Plant Nutrition Canada

Tom Bruulsema,
Plant Nutrition Canada

UNIVERSITY OF WATERLOO | the water INSTITUTE

Geography, Earth and Environmental Sciences
Eutrophication: from Process to Water Quality Management
23 November 2021

Responsible Plant Nutrition for Abundant Food & Clean Water

1

Plant Nutrition, Water Quality, and Abundant Food

1. Frameworks: 4R Nutrient Stewardship, Responsible Plant Nutrition
2. Lake Erie harmful algal blooms
3. Managing agricultural phosphorus
4. Climate-smart farming
5. Managing agricultural nitrogen

Plant Nutrition Canada

2

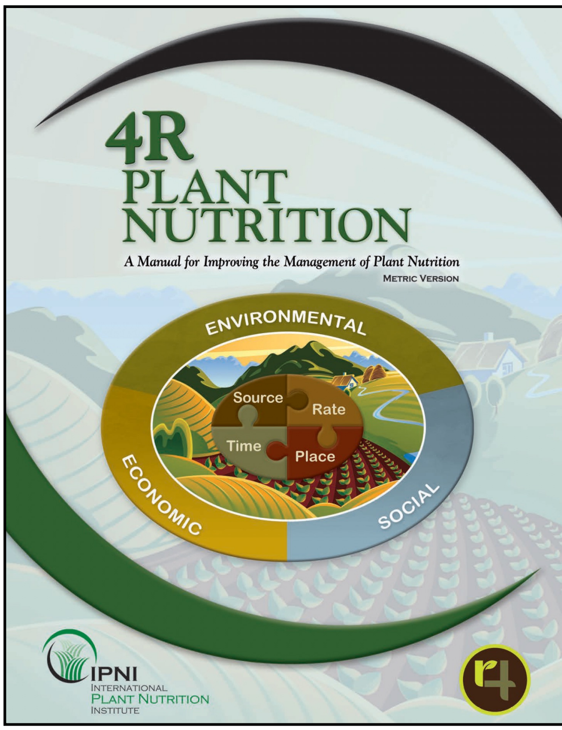
Plant Nutrition Canada

Research Resources News About Contact

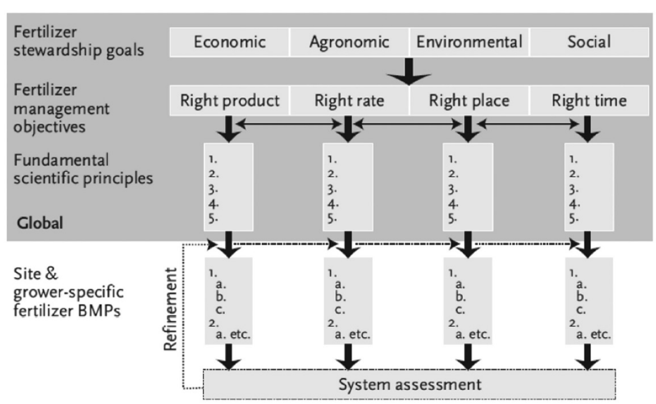
Nutrient Stewardship

Pillar	APPLY SCIENCE	INTERPRET SCIENCE	EXTEND SCIENCE
Detail	Lead, shape and mold concepts and intended implementation pathways for nutrient stewardship	Explain implications, strengths and limitations of new scientific reports on issues relevant to nutrient stewardship	Educate and inform practitioners on science-based principles underlying agronomic practices relevant to nutrient stewardship
Audiences	Agri-environmental scientists, industry leaders & agronomists	Industry association personnel	Retailers, Certified Crop Advisers, government and agricultural value chain personnel

3



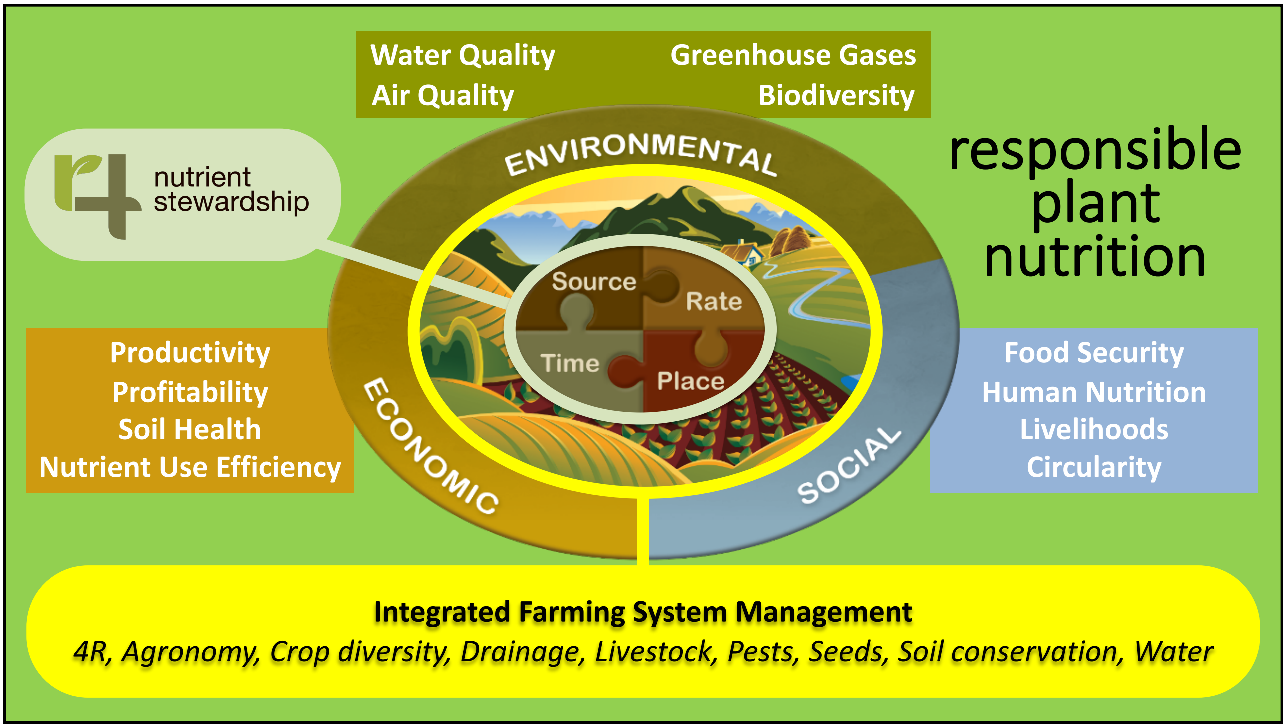
4R Nutrient Stewardship Framework



Fixen et al., 2007
IPNI, 2012

Plant Nutrition Canada

4



5

A NEW PARADIGM FOR PLANT NUTRITION

SCIENTIFIC PANEL
ON RESPONSIBLE PLANT NUTRITION

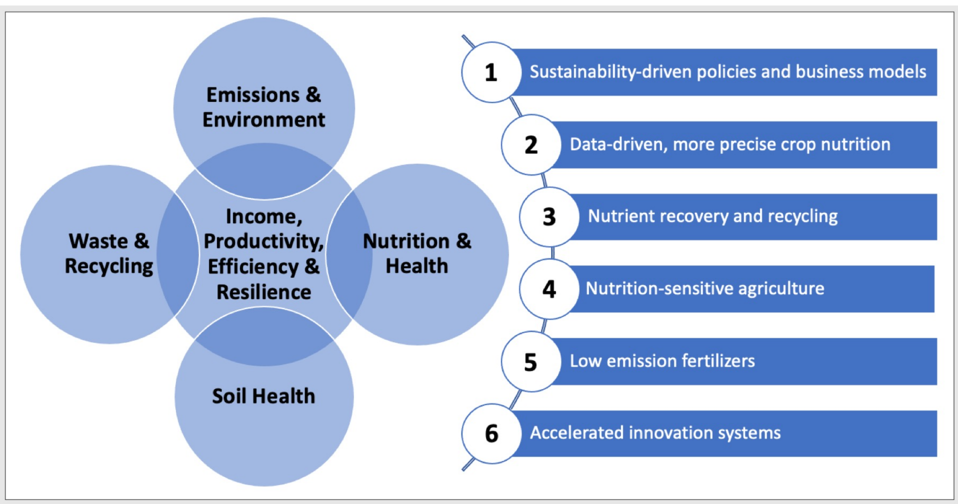


Figure 1. The five interconnected aims of responsible plant nutrition, and six key actions to take.

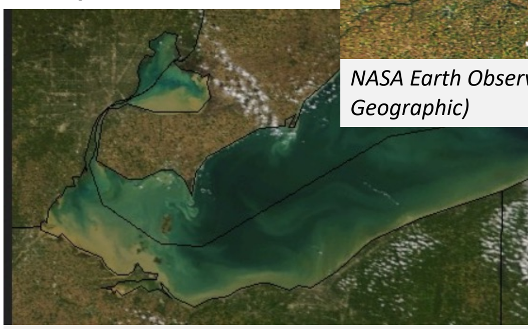
The outcome of this transformation will be a ***new societal plant nutrition optimum*** *rather than a purely economic optimum. The new nutrient economy will become an integral component of a* ***low carbon emission, environment-friendly and circular economy****, supporting the needs of a rising global population and improving the income and livelihood of farmers worldwide.* *https://www.sprpn.org*

Plant Nutrition Canada

6

Lake Erie – both dissolved and particulate P loads are important.

NASA Earth Observatory, late Sept 2017 (National Geographic)



Terra MODIS Direct Broadcast Image 7 May 2017

Google "coastwatch Lake Erie"

Plant Nutrition Canada

7

Ancaster, Ontario – 26 June 2009 – tilled corn
SOIL EROSION IS A REAL RISK

Plant Nutrition Canada

8

Ponsonby, Ontario – 6 April 2014 – no-till

DRP in surface runoff? Invisible.

Plant Nutrition Canada

9

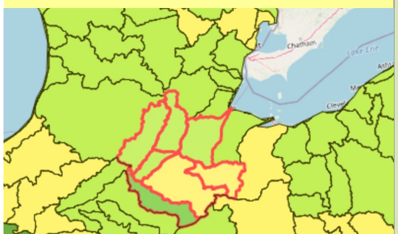
Essex County, Ontario, 30 July 2009

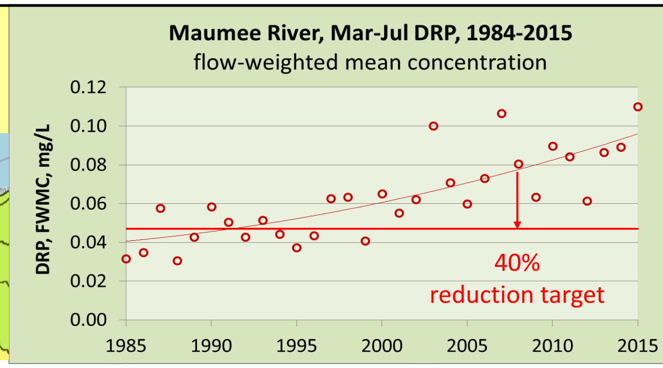
BMPs that limit soil erosion might not limit dissolved P runoff.

