IPNI International Plant Nutrition Institute

Canadian Society of Soil Science
Société Canadienne de la science du sol

Trent University, Peterborough, Ontario
Tuesday, 13 June 2017

Metrics of sustainable phosphorus management

4R nutrient stewardship

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Agrium Inc.

Arab Potash Company

BHP Billiton

CF Industries Holdings, Inc.

International Raw Materials LTD

Kingenta Ecological Engineering Group Co., Ltd.

K+S KALI GmbH

The Mosaic Company

OCP S.A.

PhosAgro

PotashCorp

Shell Sulphur Solutions

Simplot

Sinofert Holdings Limited

Yara International ASA

The **International Plant Nutrition Institute** is supported by leading fertilizer manufacturers.

Its mission is to develop and promote science for responsible management of crop nutrition.

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Outline – metrics of sustainable P management

1. **Sustainability Perspectives**
   - Ecosystem services
   - Global stocks and flows
2. **Metrics & Indicators**
   - Balances, footprints, and use efficiency
   - Soil tests: up to the task?
3. **Quantification of management impacts**
   - 4R Research efforts

4R nutrient stewardship

http://phosphorus.ipni.net/

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Phosphorus Sustainability Perspectives

- Food industry
  - Needs clear simple metrics of sustainability impact
- Producers
  - Burden of sustainability reporting requirements
- Scientists
  - Management impact on P loss too complex to quantify
  - Lack of consensus on metrics and material flows

Ecosystem Services

Food-fiber-fuel

Nutrient cycling

C storage

Water retention

Landscape aesthetic

Impacts of P

Crop productivity

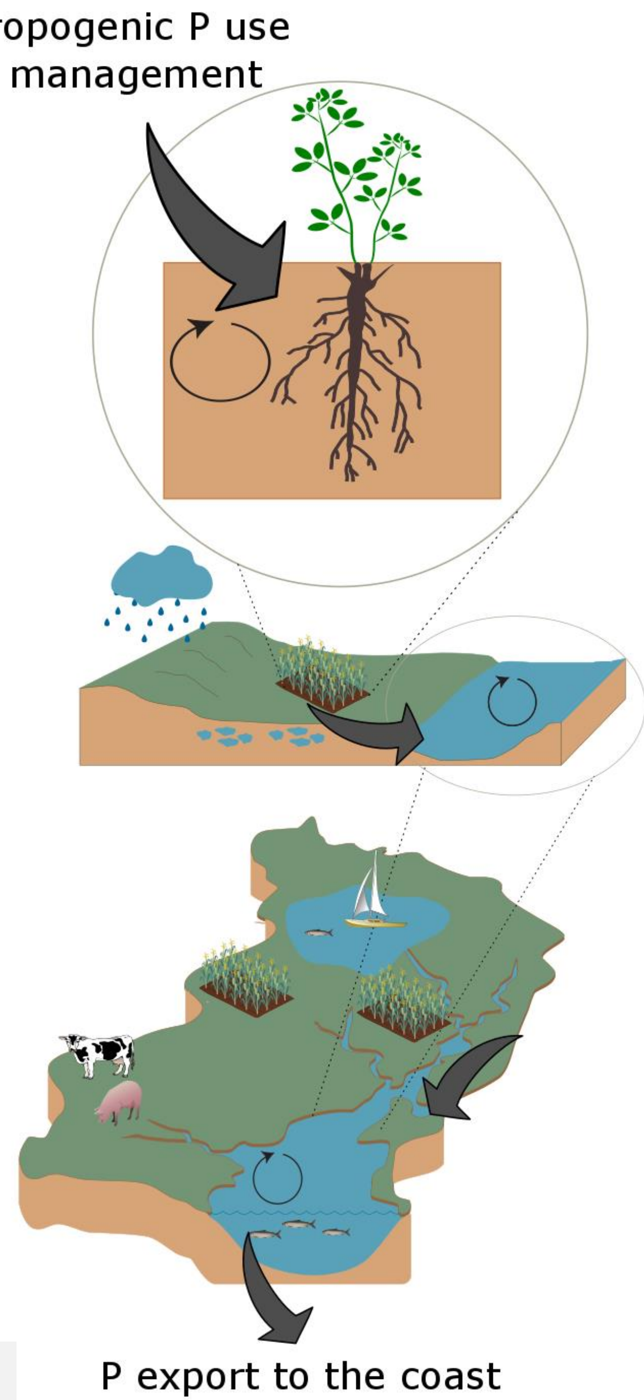
Biodiversity

Water quality

Fish

Recreation

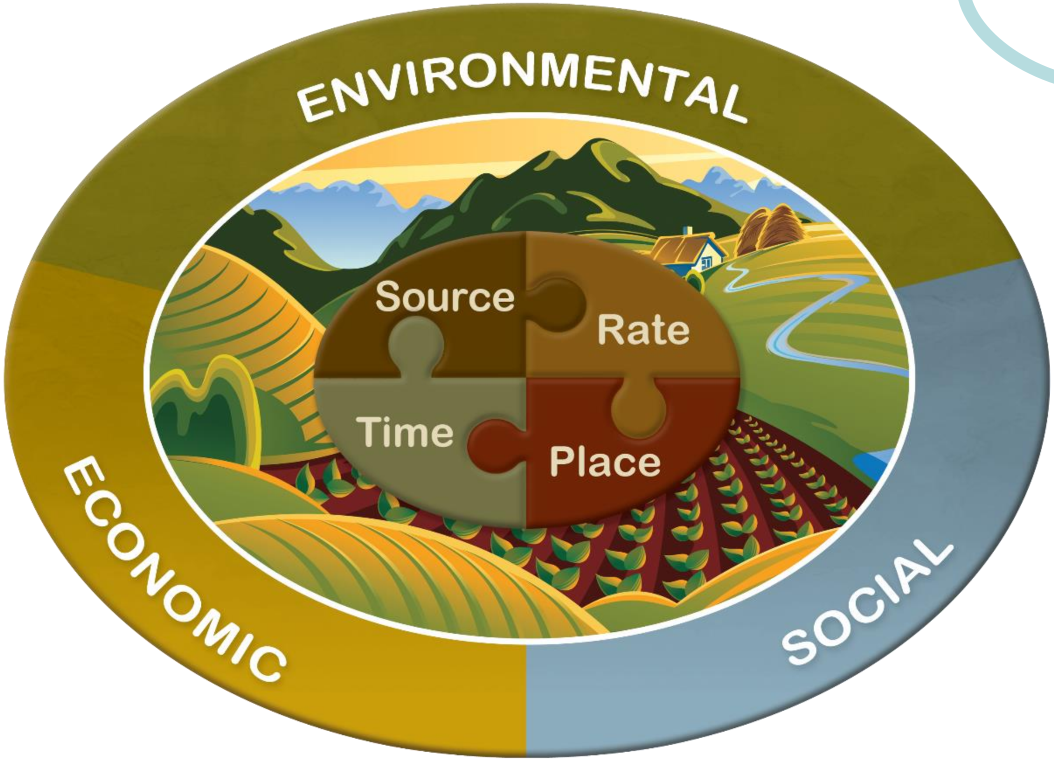
Property value



Adapted from MacDonald et al 2017

4R Phosphorus for Sustainable Crop Nutrition

Actions (adoption metrics)



