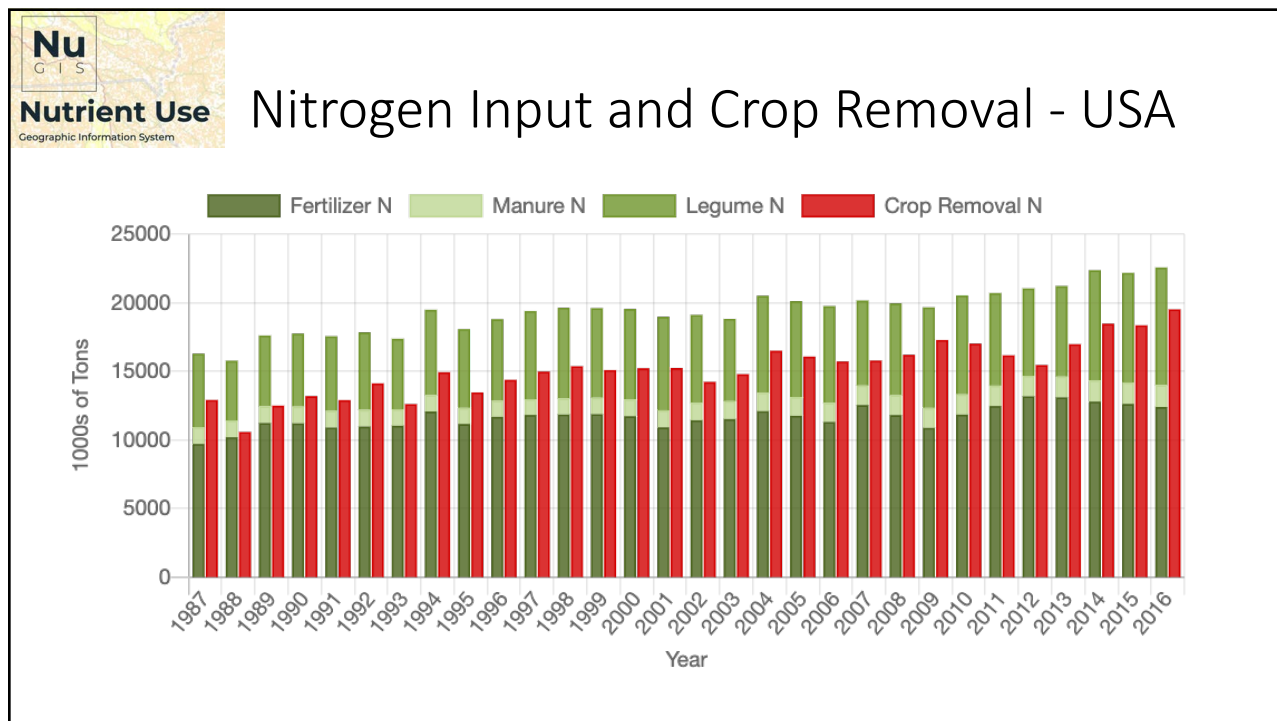
Data Source: FAOSTAT Crop Nutrient Budgets



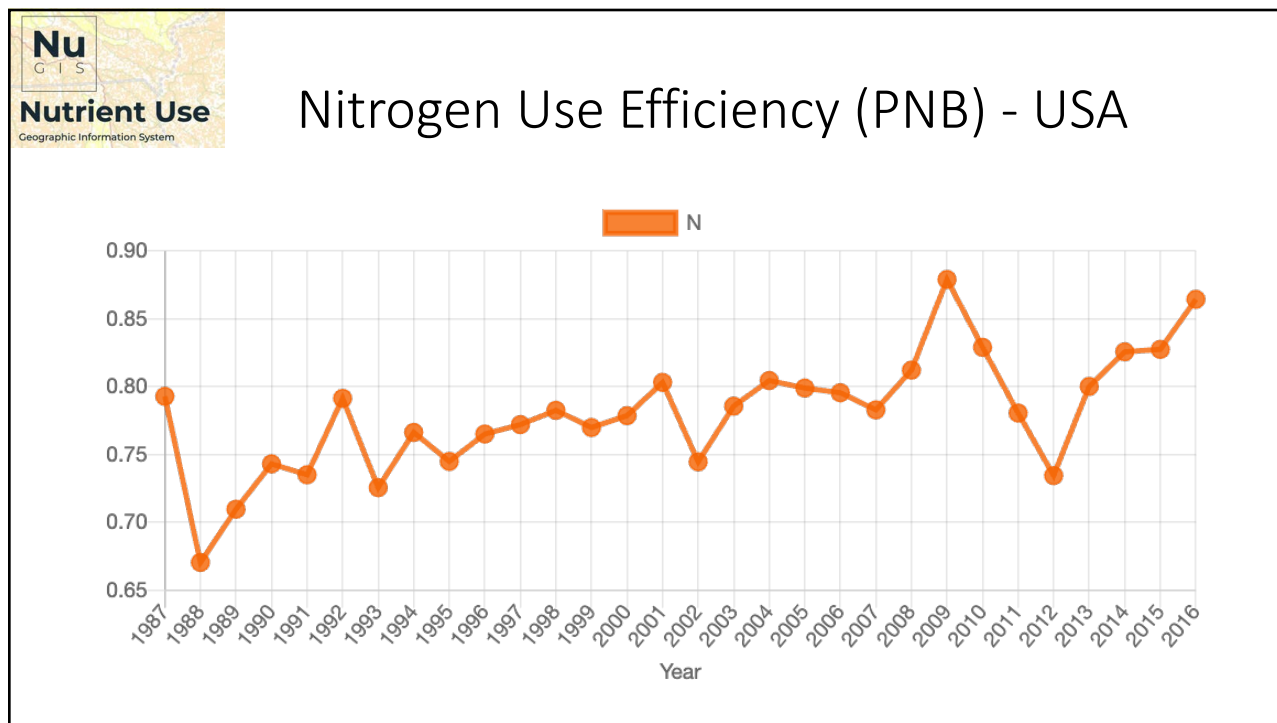
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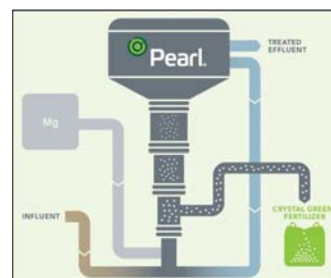
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RPN Aim #2. Increase nutrient recovery & recycling from waste