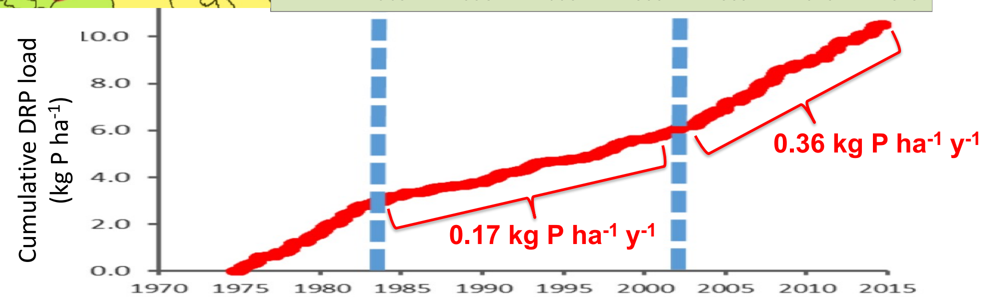
Plant Nutrition Canada

10

Maumee river watershed: dissolved P trends increasing since 2002







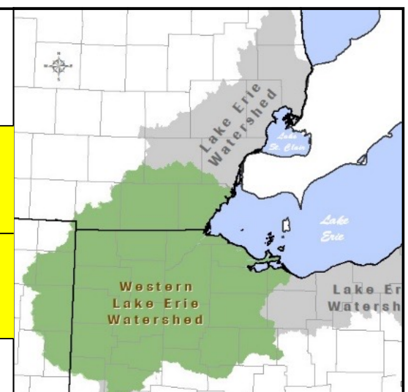
1. David Baker & Laura Johnson, National Center for Water Quality Research, Tiffin, OH
2. Jarvie et al., 2016, J Environ. Qual.

11

Western Lake Erie Watershed

Year	Outputs, kt P_2O_5 crop removal	Inputs, kt P_2O_5 fertilizer	manure	PUE
1987	92	103	17	76%
2016	136	73	22	143%

- Cropland PUE almost doubled.
- Loss of dissolved P to the lake also doubled.
- ***Unintended consequence of conservation tillage with broadcast application of P fertilizer.***

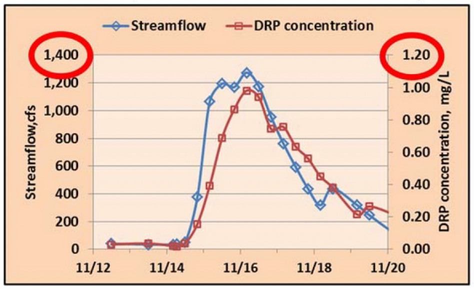


Jarvie et al., 2017, J Environ. Qual. 46(1):123-132

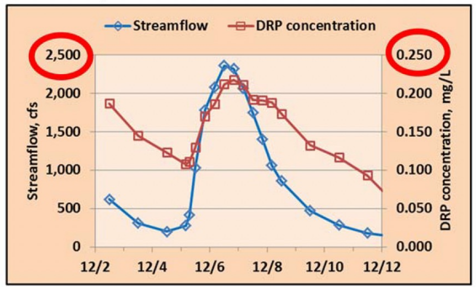
12

Honey Creek: comparing two runoff events in fall 2011

14 Nov., after 6d field activity



5 Dec., after 2 further rainstorms



0.64 mg/L	Mean DRP concentration	0.18 mg/L
0.35 kg P_2O_5/ha	DRP load/ha of watershed	0.18 kg P_2O_5/ha

1. Intense rainstorms following broadcast of P can generate high P concentrations in runoff but the direct agronomic or economic importance can be minimal.
2. As the time intervals increase between surface broadcast P applications and runoff-producing rainfall events, DRP concentrations spike less.

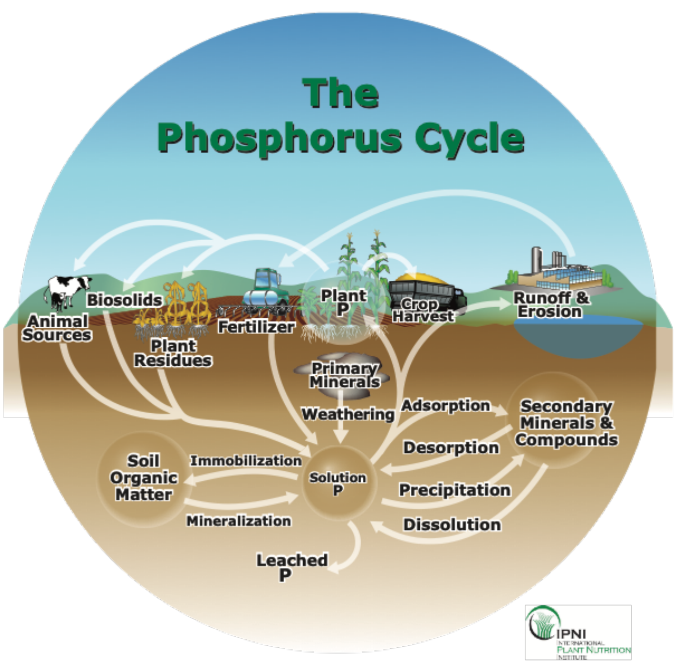
David Baker, Heidelberg University

IPNI

Ohio, Sandusky river watershed

Plant Nutrition Canada

13

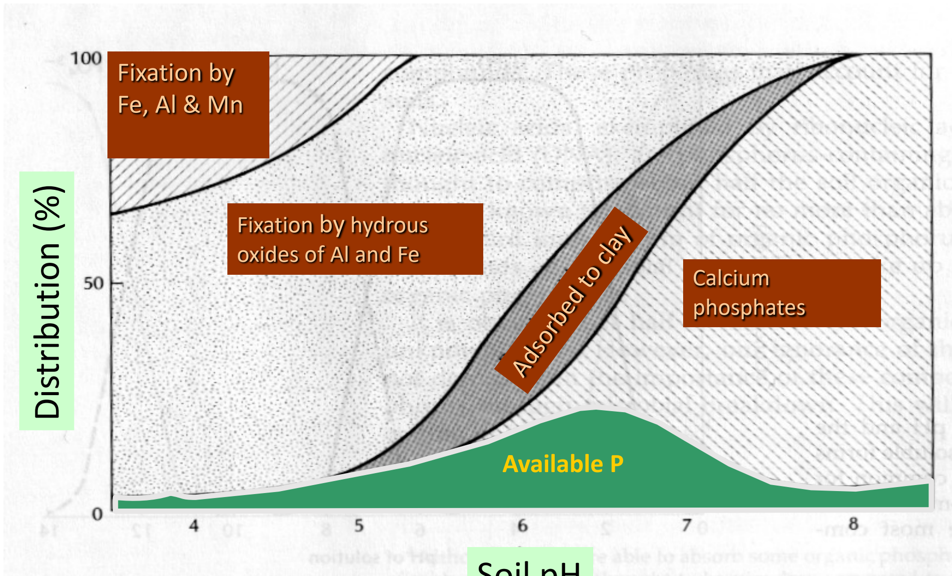


IPNI International Plant Nutrition Institute

Plant Nutrition Canada

14

Fixation of Added P

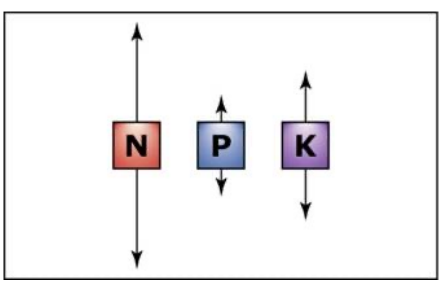


Source: NC Brady, 1990. The Nature and Properties of Soils.

15

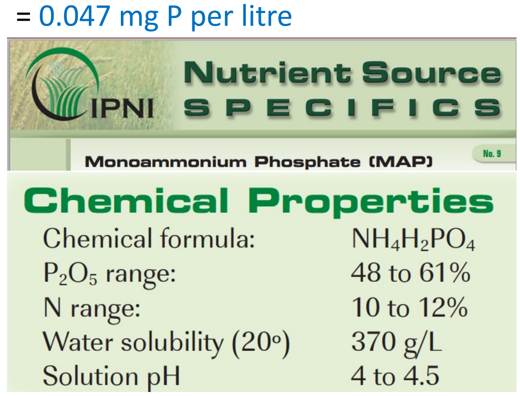
Soil Retains P, but Fertilizer P is Soluble P

Relative mobility of nutrients in soil



MAP (11-52-0) has water solubility of 370 g/L
= 84,000 mg P per litre

Maumee river target for DRP
= 0.047 mg P per litre

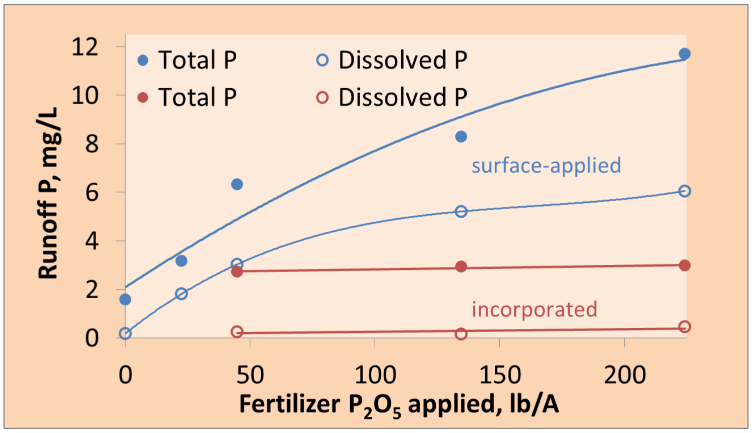


Chemical Properties

Chemical formula:	$NH_4H_2PO_4$
P_2O_5 range:	48 to 61%
N range:	10 to 12%
Water solubility (20°)	370 g/L
Solution pH	4 to 4.5

16

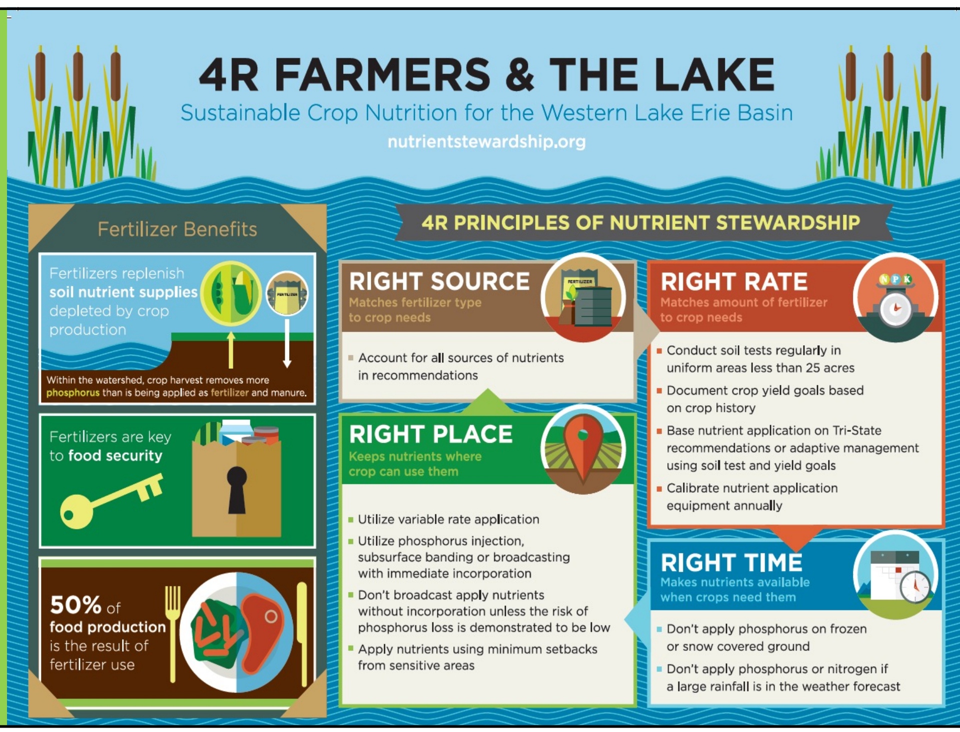
Placing P in the soil reduces P loss from a single immediate runoff event



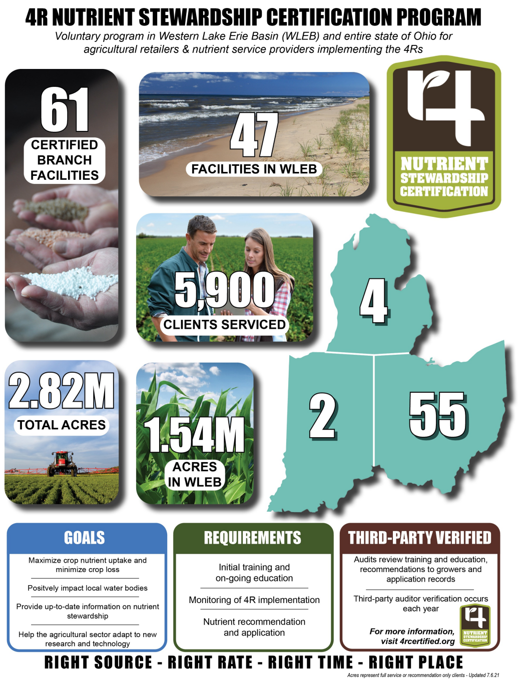
Concentration of dissolved and total P in runoff from a clay loam soil in North Carolina, from artificial rainfall immediately following application of superphosphate fertilizer. Incorporation was to a depth of 5 inches by rotary tillage following application. Data from Tarkalson and Mikkelson (2004).