Key Outcomes (impact metrics)

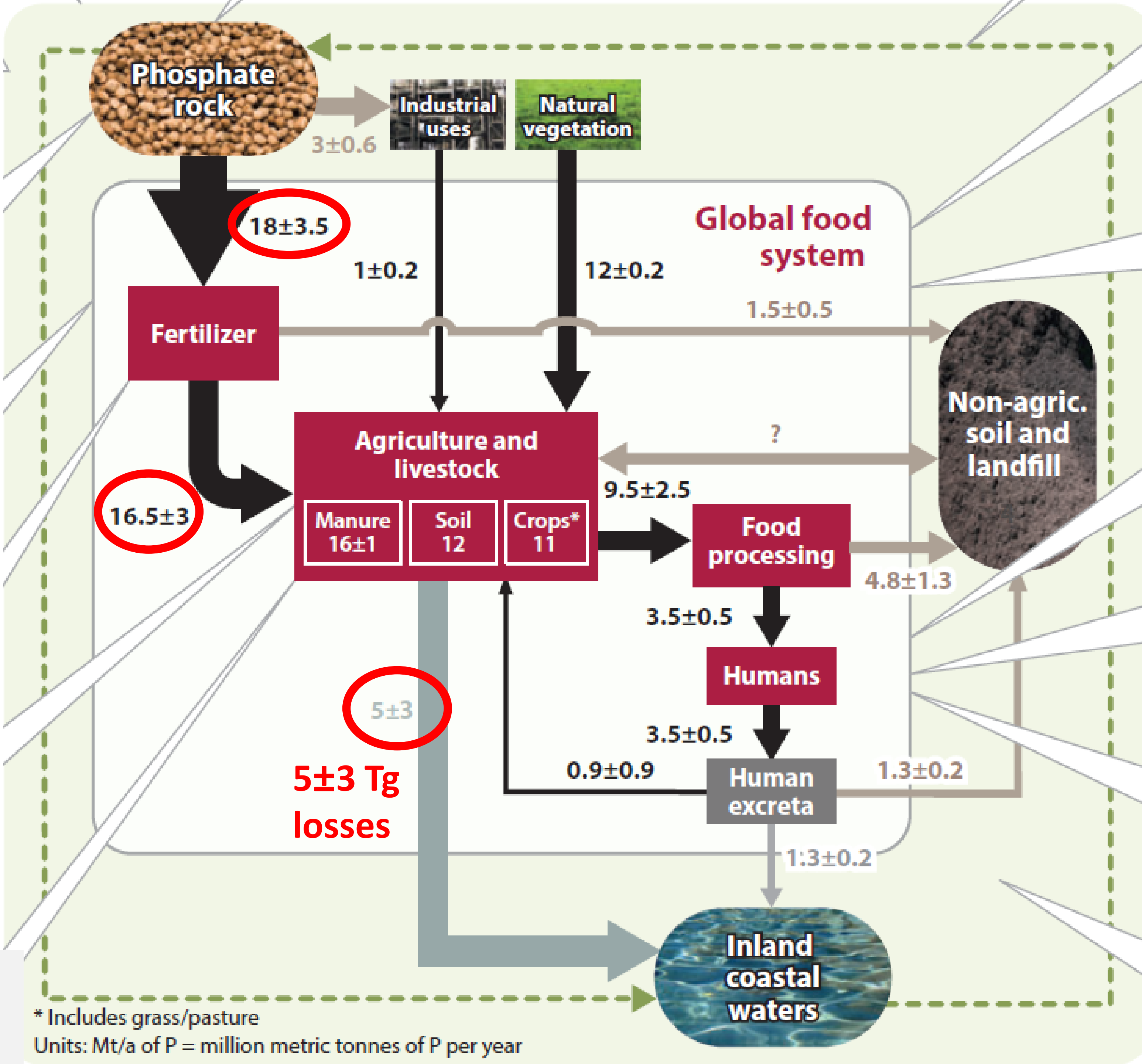
1. **Farmland productivity**
2. **Soil health**
3. **Nutrient use efficiency**
4. **Water quality**

Global P material flow analysis

PUE: 19% (3.5/18)

Loss ratio:
[2009] 46%
[here] 28%
[Bouwman et al., 2009] 14% (fert only) or 6% (all inputs)