NUE INDICATORS	USES
a) PNB – farm gate b) AE, RE	a) Opportunity b) Nutrient availability

4R source principle: Use recycled forms where feasible.

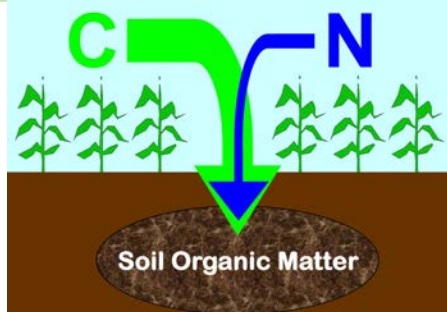
- Struvite
- Processed manure
- Nutrients recovered from food waste



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RPN Aim #3. Lift & sustain soil health & soil carbon

NUE INDICATORS	USES
PNB (NHI)	Potential change in soil nutrient storage



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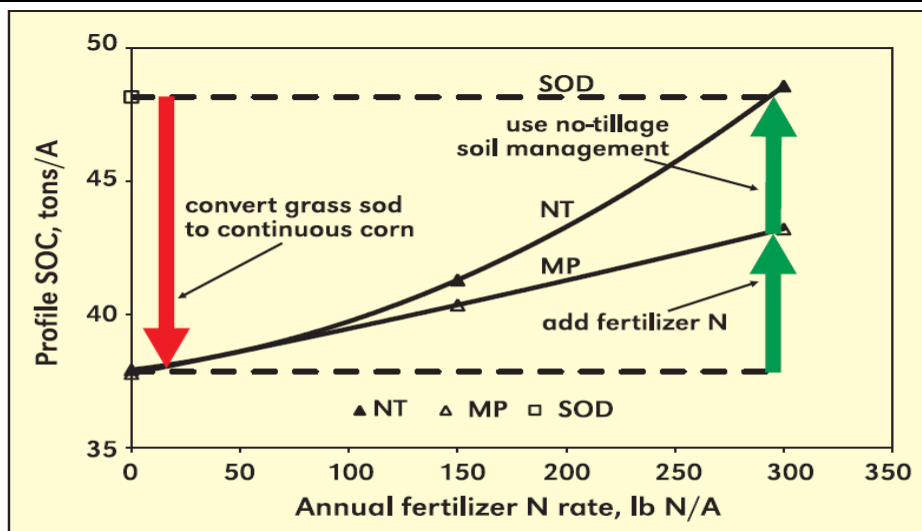


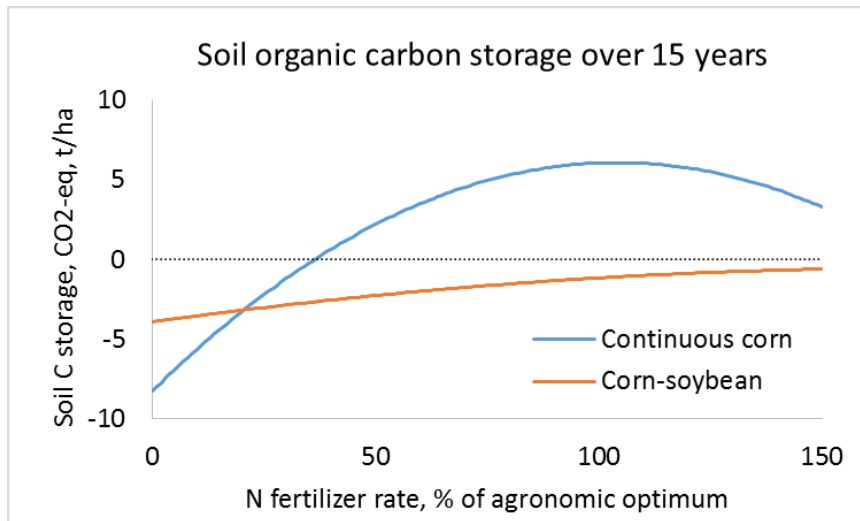
Figure 5. The impact of fertilizer N on total profile SOC levels found after 39 years of cropping to continuous corn with a winter cereal cover crop.