Plant Nutrition Canada

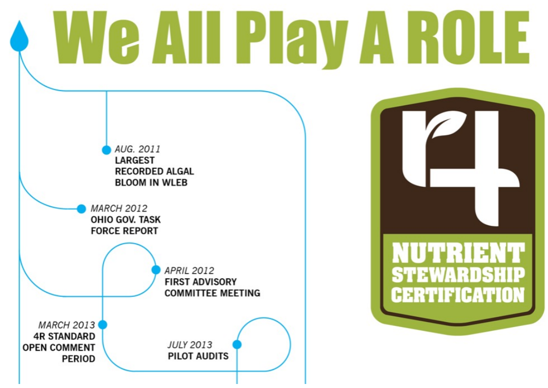
17



18



4R Certification in Western Lake Erie Basin (WLEB)



Plant Nutrition Canada

19

Fall Strip-till Banding

- Puts the P in the soil
- Keeps residue on the soil
- RTK GPS for precision planting

Greg LaBarge, Ohio State University Extension

Plant Nutrition Canada

20

Granular P delivery by air, placed 4” to 6” deep

Plant Nutrition Canada

21

Strip tillage with granular placement puts P in the right place – and controls erosion.

Plant Nutrition Canada

22

Some growers fertilize all their crops in bands near the seed.

Plant Nutrition Canada

23

Broadcast? at the right time to avoid runoff

Plant Nutrition Canada

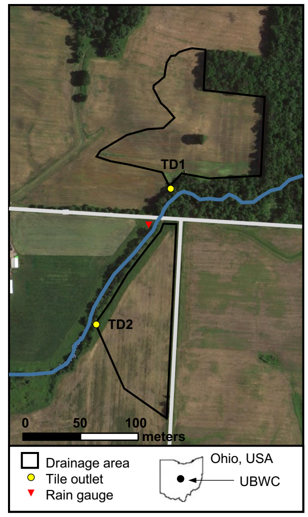
24

Effect of tillage on preferential flow and phosphorus transport

Soil type: Silt loam
Tile depth: 90 cm
Soil test P: 30 ppm Mehlich-3P
Tillage: No-till

2014 management
May 6th – Applied MAP @ 45 kg P/ha
May 8th – Tilled field TD1 (disc)
(TD2 remained no-till)

Study Objective
Compare P transport before and after tillage and between tilled and no-till fields

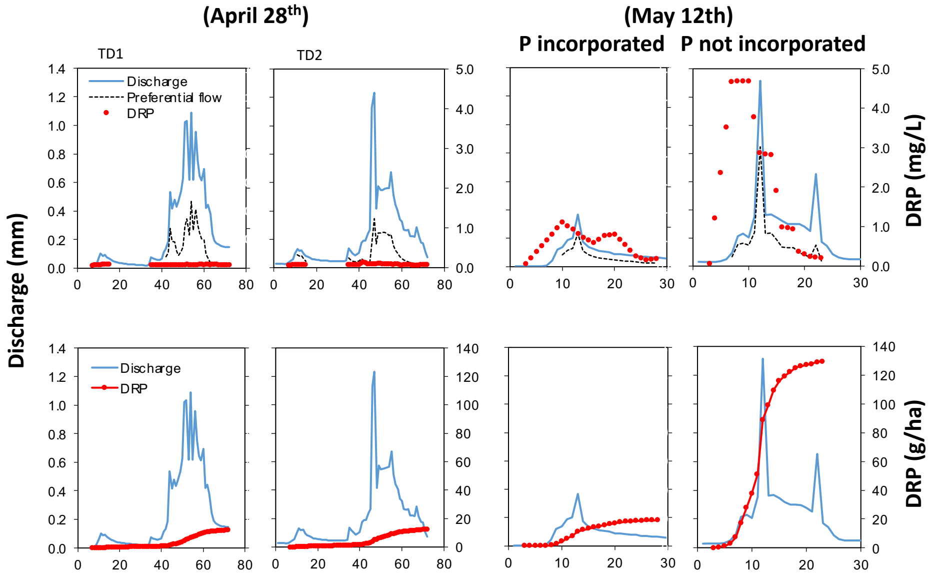


Williams and King, USDA-ARS, Columbus, Ohio

25

Before P application & tillage (April 28th)

After P application & tillage (May 12th)



Incorporating P reduced DRP loss from 130 g/ha to 18 g/ha

Williams and King, USDA-ARS, Columbus, Ohio

26

4R efficacy for reducing P loss, % reduction

- ranges found in field experiments across the USA and Canada

Practice	Dissolved P	Particulate P
Source	---	---
Rate	60 to 88%	0
Time	41 to 42%	0
Place	20 to 98%	-60% to 0
Soil inversion	0 to 92%	-59% to 0
Conservation tillage	-308 to -40%	-33 to 96%

Dodd & Sharpley, 2015. Nutrient Cycling in Agroecosystems.

Plant Nutrition Canada

27

6 | Journal of Environmental Quality MACRAE ET AL.

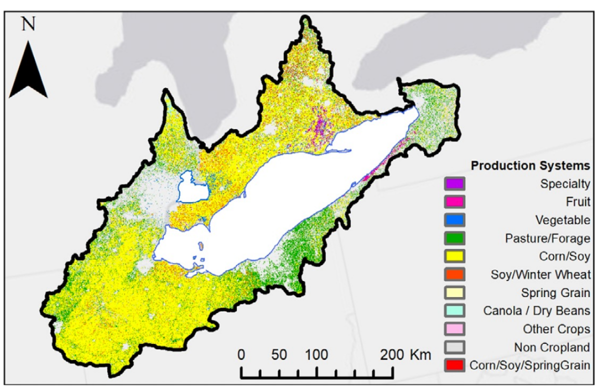


FIGURE 3 Variability in agricultural production systems in the Lake Erie watershed. Data sources are described in the Supplemental Material

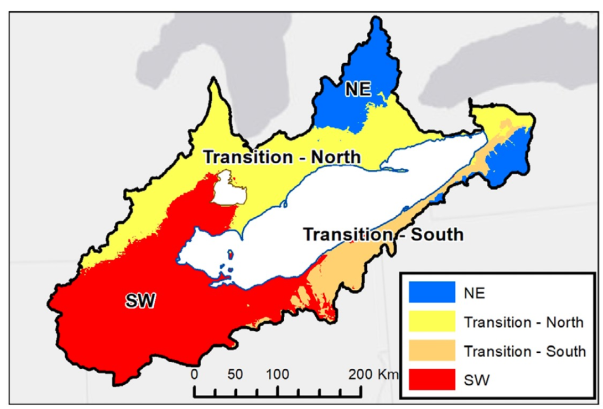


FIGURE 4 Differing P management regions within the Lake Erie watershed. Data from Figures 1 and 2 were compiled to produce the classification regions. The methods used are described in Supplemental Material. NE, northeast; SW, southwest

One size does not fit all: Toward regional conservation practice guidance to reduce phosphorus loss risk in the Lake Erie watershed. Macrae et al., 2021 JEQ. ***>>> OSCIA webinars 29-30 November!***

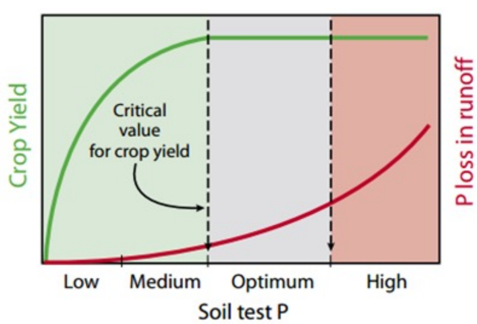
Plant Nutrition Canada

28

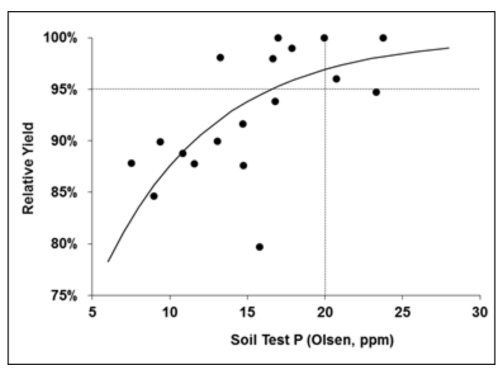
Soil fertility and nutrient balance are relevant metrics for crop nutrition in Lake Winnipeg and Lake Erie watersheds

29

Soil test phosphorus levels relate to probabilities of crop yield response and risks of environmental impacts.



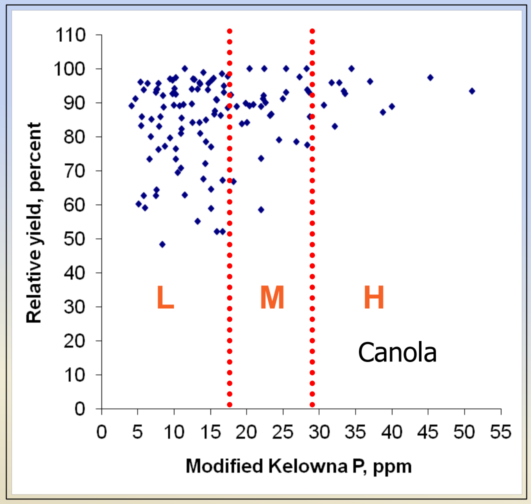
As soil P increases so does crop yield and the potential for P loss in runoff. The interval between the critical soil P value for yield and runoff P will be important for P management.



30

P fertilizer responses and critical soil test P thresholds under field conditions are not exact

- **Given the large variability, a probability approach may be more realistic than a "response curve" … ie. a low, medium, or high probability of a response to P**

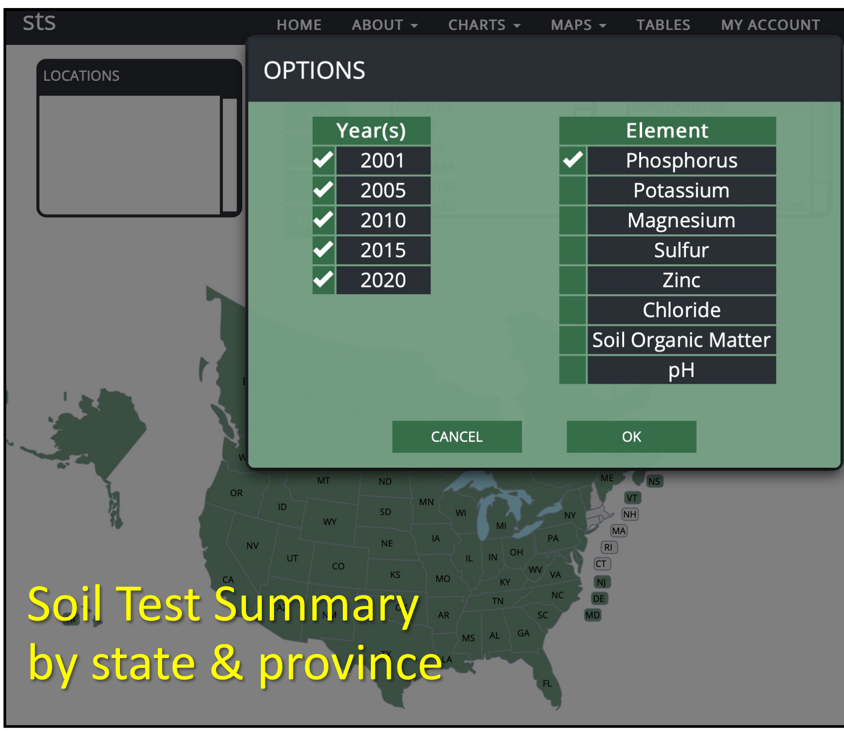


Ross McKenzie, Alberta Agric.