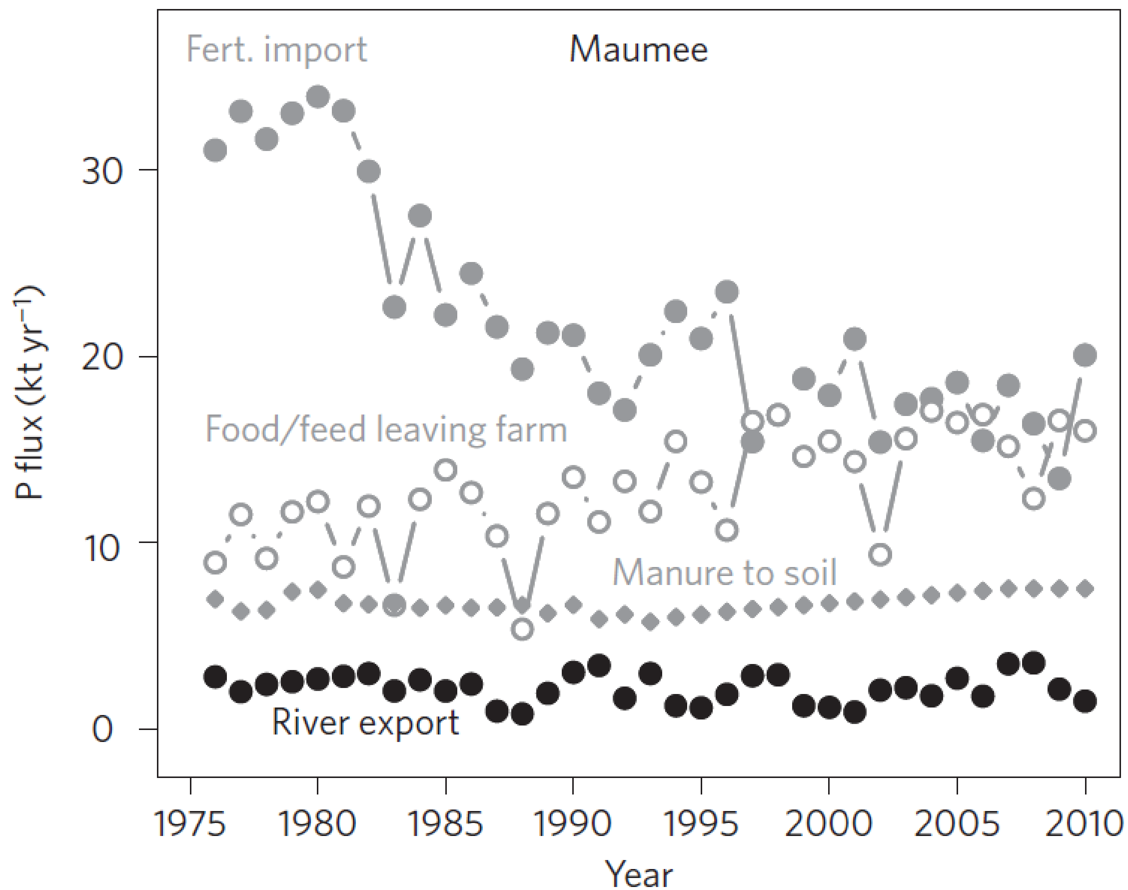
Cordell & White, 2014



Watershed scale: Maumee River

NATURE GEOSCIENCE DOI: 10.1038/NGEO2693

River export: 5-20% of fertilizer input



Powers et al., 2016. Nature Geoscience 9(5):353-356.

Measured losses from well-managed fields are no more than a few % of P applied

Table 2. Mean annual N and P loss in runoff is a small proportion of that added in fertilizer (2014 to 2015), Arkansas.

Crop system	Location	Applied	Loss	Loss expressed as portion of fertilizer nutrient added
		- - lb/A/year - -		%
		Phosphorus		
Pasture	Elkins	50	0.1	0.2
Corn	Atkins	22	0.5	2.3
Cotton	Dumas	42	1.9	4.5
Corn	Dumas	41	0.9	2.2

Sharpley et al., 2016. Better Crops 100(3):13-15.

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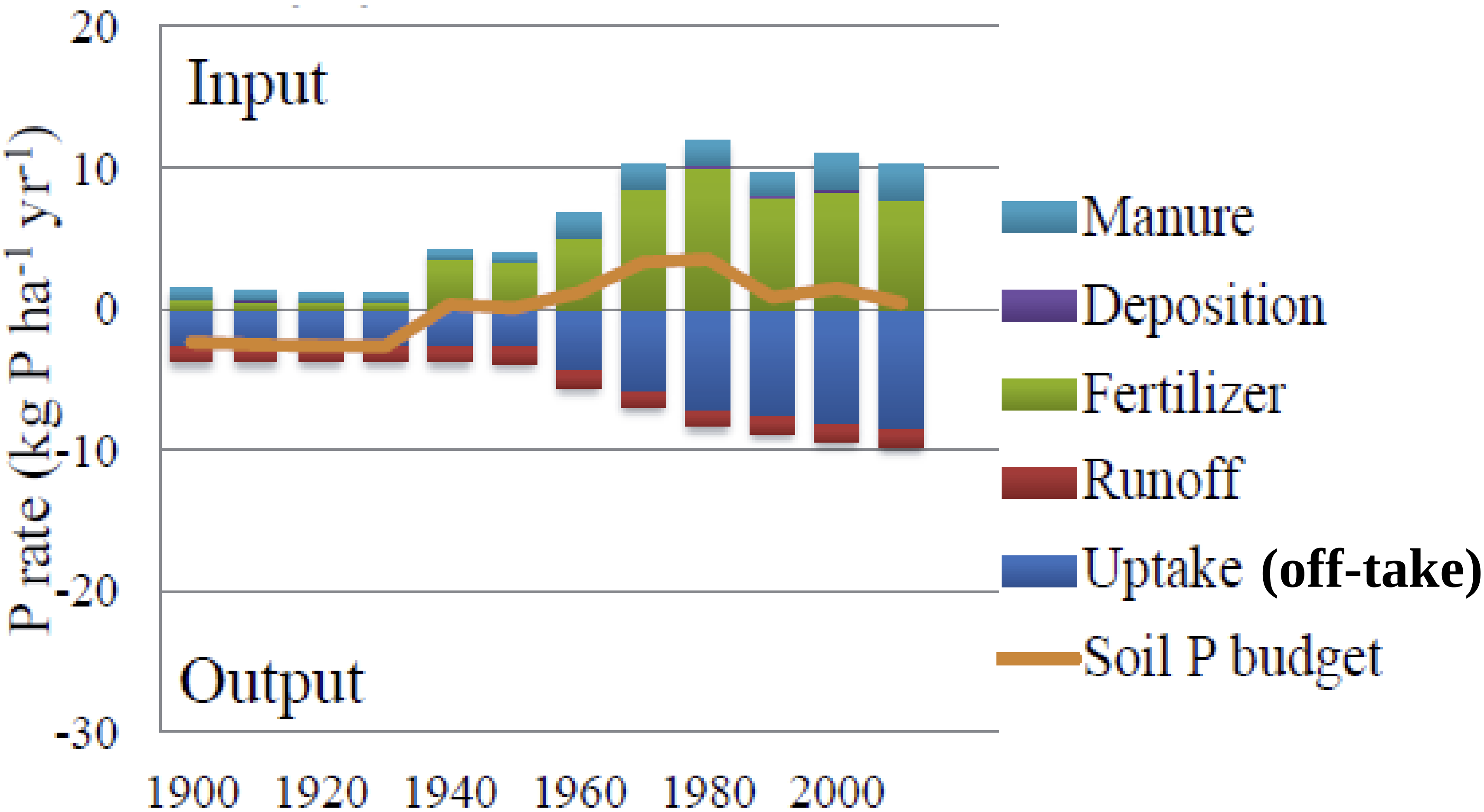
North American Phosphorus Balance, 1900-2010