Grove et al., 2009, Kentucky, Better Crops, 2009 issue #4



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Optimum N rate is similar for yield & soil organic matter



Adapted from Poffenbarger et al., 2017. PLoS ONE 12(3): e0172293



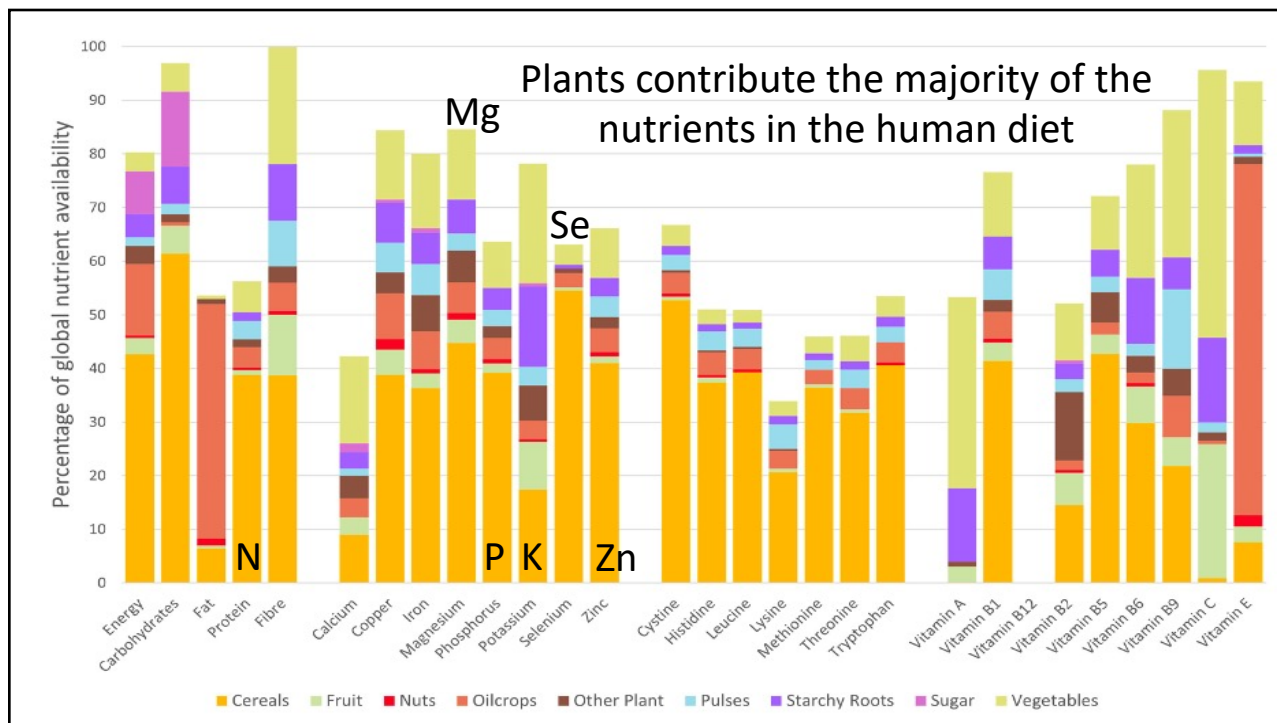
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RPN Aim #4. Enhance human health through nutrition-sensitive agriculture

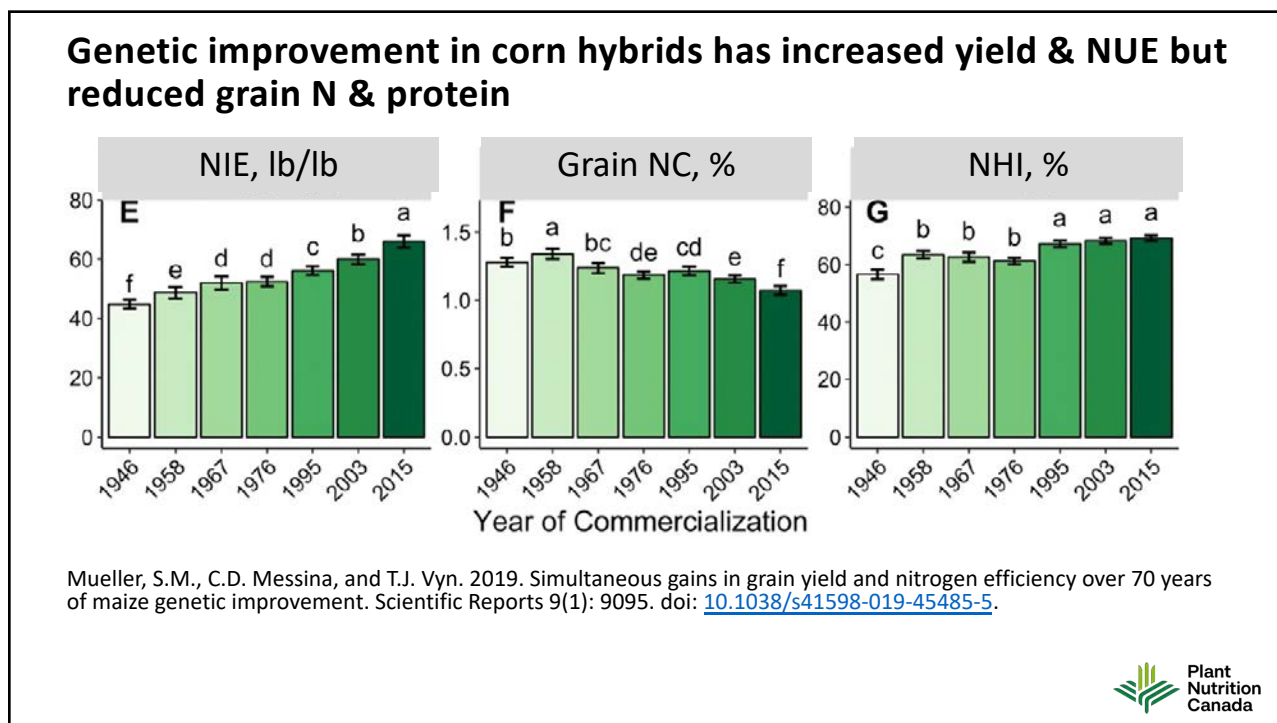
NUE INDICATORS	USES
NC & NHI	Transfer of nutrient to nutritional quality



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Fertilizing corn with zinc for yield improvement improves zinc concentration for human health –but not enough!