Slide courtesy of Dr. Don Flaten, University of Manitoba

University of Manitoba

31

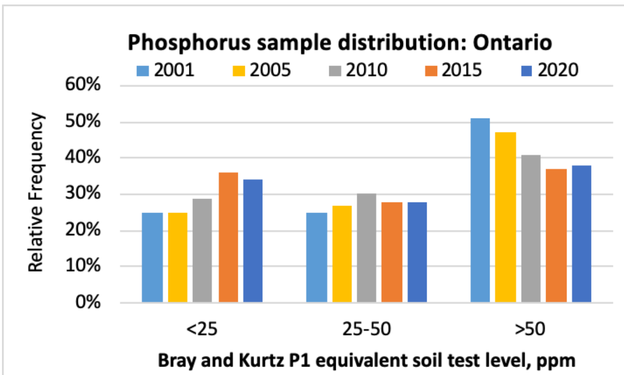


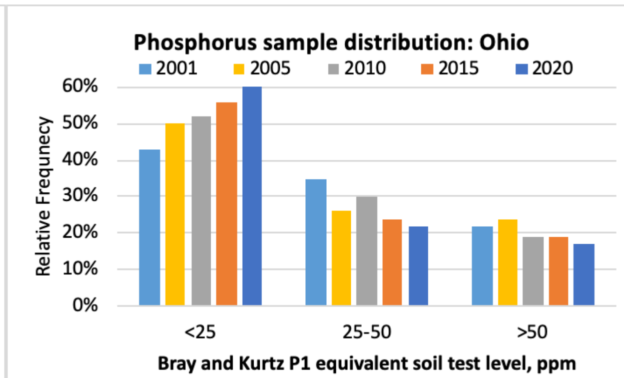
http://soiltest.tfi.org

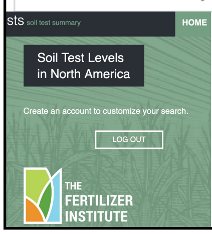
Plant Nutrition Canada

32

Ontario and Ohio 2001-2020 – drawdown of legacy P





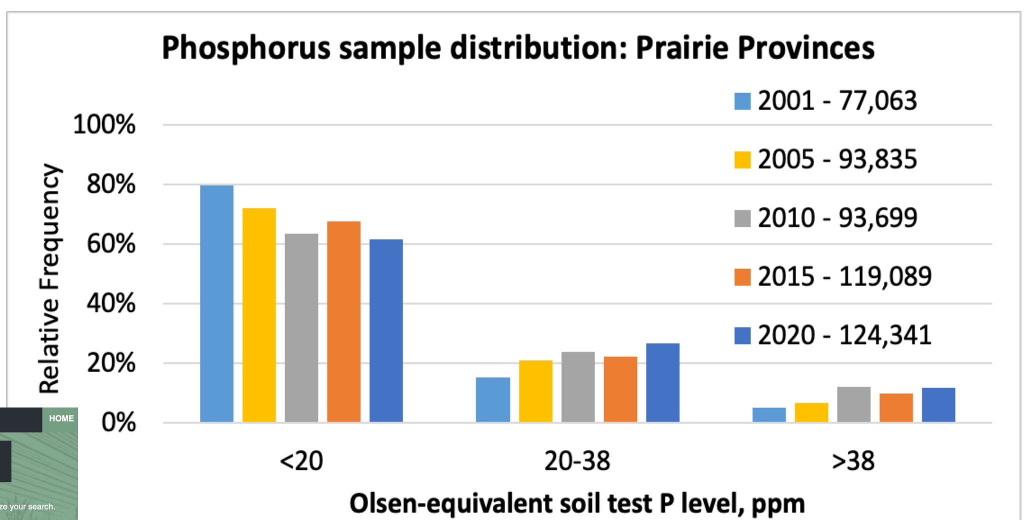


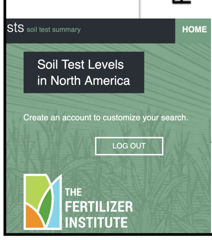
http://soiltest.tfi.org

Plant Nutrition Canada

33

Soils of the Canadian Prairies: much lower in P



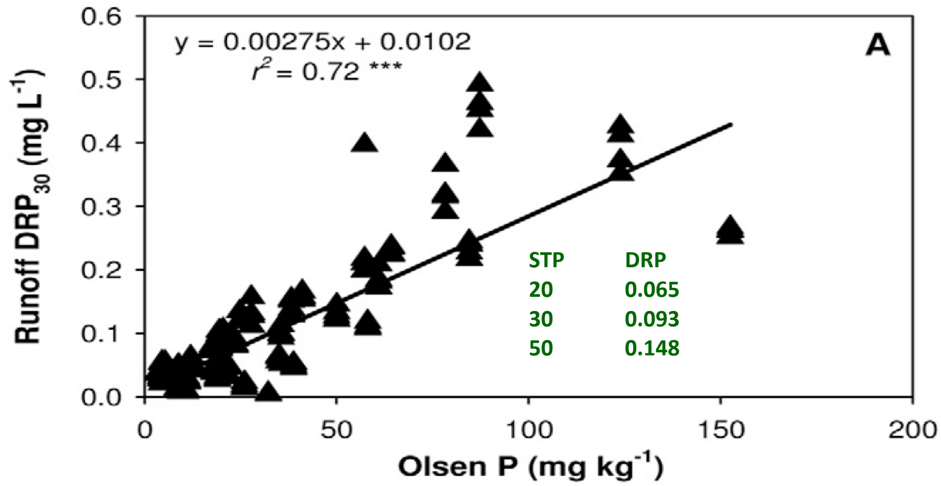


http://soiltest.tfi.org

Plant Nutrition Canada

34

Soil test P and runoff P in Ontario



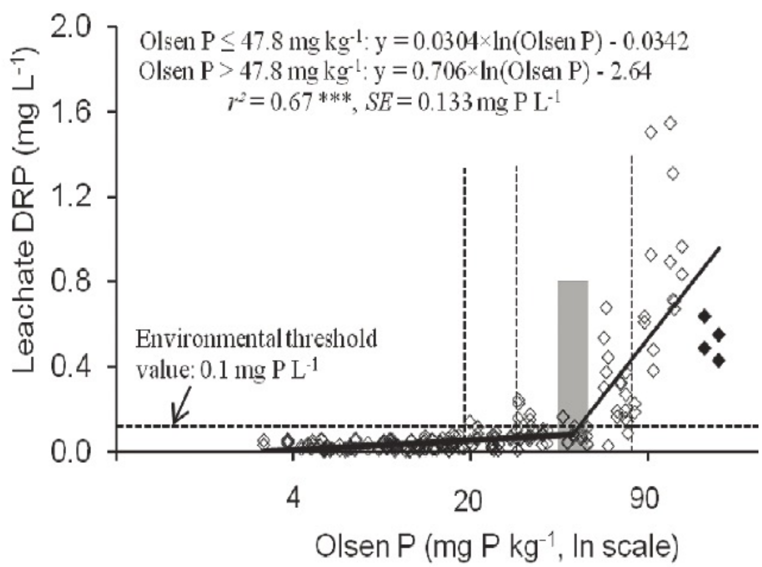
Six soil series, ten sites each, ranging in soil test P.
Standardized runoff boxes, rainfall applied at 3” per hour for 30 minutes runoff.

Wang et al., 2010. J. Environ. Qual. 39:1771–1781

Plant Nutrition Canada

35

Soil test P and P leaching through Ontario soil columns

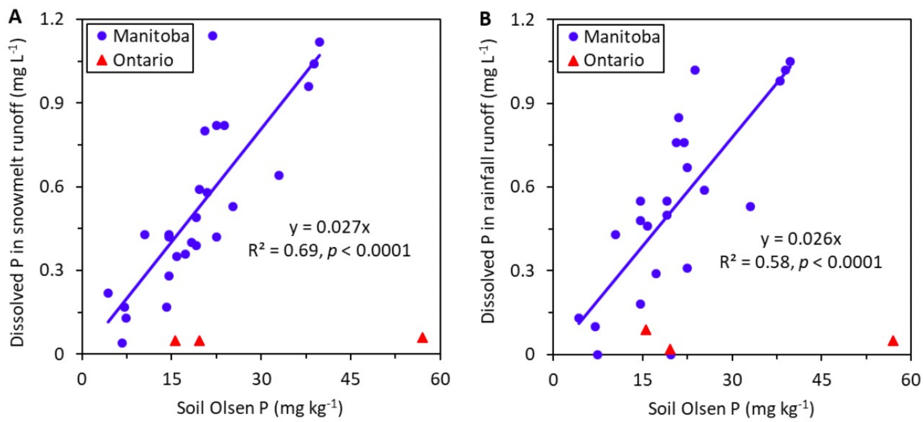


Wang et al., 2012. Soil Sci Soc Amer J 76:220-229

Plant Nutrition Canada

36

Soil test P may relate differently to runoff DRP in the prairies



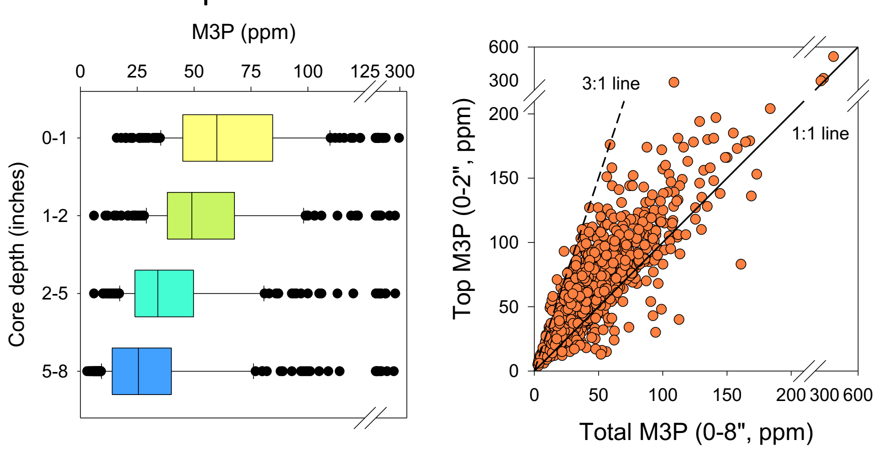
Liu, J., J.A. Elliott, H.F. Wilson, M.L. Macrae, H.M. Baulch, et al. 2021. Phosphorus runoff from Canadian agricultural land: A cross-region synthesis of edge-of-field results. Agric. Water Manag. 255: 107030. https://doi.org/10.1016/j.agwat.2021.107030.