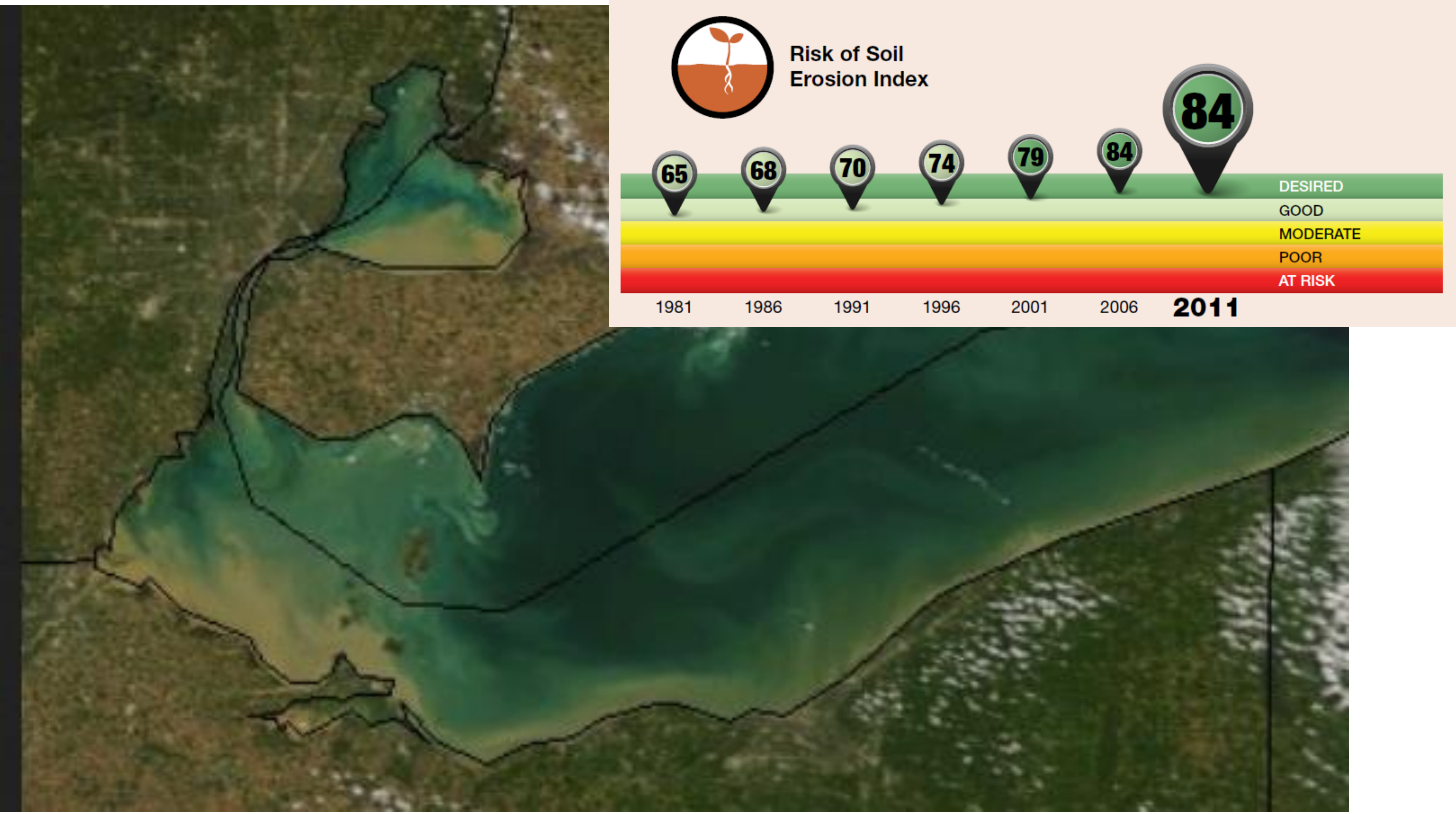


Zhang, Beusen, et al., 2017. Biogeosciences, 14, 2055–2068.

Soil Erosion: making progress?

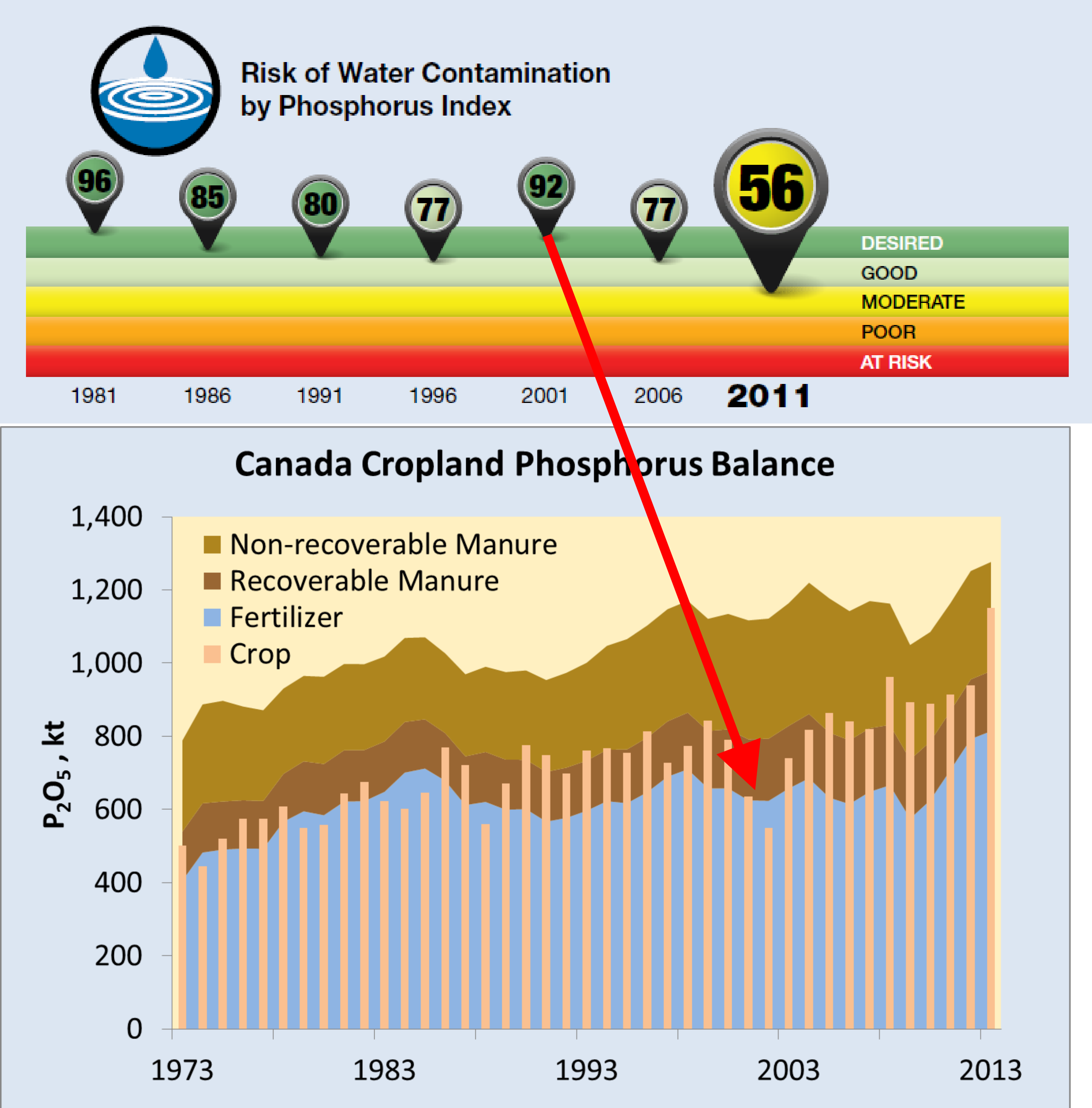
Report #4
Agri-Environmental Indicators Report Series