Global meta-analysis, 67 studies:

Zn fertilizer	Yield, bu/A	[Zn], ppm
Without	79	22
With	96	27
% increase	17%	25%

Target for alleviating human Zn deficiency: 38 ppm

Mutambu, D., J. Kihara, M. Mucheru-Muna, P. Bolo, and M. Kinyua. 2023. Maize grain yield and grain zinc concentration response to zinc fertilization: A meta-analysis. *Heliyon* 9(5). doi: [10.1016/j.heliyon.2023.e16040](https://doi.org/10.1016/j.heliyon.2023.e16040).



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RPN Aim #5. Minimize losses (GHG, pollution, biodiversity)

NUE INDICATORS	USES
PNB (RE)	Potential for nutrient losses



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AgSurplus 1985-2019 Trend

TN Trend, kg/ha

- Less than -25
- 25 to -5
- 5 to -2
- 2 to 0
- 0 to 2
- 2 to 5
- 5 to 25
- 25 or more
- Missing

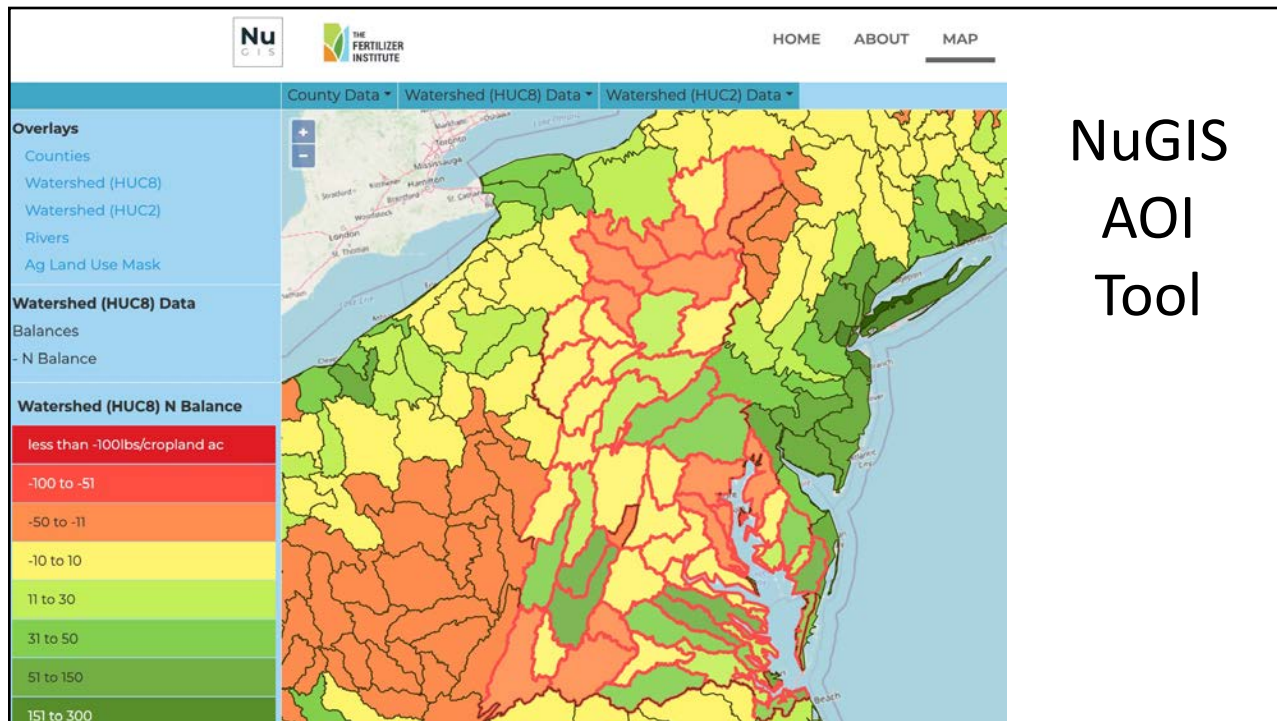
E Does higher NUE reduce N loads?

“Over the 1985–2019 time period, declines in total nitrogen (TN) loads have been reported in nearly all of the major tributaries to the Chesapeake Bay”

“Despite all of these positive developments, recent increases in agricultural surpluses from 2009–2019 highlight that water quality gains may soon be reversed in many agricultural areas of the basin.”