Plant Nutrition Canada

37

Soil test P stratification

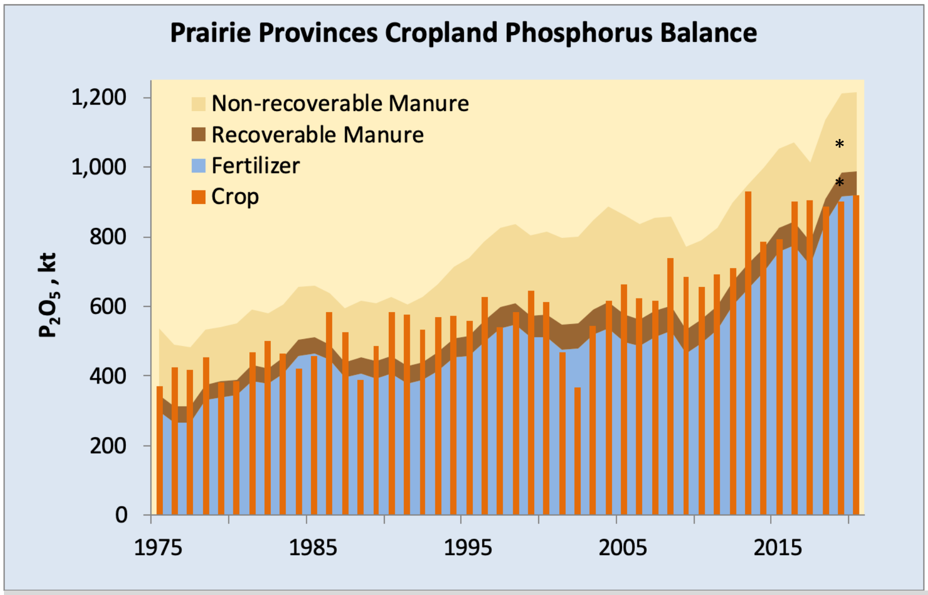
- Interaction of conservation tillage and “right place”
- 1500+ samples



Dr. Laura T. Johnson, Heidelberg University, Ohio, USA

Plant Nutrition Canada

38



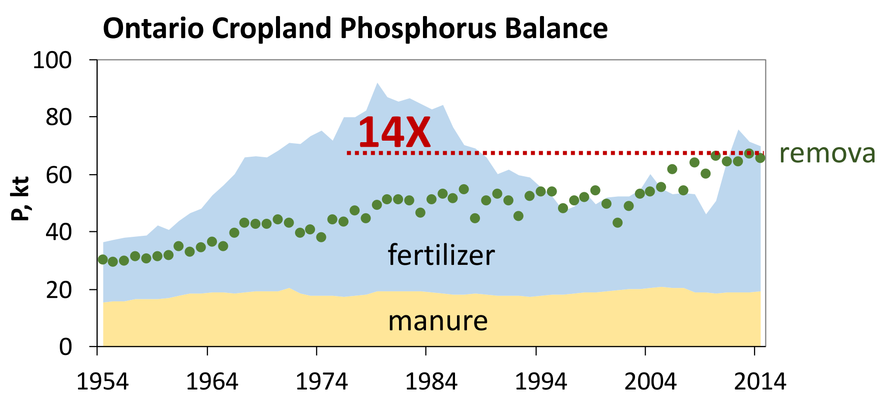
Crop removal of phosphorus often exceeds inputs [NUE>100%]

Calculated from CANSIM data for crops, livestock, and fertilizer using methods of IPNI NuGIS.
** assumes no change in manure P since 2013.*

Plant Nutrition Canada

39

Ontario's **cumulative P surplus** amounts to 14 years of current crop removal.



= > 500 lb P_2O_5 per cropland acre

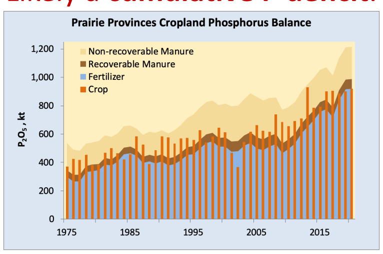
See Bruulsema et al. (2019) J Environ Qual (for USA, Europe, and Brazil)

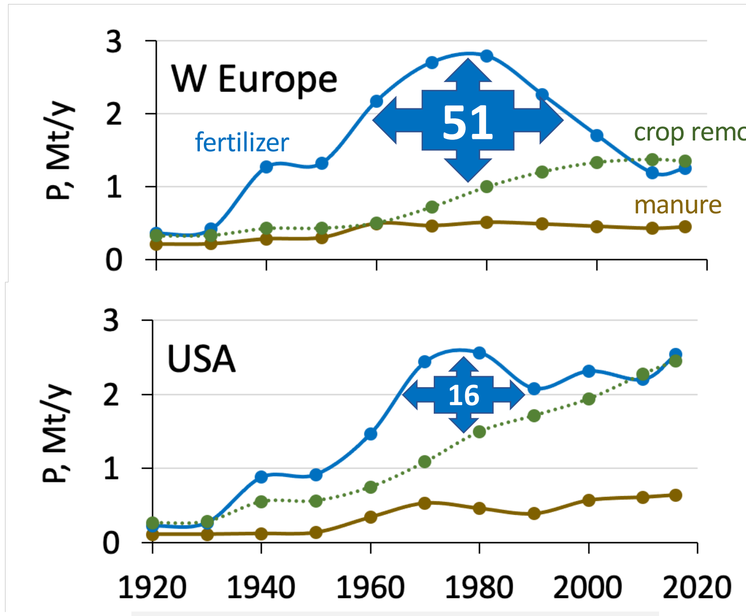
40

Crop P balances 1920-2016

The **cumulative P surplus** amounts to **51 years** crop removal in Western Europe, and **16 years** in the USA.

The Canadian prairies differ. Likely a **cumulative P deficit**.

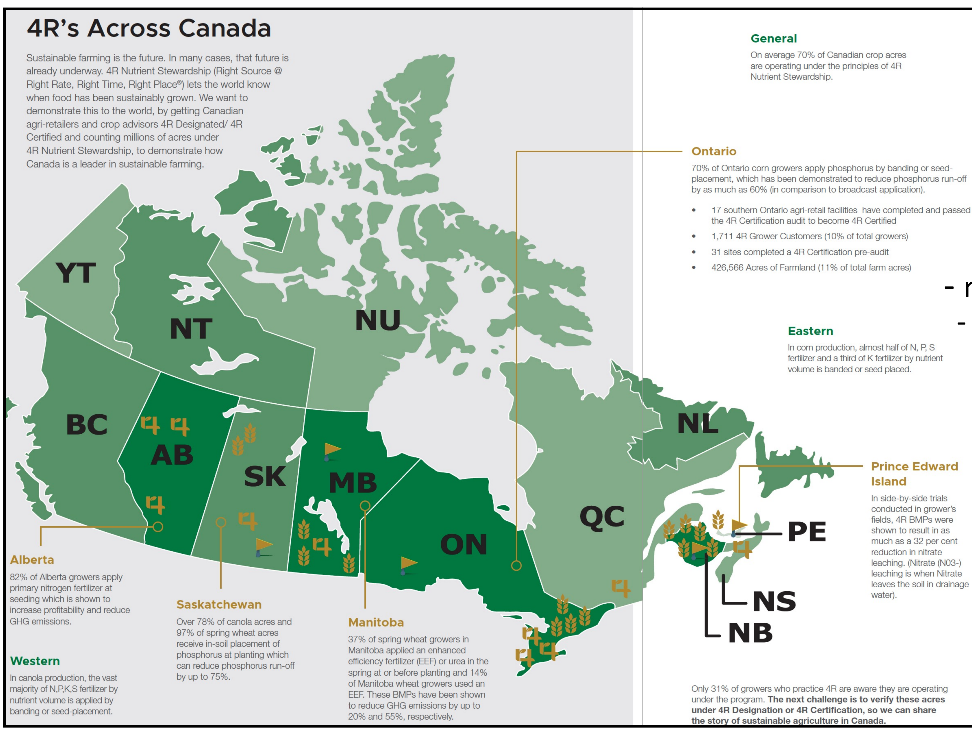




Bruulsema et al., 2019. J. Environ. Qual. 48(5).
doi: 10.2134/jeq2019.02.0065.

Plant Nutrition Canada

41



4R Designation
(AB-SK-MB)
4R Certification
(ON & PE)
- reached 2M ha in 2020
- goal of 6M ha by 2025

Fertilizer Canada

42

Stratus
AG RESEARCH
Real Story. Better Decisions.

FERTILIZER USE

Ontario
CDN 2020

Fertilizer Canada 4R Fertilizer Use Survey

- 2016-2021
- Key crops in Ontario and Western Canada
- Source x rate x time x place
- N, P, K & S
- Canadian prairies: 95% of fertilizer P is applied subsurface

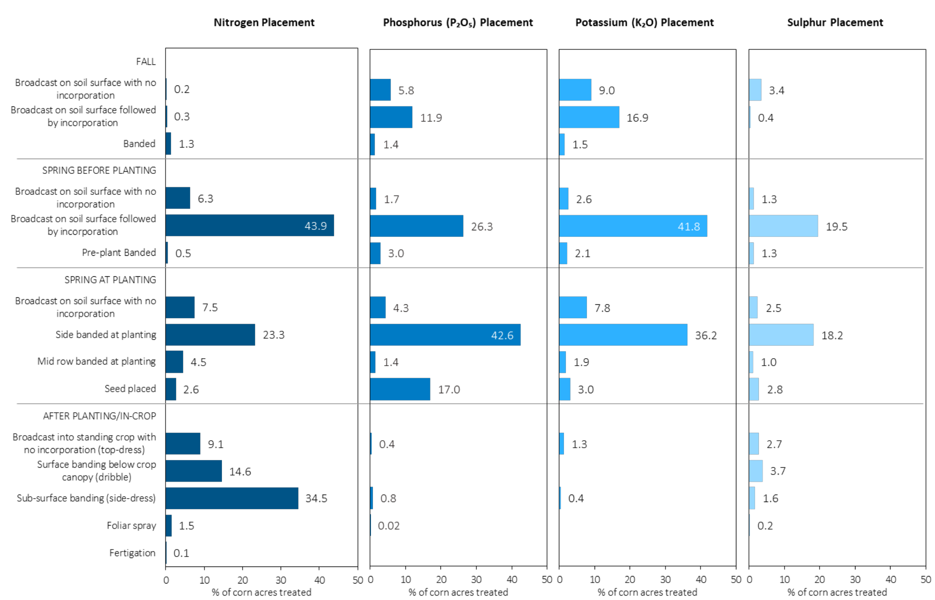
43

FERTILIZER USE

Ontario
CDN 2020

Grain Corn

Fertilizer Placement in Corn - % Crop Acres

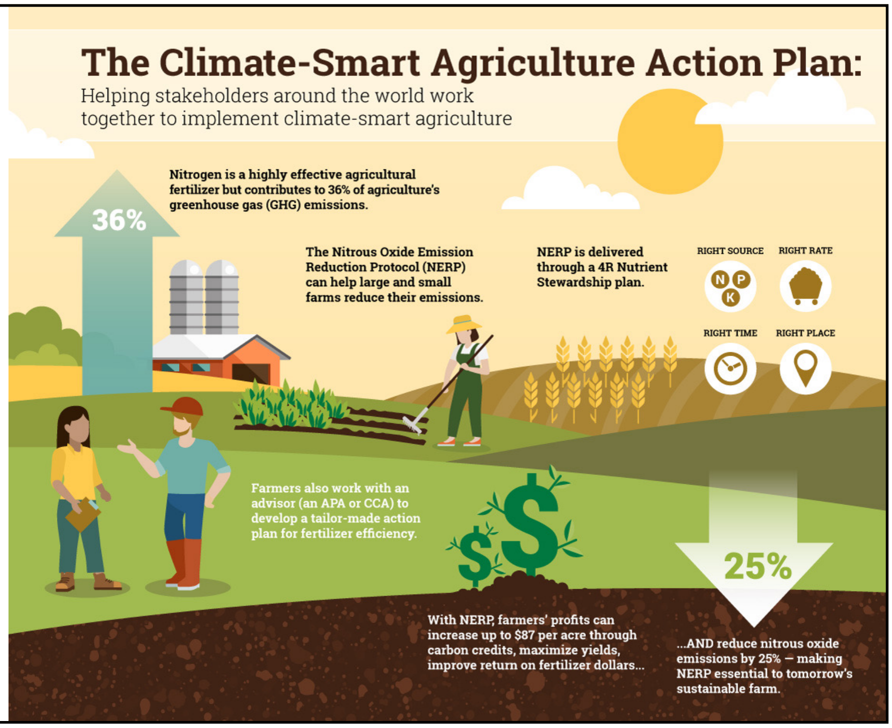


Note: Nutrients were defined based on the primary component of each fertilizer type

Stratus
AG RESEARCH

44

Climate Smart 4R Plant Nutrition



45

4R nutrient stewardship

RIGHT
N P K
SOURCE

vs.