Environmental Sustainability of Canadian Agriculture



Terra MODIS Direct Broadcast Images 7 May 2017

Report #4
Agri-Environmental Indicators Report Series
Environmental Sustainability of Canadian Agriculture



The Dubious Relationship Between P Use Efficiency and Loss Mitigation

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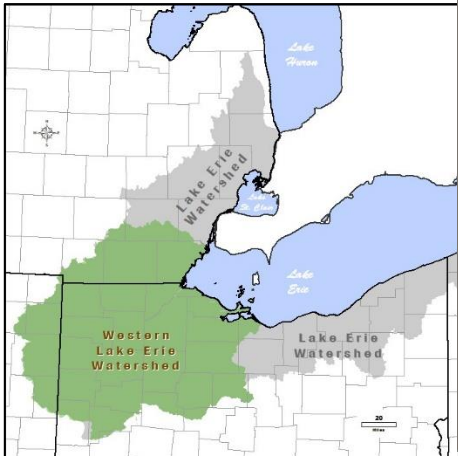
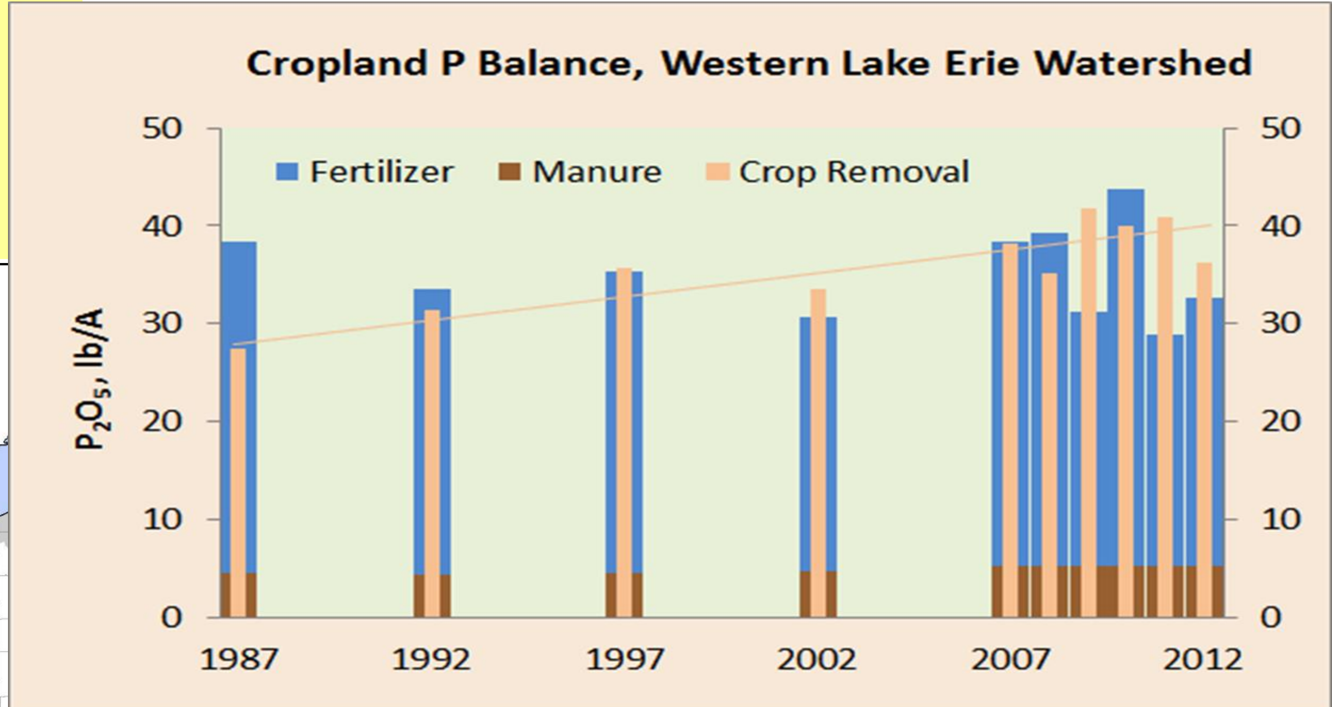
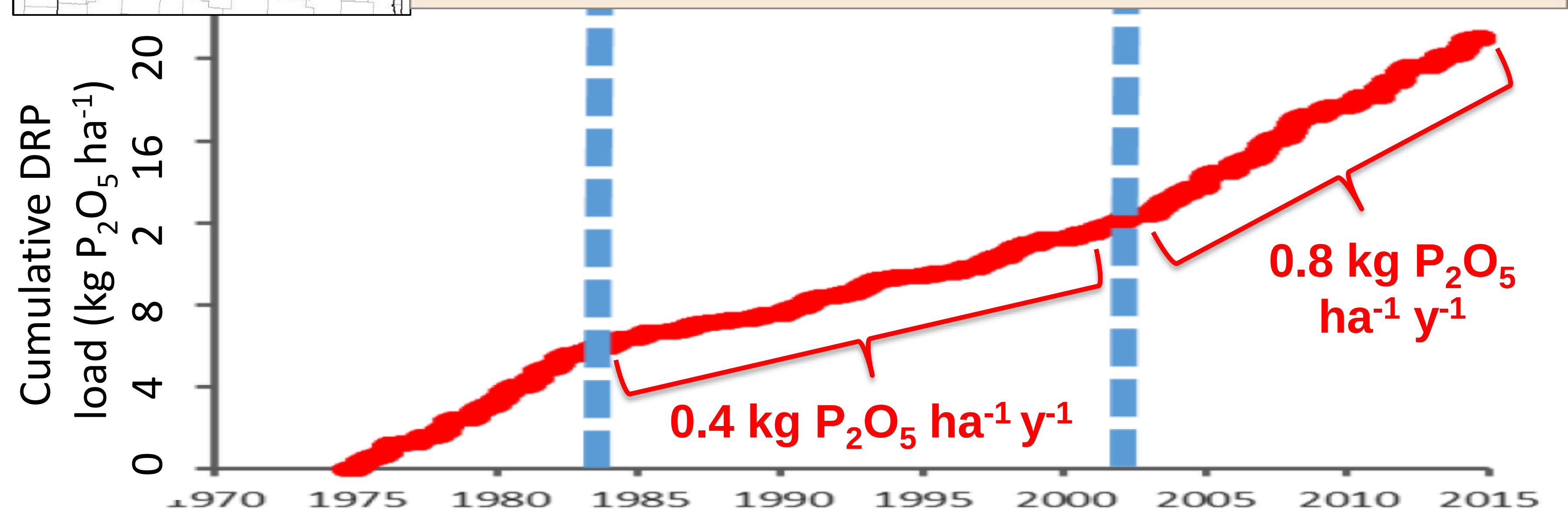
Western Lake Erie: dissolved P trends increasing since 2002