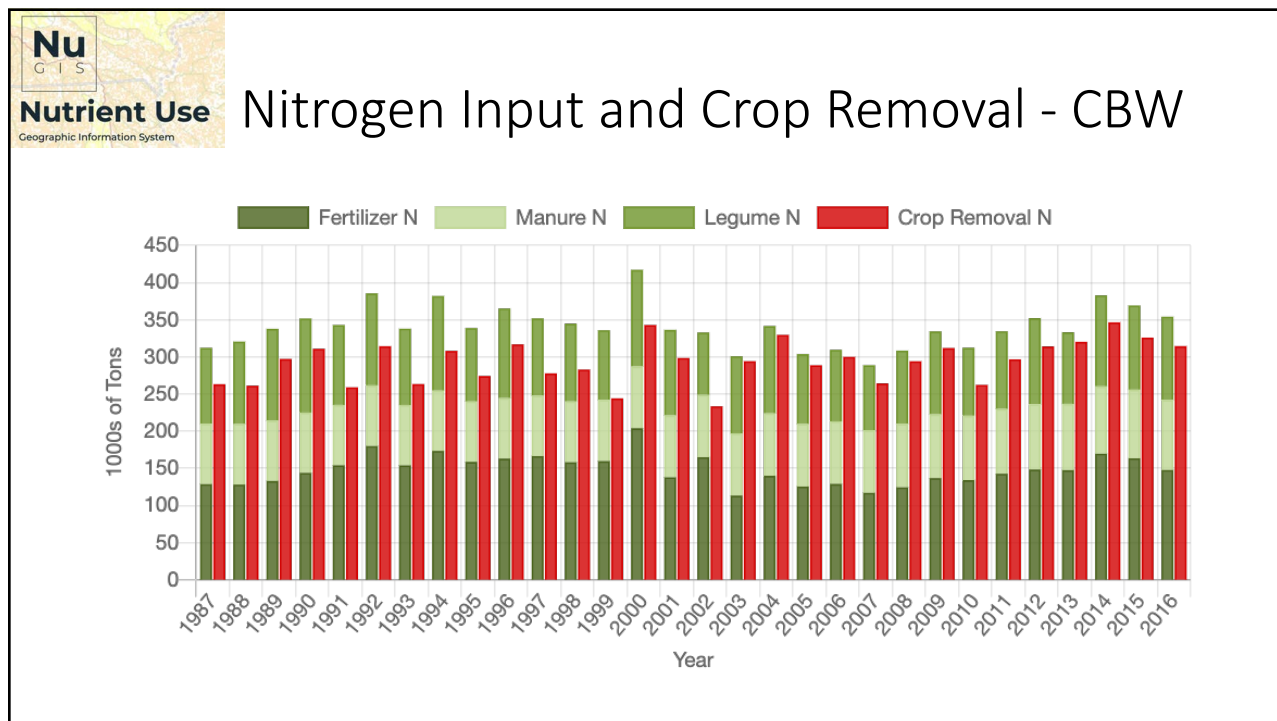
Sabo, R.D., B. Sullivan, C. Wu, E. Trentacoste, Q. Zhang, et al. 2022. Major point and nonpoint sources of nutrient pollution to surface water have declined throughout the Chesapeake Bay watershed. Environmental Research Communications 4(4):045012. doi: [10.1088/2515-7620/AC5DB6](https://doi.org/10.1088/2515-7620/AC5DB6).

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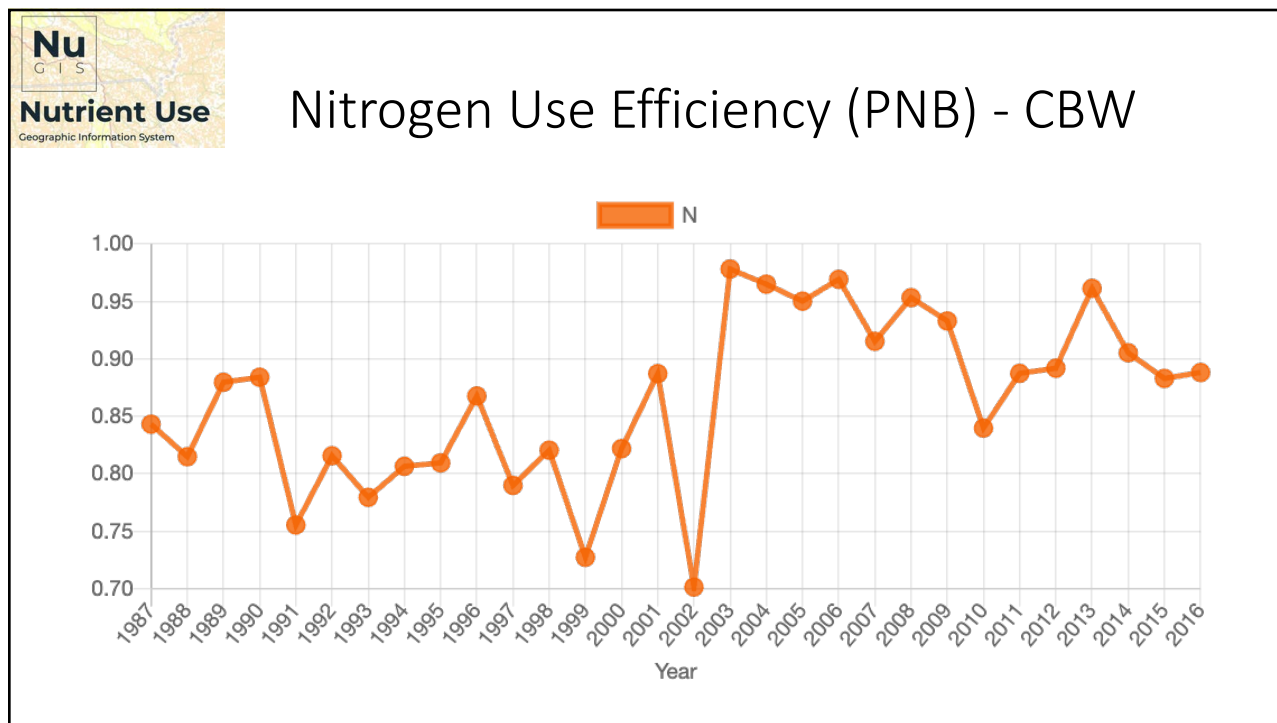