Fertilizer + nitrification and urease inhibitors

Question: do inhibitors reduce nitrous oxide (N_2O) emissions?

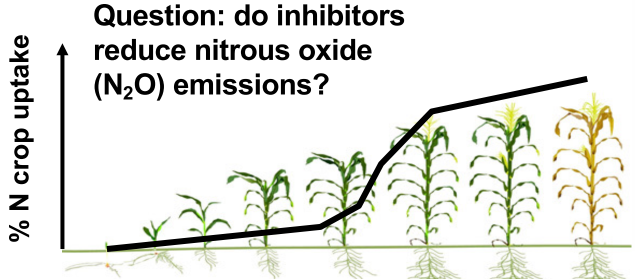


Image from www.pioneer.com

Significant reduction in nitrous oxide emissions in two of 3 years due to inhibitor use with urea and UAN: **40% on average**

Response is dynamic and varies with weather

Agriculture, Ecosystems and Environment 300 (2020) 106996

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

ELSEVIER

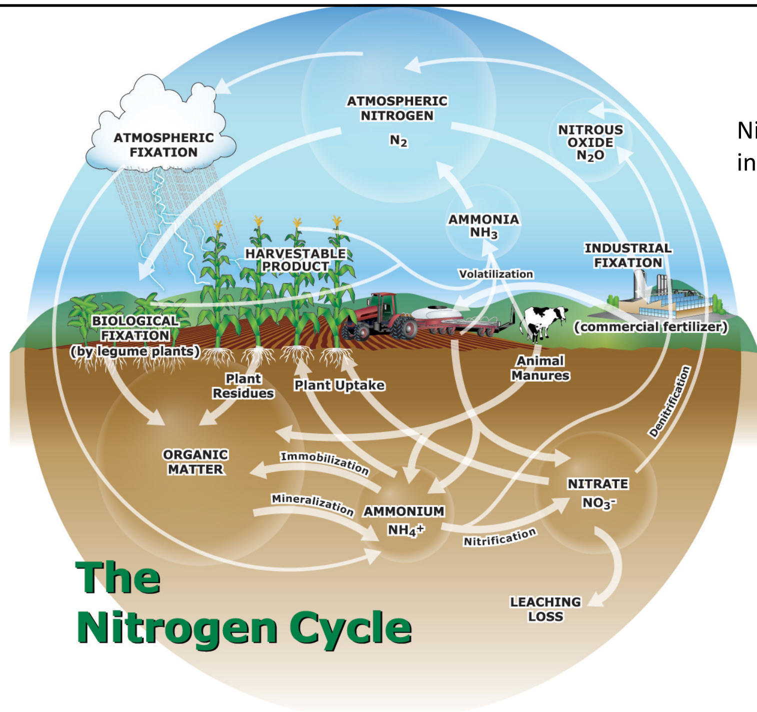
High temporal resolution nitrous oxide fluxes from corn (*Zea mays* L.) in response to the combined use of nitrification and urease inhibitors

Pedro Vitor Ferrari Machado[a,*], Katarina Neufeld[a], Shannon E. Brown[a], Paul R. Voroney[a], Thomas W. Bruulsema[b], Claudia Wagner-Riddle[a]

[a] School of Environmental Sciences, University of Guelph, 50 Stone Road East, Guelph, ON, N1G2W1, Canada
[b] International Plant Nutrition Institute, 18 Maplewood Drive, Guelph, ON, N1G1L8, Canada

46

46



Nitrous oxide is emitted into a global pool

47

Strong scientific support for nitrification inhibitors reducing nitrous oxide emissions

"Compilers can develop Tier 2 emission factors specific to mitigation options such as the application of **nitrification inhibitors** (Akiyama et al. 2010, Ruser & Schulz 2015, Gilsanz et al. 2016)."
[2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories]

Meta-analysis results:

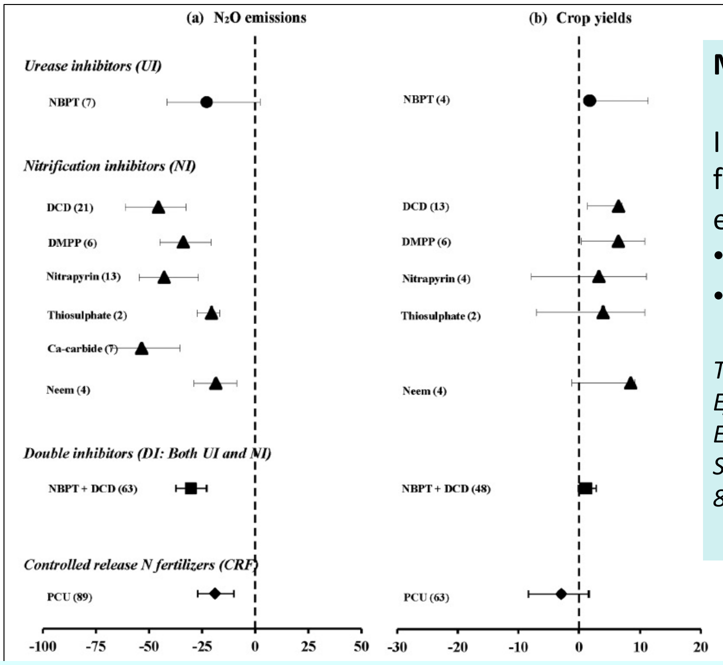
Akiyama et al 2010 – 38%
Ruser & Schulz 2015 – 35%
Gilsanz et al 2016 – 34% to 42%
Abalos et al 2016 – 26%
Thapa et al, 2015 – 20% to 40%
DeCock, 2014 – 18% to 55%
Eagle et al, 2017 – 15% to 39%

Maaz, Sapkota, et al. 2021. Meta-analysis of yield and nitrous oxide outcomes for nitrogen management in agriculture. Glob. Chang. Biol.

- "we found the use of EEFs (e.g., urease inhibitors, nitrification inhibitors, neem, or polymer coated urea) reduced N_2O emissions. The current finding of a **reduction of 24%** falls within the range reported by other meta-analyses (Eagle et al., 2017; Lam et al., 2017; Li et al., 2018; Qiao et al., 2015; Snyder et al., 2009; Thapa et al., 2016; Xia et al., 2017). **Unlike other predictors, EEFs appear to have a consistent effect under a range of conditions and thus generalizable**."

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

48



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

Meta-analysis

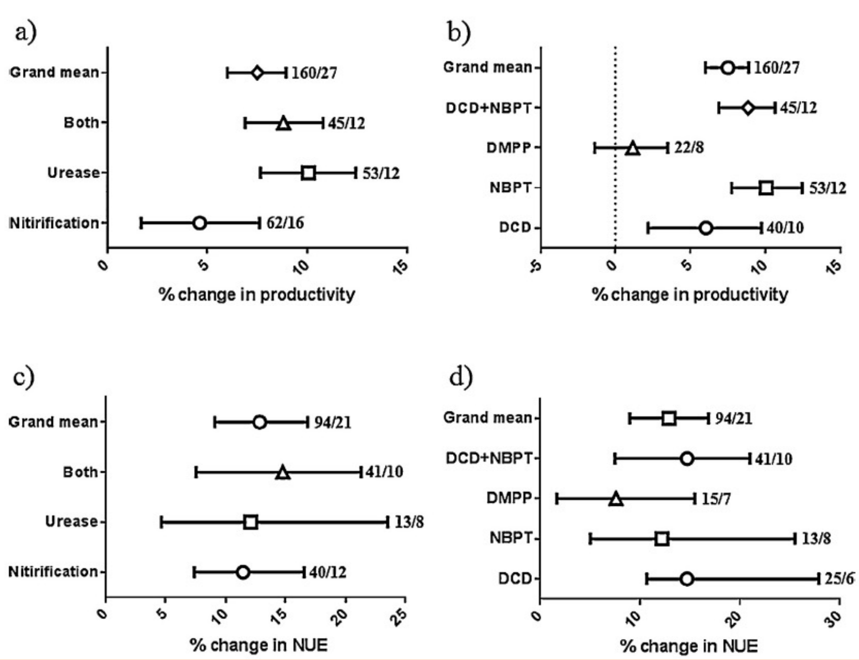
Inhibitors and controlled-release fertilizers have more impact on emissions than on yield

- 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

Plant Nutrition Canada

49



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

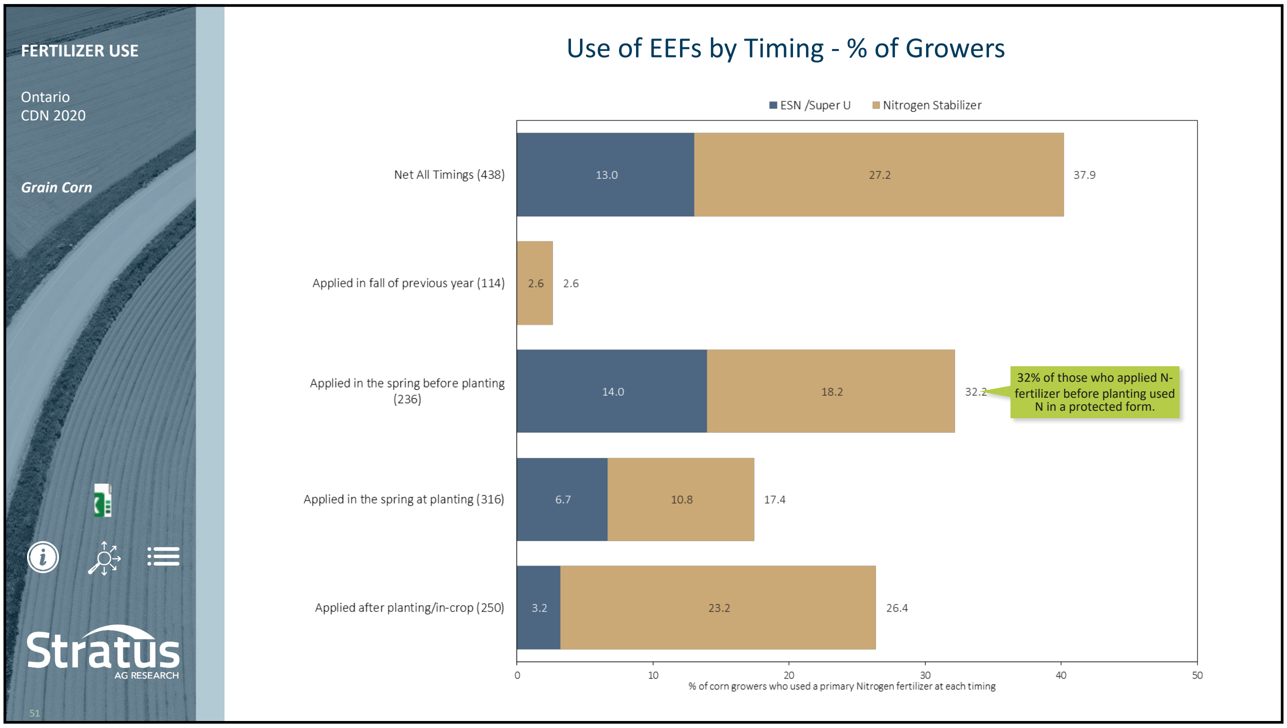
Inhibitors improve Nitrogen Use Efficiency more than Yield