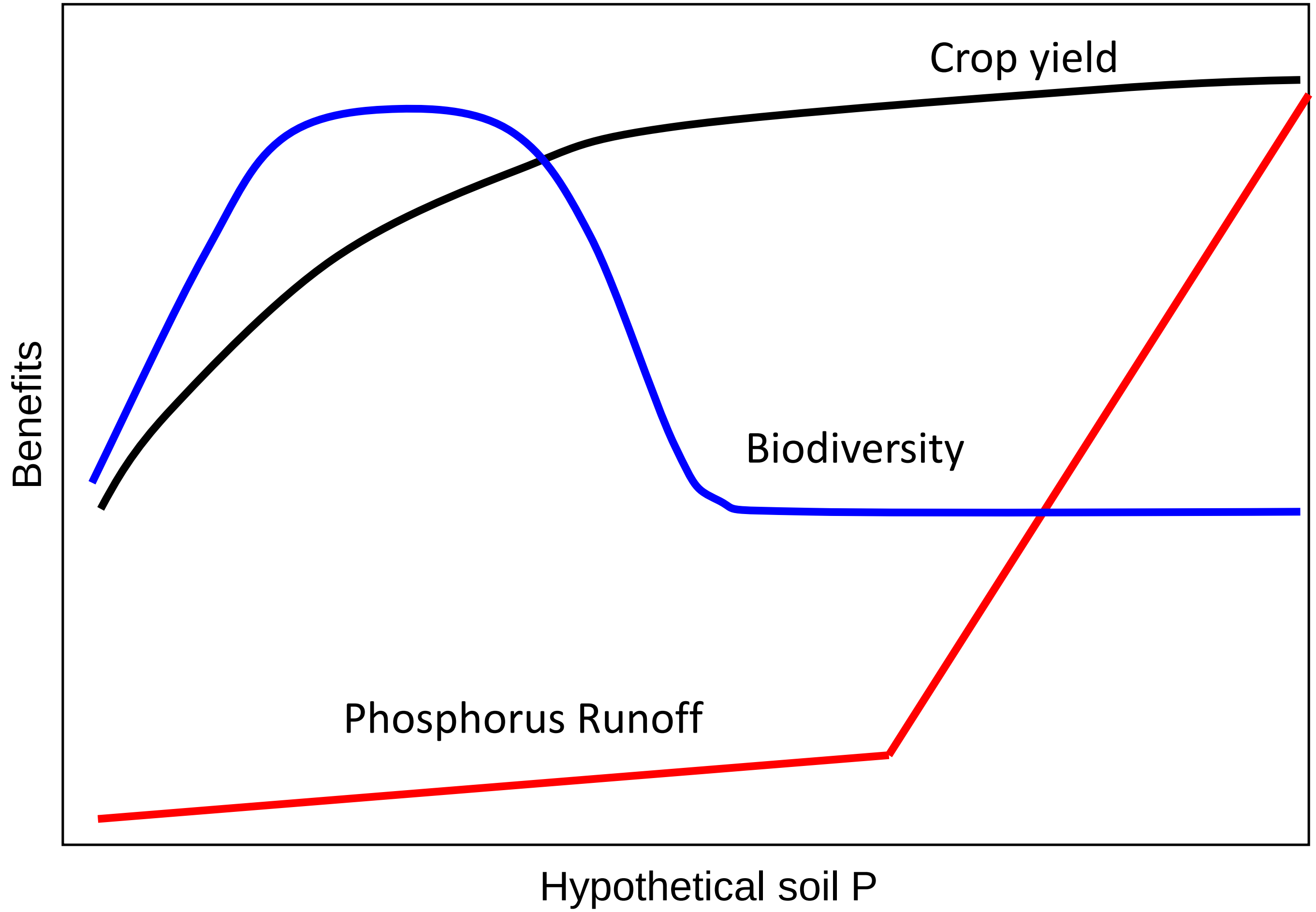






Jarvie et al., 2016, J Environ. Qual.

Soil test P management for multiple ecosystem services



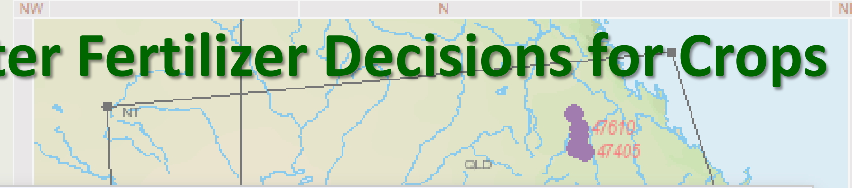
Weintraub, Johnson, et al.