NuGIS
AOI
Tool

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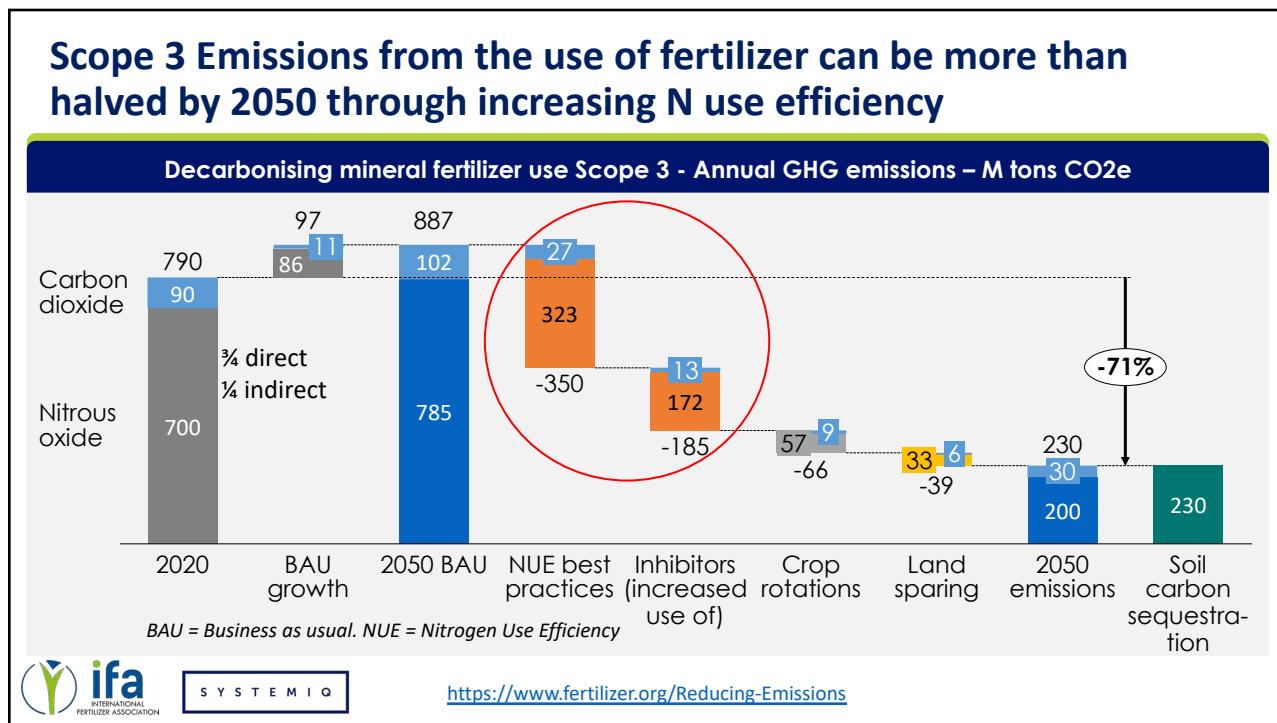
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NUE and GHG

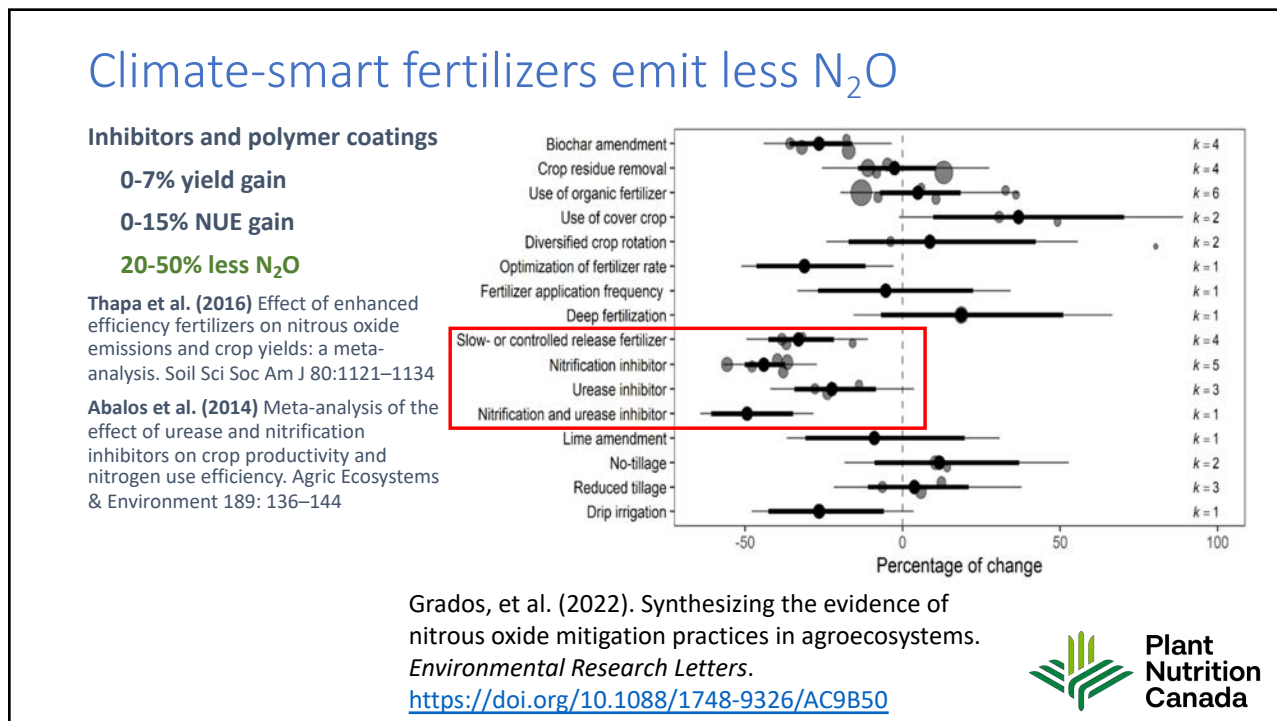
By 2050:

- Increasing global **NUE** from 50% to 70% could reduce emissions by 320 Mt CO₂e
- **Baseline 2020** = 717 Mt CO₂e annually

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Net-zero future has many moving pieces

- Green ammonia: IFA projects 3.5 Mt by 2027, almost 85 Mt after 2027.
- Urea: CO₂ release = 1.6 tons per ton of N (IPCC)
- “In the Sustainable Development Scenario the use of urea-based fertilisers declines by 28% by 2050 compared to today, replaced by ammonium nitrate and calcium ammonium nitrate.”
- “In both scenarios (SD and NZ) some of the CO₂ required for urea has to be obtained from sources other than the process CO₂ emission streams of ammonia plants.”
- “if all ammonia were produced via either electrolysis or methane pyrolysis ... neither route would generate CO₂ for use in urea production.” (IEA, 2021)

iea

Ammonia Technology Roadmap

Towards more sustainable nitrogen fertiliser production



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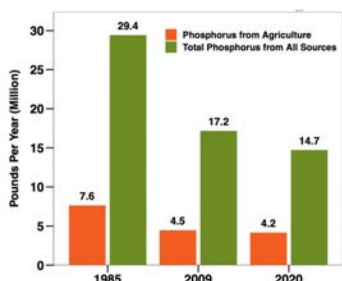
Assessing 4R programs



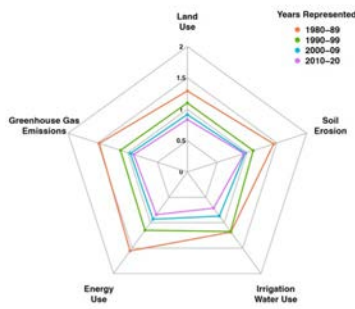
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Sustainability Performance Reporting

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



Chesapeake Bay Water Quality



Corn for grain

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

4R NUTRIENT STEWARDSHIP CERTIFICATION PROGRAM
 Voluntary program in Western Lake Erie Basin (WLEB) and entire state of Ohio for agricultural retailers & nutrient service providers implementing the 4R's

- 60 CERTIFIED BRANCH FACILITIES
- 47 FACILITIES IN WLEB
- 4 NUTRIENT STEWARDSHIP CERTIFICATION
- 5,800 CLIENTS SERVICED
- 4 CLIENTS
- 2.83M TOTAL ACRES
- 1.56M ACRES IN WLEB
- 56 CLIENTS



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4R's Across Canada

Sustainable farming is the future. In many cases, that future is already underway. 4R Nutrient Stewardship (Right Source @ Right Rate, Right Time, Right Place) lets the world know when food has been sustainably grown. We want to demonstrate this to the world, by getting Canadian agri-retailers and crop advisors 4R Designated/4R Certified and counting millions of acres under 4R Nutrient Stewardship, to demonstrate how Canada is a leader in sustainable farming.

Alberta
82% of Alberta growers apply primary nitrogen fertilizer at seeding which is shown to increase profitability and reduce GHG emissions.

Saskatchewan
Over 78% of canola acres and 97% of spring wheat acres receive in-soil placement of phosphorus at planting which can reduce phosphorus run-off by up to 75%.

Manitoba
37% of spring wheat growers in Manitoba applied an enhanced efficiency fertilizer (EEF) or urea in the spring at or before planting and 14% of Manitoba wheat growers used an EEF. These BMPs have been shown to reduce GHG emissions by up to 20% and 55%, respectively.

Western
In canola production, the vast majority of NPKS fertilizer by nutrient volume is applied by banding or seed placement.

General
On average 70% of Canadian crop acres are operating under the principles of 4R Nutrient Stewardship.

Ontario
70% of Ontario corn growers apply phosphorus by banding or seed placement, which has been demonstrated to reduce phosphorus run-off by as much as 60% (in comparison to broadcast applications).

- 17 southern Ontario agri-retail facilities have completed and passed the 4R Certification audit to become 4R Certified
- 1,711 4R Grower Customers (19% of total growers)
- 31 sites completed a 4R Certification pre-audit
- 426,566 Acres of Farmland (11% of total farm acres)

Eastern
In corn production, almost half of N, P, S fertilizer and a third of K fertilizer by nutrient volume is banded or seed placed.

Prince Edward Island
In side-by-side trials conducted in grower's fields, 4R BMPs were shown to result in as much as a 32 per cent reduction in nitrate leaching. Nitrate (NO3-) leaching is when Nitrate leaves the soil in drainage water.

Only 31% of growers who practice 4R are aware they are operating under the program. The next challenge is to verify these acres under 4R Designation or 4R Certification, so we can share the story of sustainable agriculture in Canada.

4R Designation (AB-SK-MB)

4R Certification (ON & PE)

- reached 9M acres in 2022

- goal of 15M acres by 2025

- 364 4R agronomists

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AG RESEARCH
Real Story. Better Decisions.