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

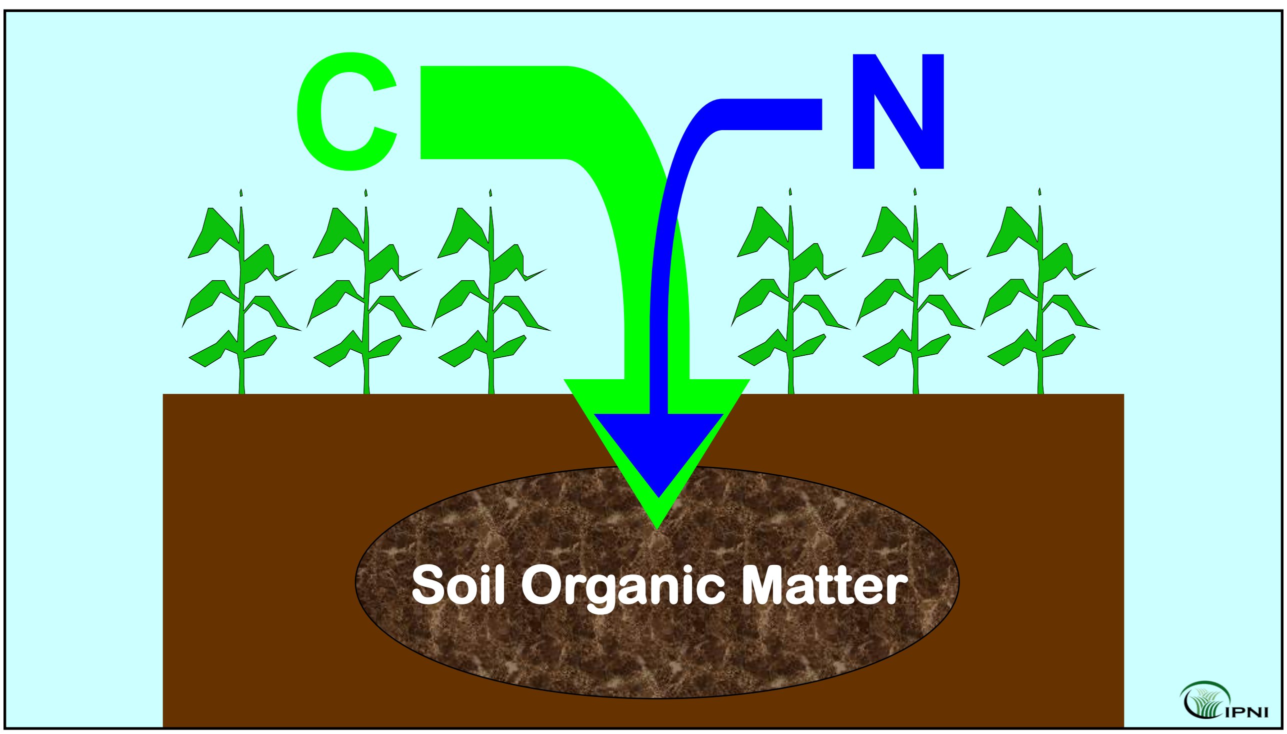
Abalos et al. (2014) Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity and nitrogen use efficiency. Agriculture, Ecosystems and Environment 189: 136–144

Plant Nutrition Canada

50


FERTILIZER USE
Ontario
CDN 2020
Grain Corn
Stratus
AG RESEARCH
51
Use of EEFs by Timing - % of Growers
ESN /Super U
Nitrogen Stabilizer
Net All Timings (438)
13.0
27.2
37.9
Applied in fall of previous year (114)
2.6
2.6
Applied in the spring before planting (236)
14.0
18.2
32.2
32% of those who applied N-fertilizer before planting used N in a protected form.
Applied in the spring at planting (316)
6.7
10.8
17.4
Applied after planting/in-crop (250)
3.2
23.2
26.4
0
10
20
30
40
50
% of corn growers who used a primary Nitrogen fertilizer at each timing

51


C
N
Soil Organic Matter
IPNI

52

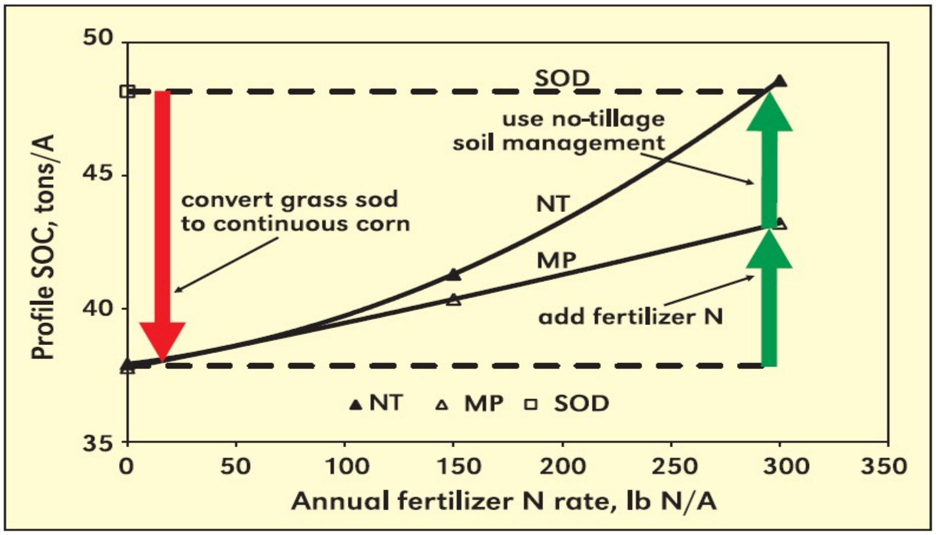
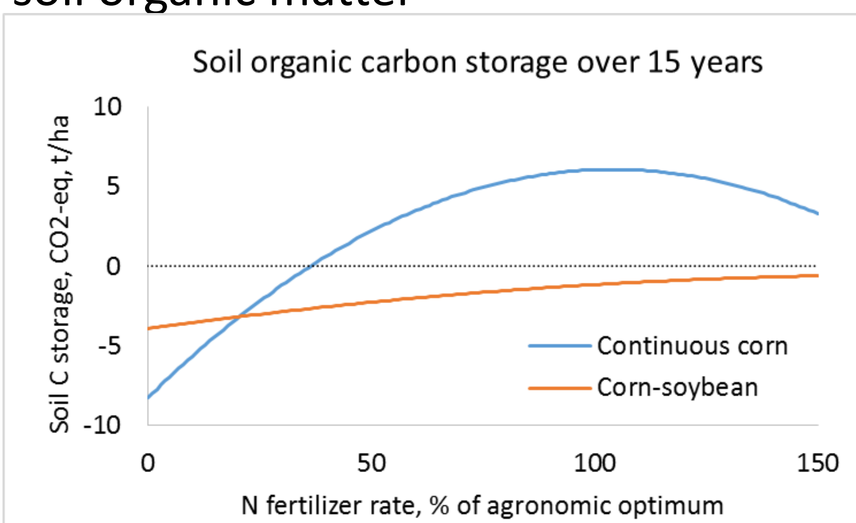


Figure 5. The impact of fertilizer N on total profile SOC levels found after 39 years of cropping to continuous corn with a winter cereal cover crop.

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

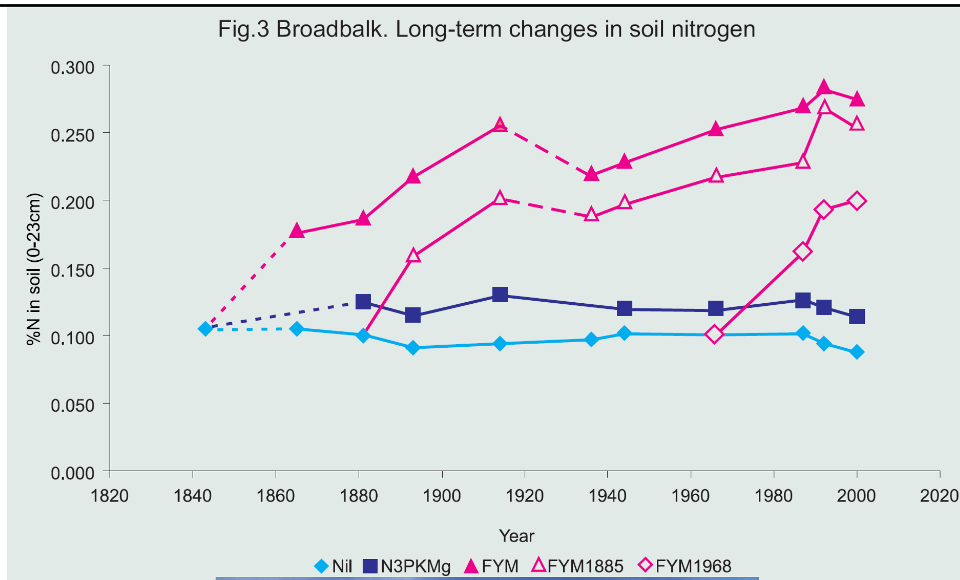
53

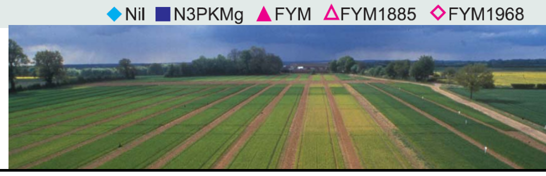
Optimum N rate is similar for yield & soil organic matter