Australia – Better Fertilizer Decisions for Crops

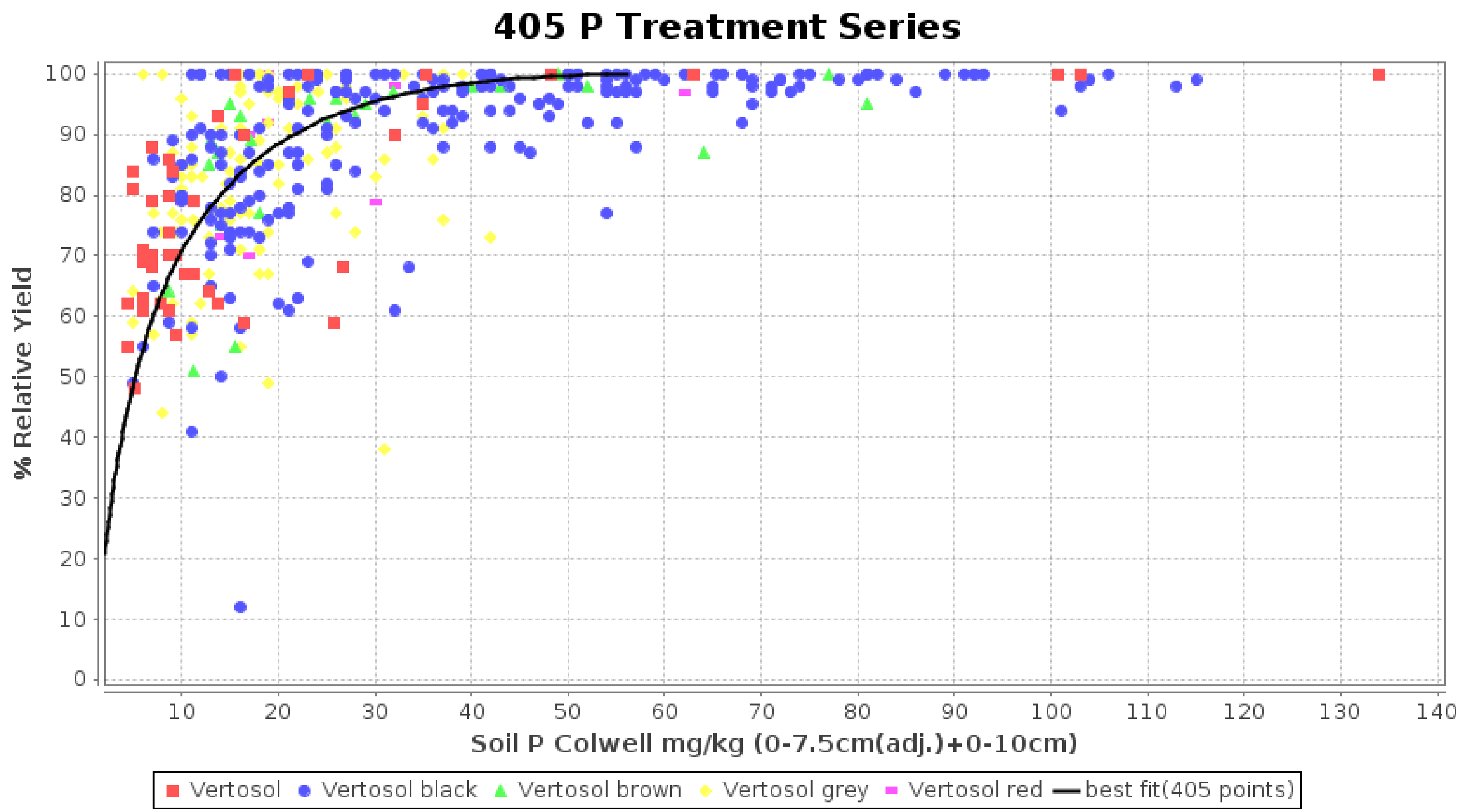
<<back

Soil test-crop response calibrations

414 P trials fit your initial selection criteria. Their locations with Australian Soil Class are plotted on the map.



print



Soil test calibration:

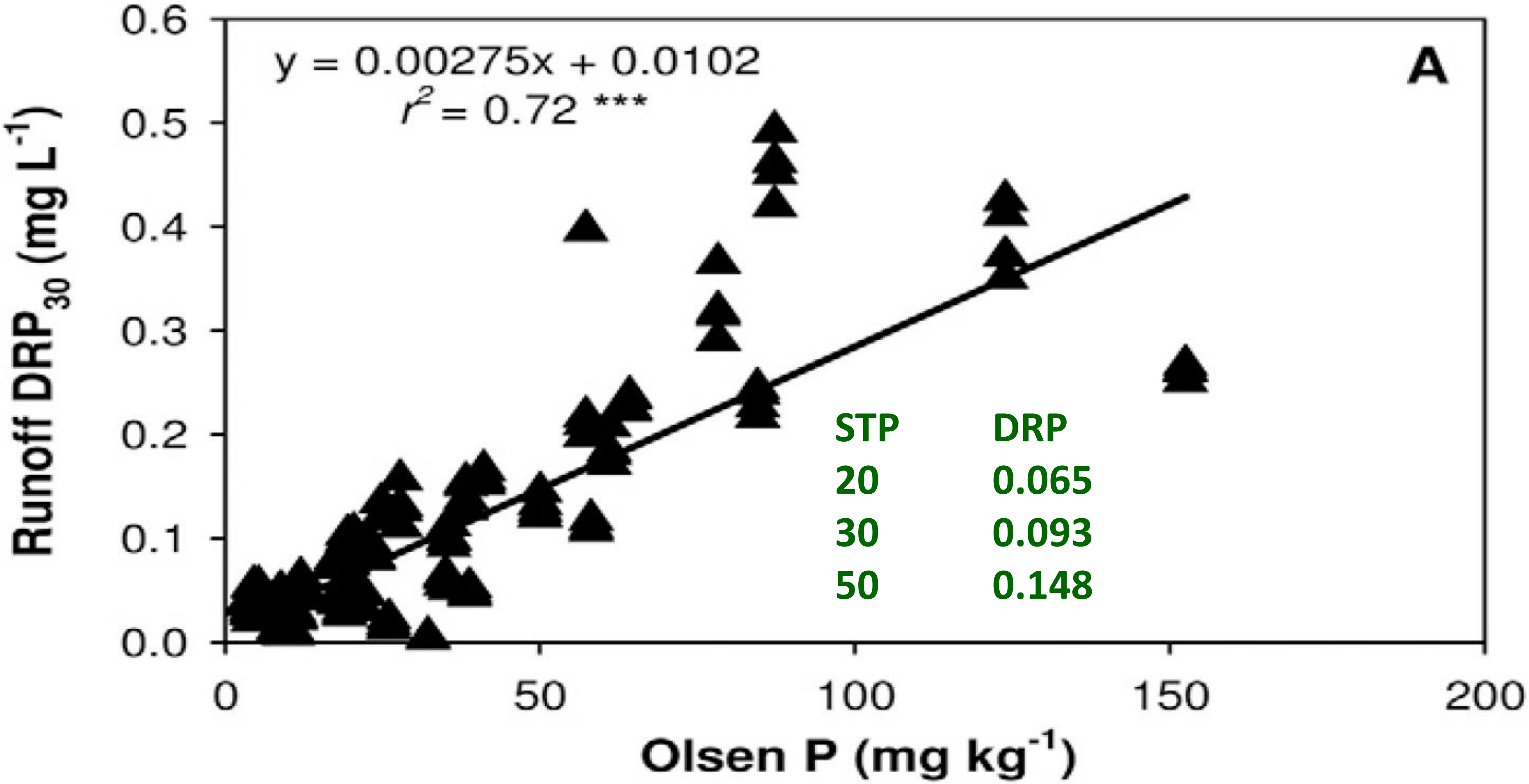
80% Relative Yield: 14.0 (12.0 - 16.0) Correlation R: 0.61 Slope RY(50-80): 3.4 (2.9 - 3.9)

90% Relative Yield: 22.0 (20.0 - 24.0) Regression equation: $x = e^{(3.0834(\arcsin(\mathrm{sqrt}(y/100))) + -0.77859)}$

95% Relative Yield: 29.0 (26.0 - 32.0) 70% confidence limit at 90% Relative Yield: 22.0 (21.0 - 23.0)

relationship curves will be plotted for the filter item selected. For example you may want to show the trends for each of the three most common soil textures if these data are