FERTILIZER USE
Ontario
CDN 2020

Fertilizer Canada 4R Fertilizer Use Survey

- 2016-2022, continuing
- Key crops in Ontario and Western Canada
- Source x rate x time x place
- N, P, K & S

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Stakeholders seek indicators on responsible use as well as outcomes

THEMES	INDICATORS	SUB-INDICATORS
Climate change	1. GHGs emissions	A. Emissions B. Sequestration/loss C. Mitigation
Soil	2. Soil health	A. Soil cover B. Soil erosion C. Soil organic carbon
Water	3. Water stewardship	A. Water quality B. Water use
Biodiversity	4. Biodiversity & agrobiodiversity	A. State of biodiversity & habitat change (interim for C & D) B. Conversion of farmland to urbanization C. Composite view: state of biodiversity & habitat change D. Disaggregated views: state of biodiversity & habitat change
Inputs	5. Crop inputs use / management	A. Responsible pest control product use (pesticides) B. Responsible nutrient use (fertilizer)
Waste	6. Food loss & waste	A. Reduce B. Repurpose
	7. Packaging & waste	A. Reduce / recycle B. Reuse

Canada's National Index on Agri-Food Performance

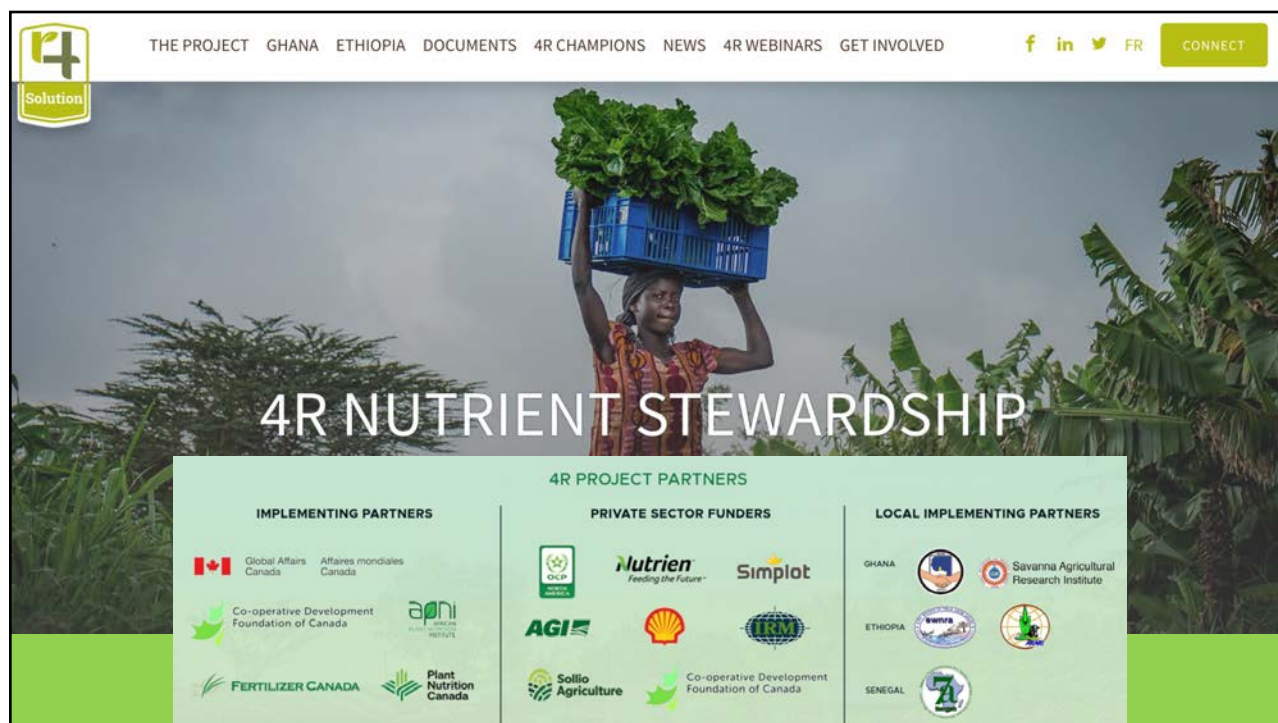
ENVIRONMENT ECONOMIC
FOOD INTEGRITY SOCIETAL WELL-BEING




Canada's agri-food sustainability indicators

A growing coalition of private-public partners are working pre-competitively to develop an integrated picture of sustainability for Canada's agri-food sector from food production to retail.

What is the recent report about?
What could a future Index measure?
What is the current plot about?











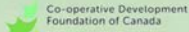



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THE PROJECT GHANA ETHIOPIA DOCUMENTS 4R CHAMPIONS NEWS 4R WEBINARS GET INVOLVED    FR [CONNECT](#)

4R NUTRIENT STEWARDSHIP

4R PROJECT PARTNERS

IMPLEMENTING PARTNERS	PRIVATE SECTOR FUNDERS	LOCAL IMPLEMENTING PARTNERS
 Global Affairs Canada / Affaires mondiales Canada  Co-operative Development Foundation of Canada  FERTILIZER CANADA  Plant Nutrition Canada	 Nutrien Feeding the Future™  Simplot  AGI  Shell  IRM  Sollio Agriculture  Co-operative Development Foundation of Canada	GHANA  Savanna Agricultural Research Institute ETHIOPIA  WARDA SENEGAL  ANR

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Summary

1. N use efficiency, considered in context, serves as an important indicator of performance, for 4R efforts, and crop production.
2. Specific indicators of NUE apply to the five aims of responsible plant nutrition: productivity, recycling, soil health, human nutrition, and emissions.
3. A partial nutrient balance, with inputs and outputs clearly defined, is the most applicable NUE indicator.
4. Assessing 4R nutrient stewardship programs depends on tracking both practices and outcomes.



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