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

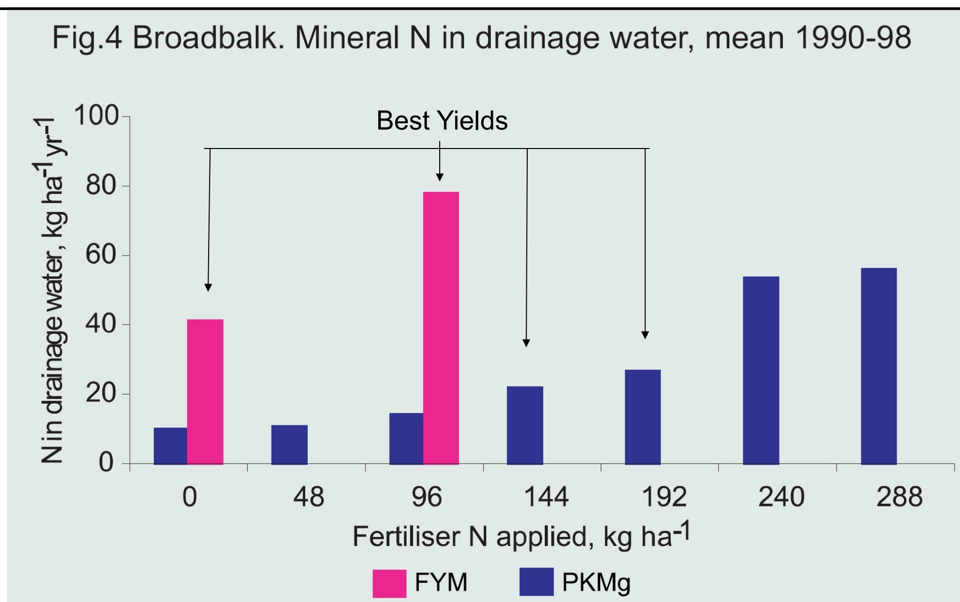
54





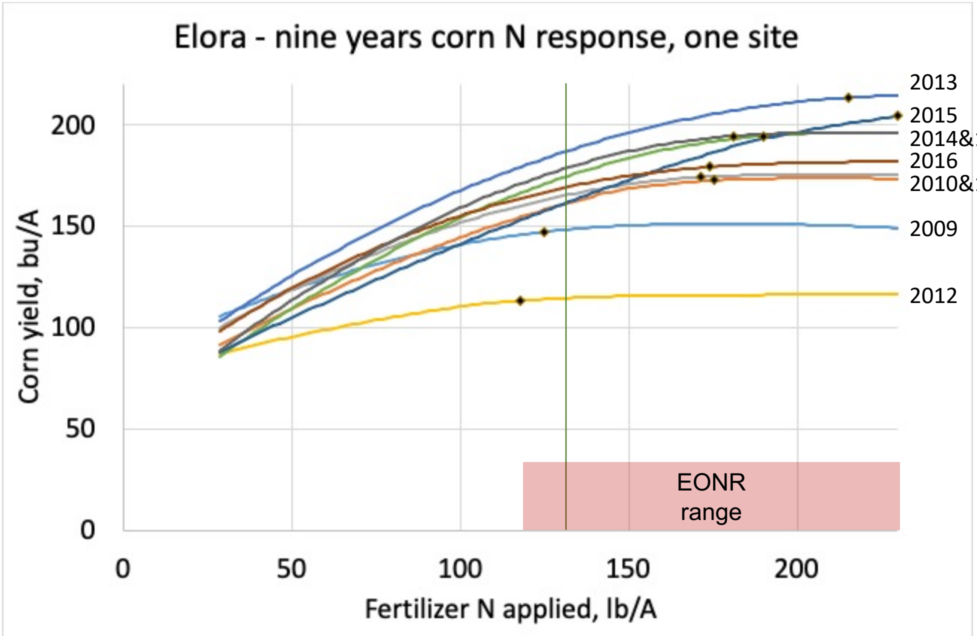
IPNI

55



IPNI

56



Optimal Rates for Corn Nitrogen Depend on Weather

S: UAN
R: 27-232 lb/A
T: PL, SD
P: injected

Deen et al. 2015. Better Crops 99(2):16-18

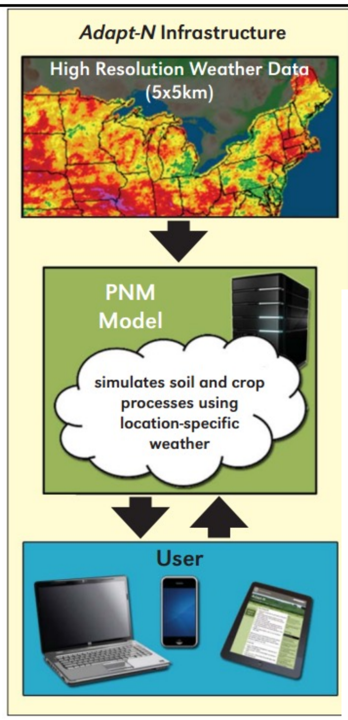
Plant Nutrition Canada

57

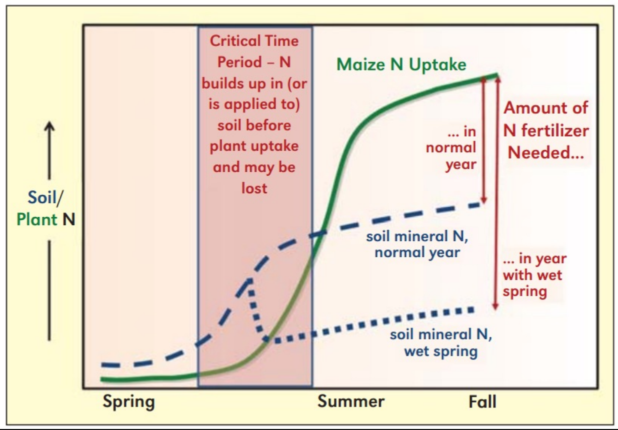
Using Adapt-N for topdress decisions - NY

IPNI

58



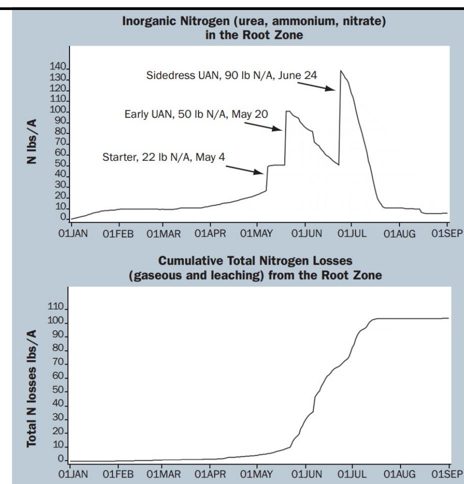
Common elements of model-based nitrogen decision support



59

Adapt-N in New York

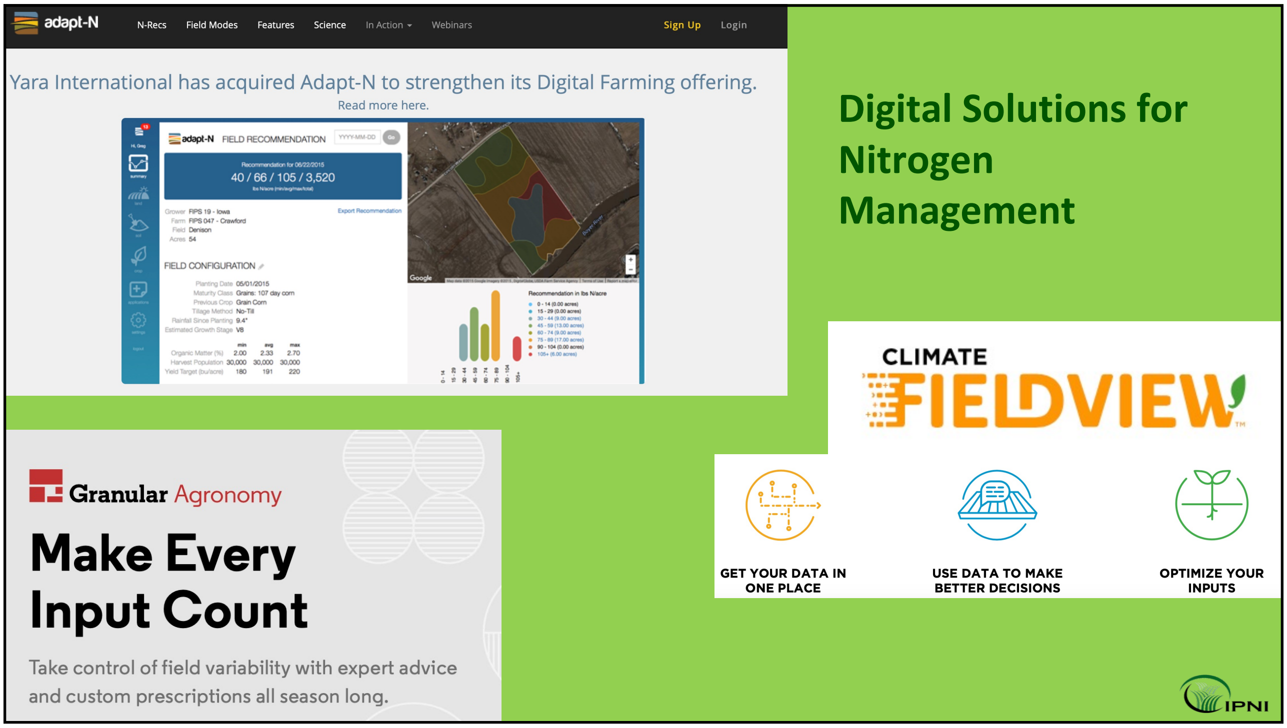
The Richardson Farm crew (left to right): Arnold, Eric, and Ryan Richardson and Nick Humphrey.



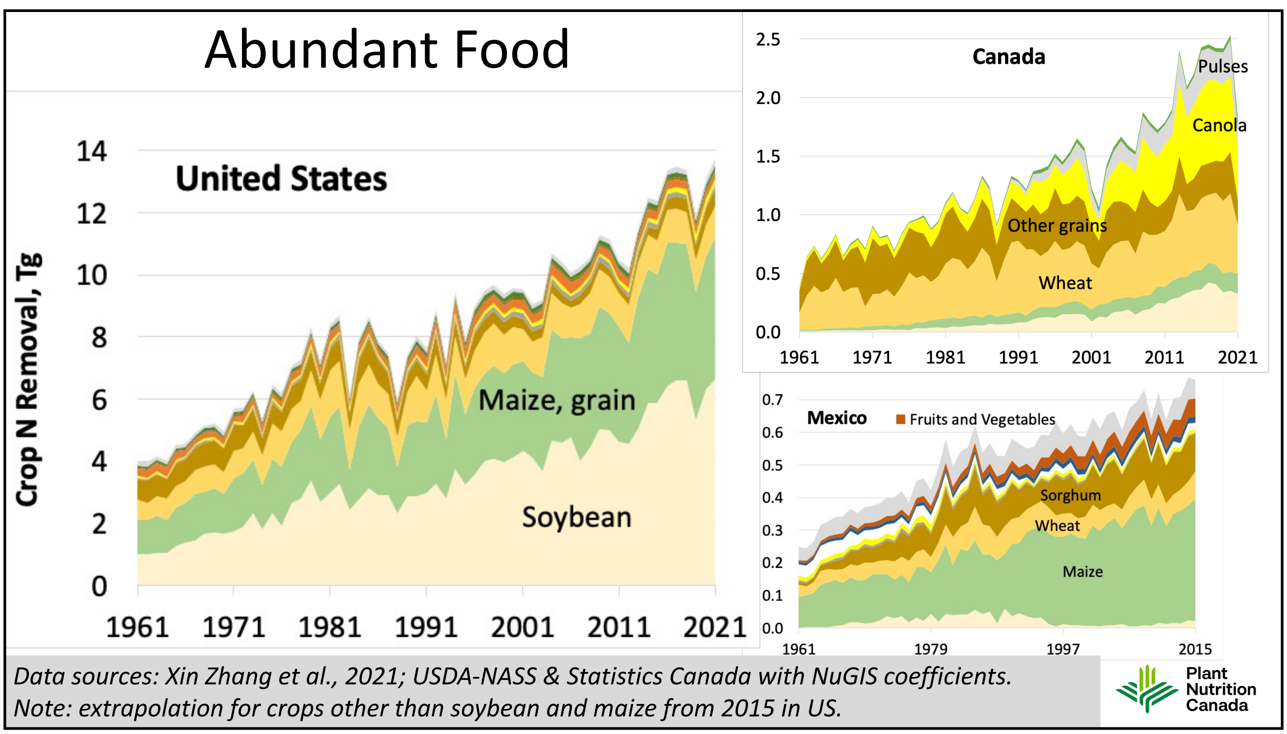
- 2013: ↑ N rates by 22-44 kg/ha, ↑ yields by 1.4-1.9 t/ha, ↑ profit $225-$300/ha.
- “Arnold and sons were struck by the tool’s graphs of soil N availability and rainfall, which clearly showed the farm’s weather-related early N losses.”
- 2011-2012: ↓ average N rates by 74 kg/ha, ↑ profit by $77/ha.

Ball, Moebius-Clune, van Es & Melkonian. 2014. IPNI 4R Plant Nutrition Manual Case Study 7.4-4

60


adapt-N
N-Recs
Field Modes
Features
Science
In Action
Webinars
Sign Up
Login
Yara International has acquired Adapt-N to strengthen its Digital Farming offering.
Read more here.
Digital Solutions for Nitrogen Management
CLIMATE FIELDVIEW
GET YOUR DATA IN ONE PLACE
USE DATA TO MAKE BETTER DECISIONS
OPTIMIZE YOUR INPUTS
Granular Agronomy
Make Every Input Count
Take control of field variability with expert advice and custom prescriptions all season long.
IPNI

61


Abundant Food
United States
Crop N Removal, Tg
Maize, grain
Soybean
Canada
Pulses
Canola
Other grains
Wheat
Mexico
Fruits and Vegetables
Sorghum
Wheat
Maize
Data sources: Xin Zhang et al., 2021; USDA-NASS & Statistics Canada with NuGIS coefficients.
Note: extrapolation for crops other than soybean and maize from 2015 in US.
Plant Nutrition Canada

62

Summary

- The fertilizer industry seeks to advance nutrient stewardship through 4R and Responsible Plant Nutrition.
- Soil test, nutrient balance and 4R practice survey data can help inform policy on changes to management – 4R and beyond – effective in reducing nutrient loads to water.
- Still need more data and better understanding of soil P – drainage water P relationships.
- Digital tools for real-time fertilizer decisions may help address the role of weather in varying demand for nitrogen.
- Collaboration invited in the furthering of 4R!

Plant Nutrition Canada

63