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

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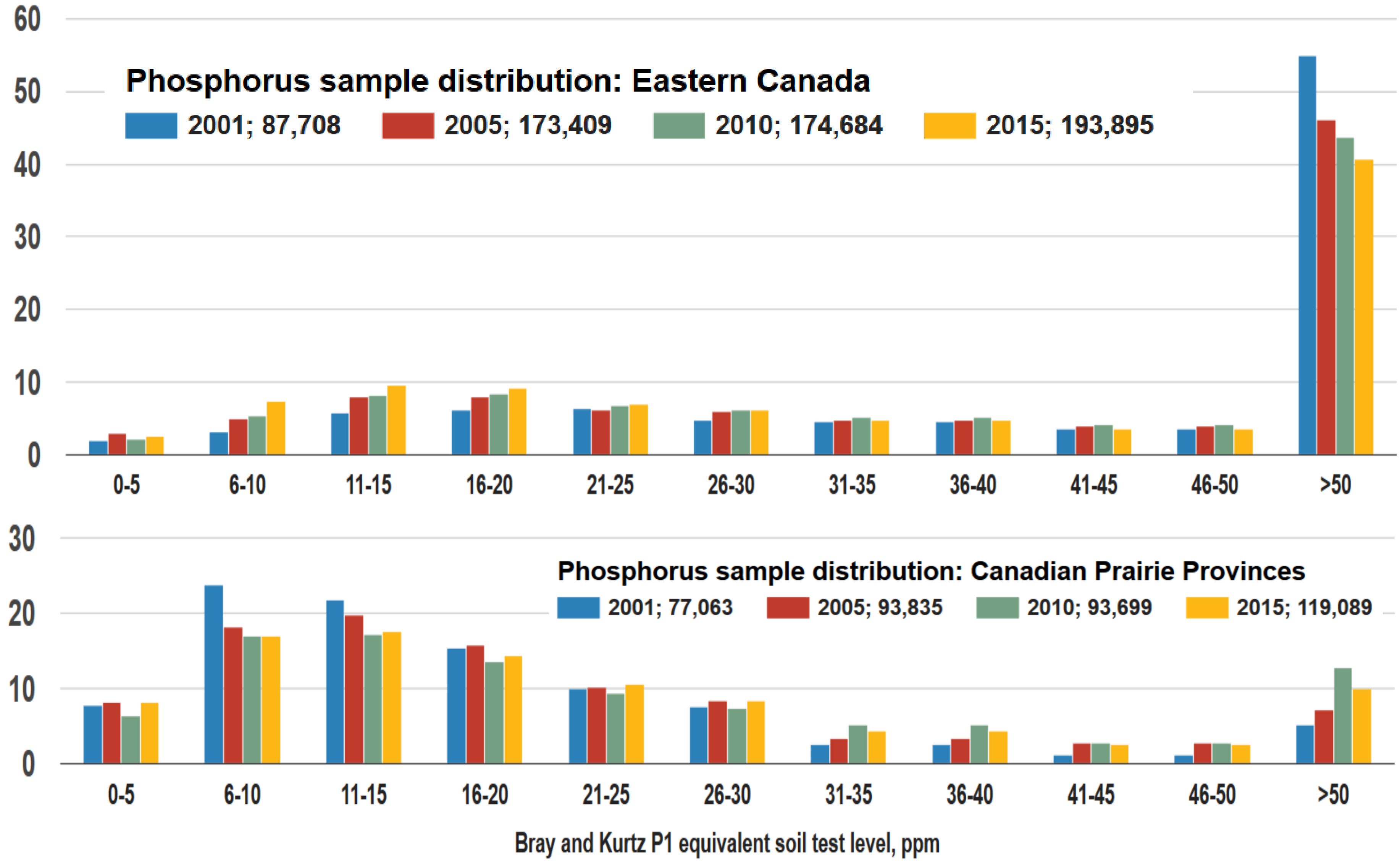
East versus West: a contrast in soil test P



http://soiltest.ipni.net

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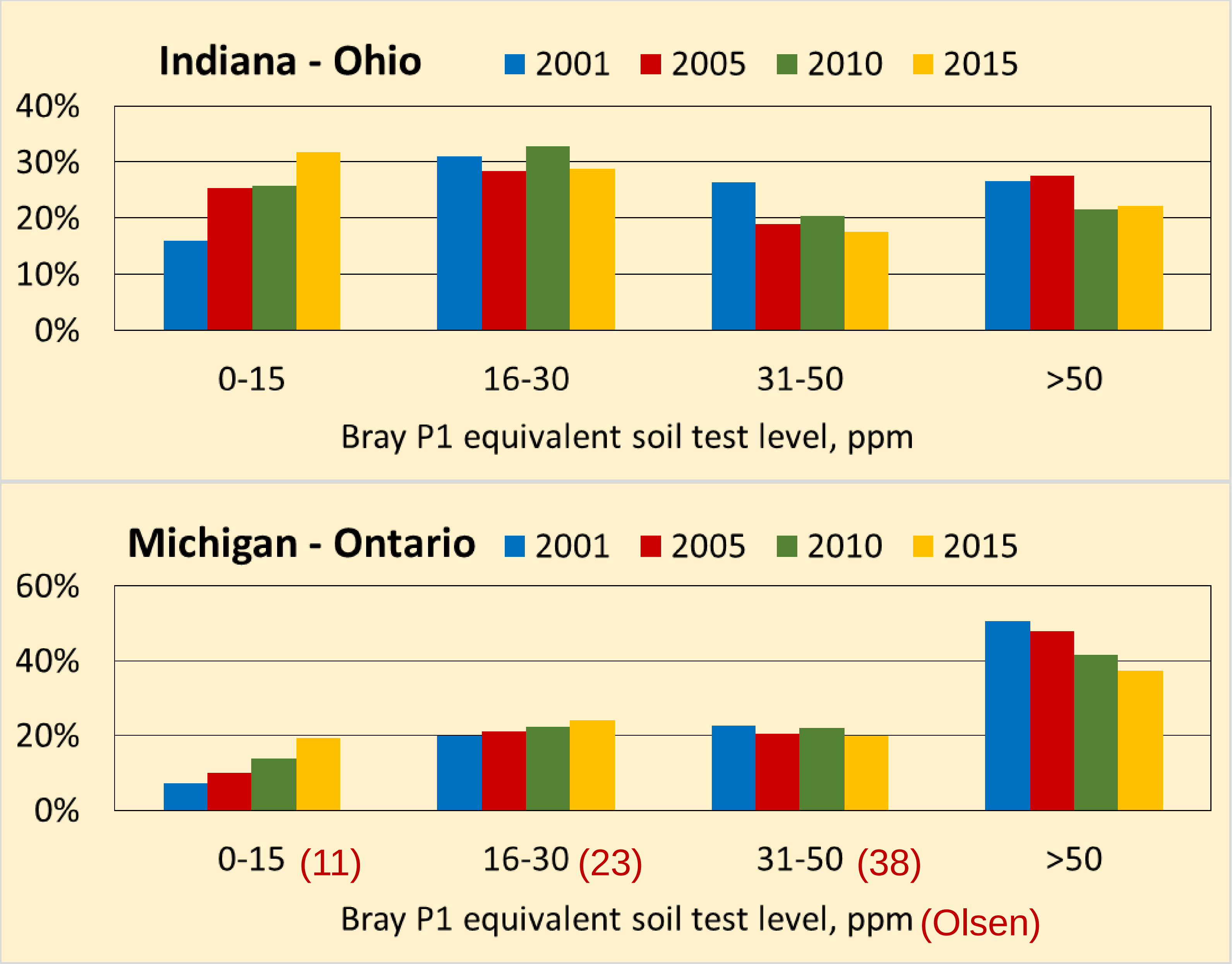
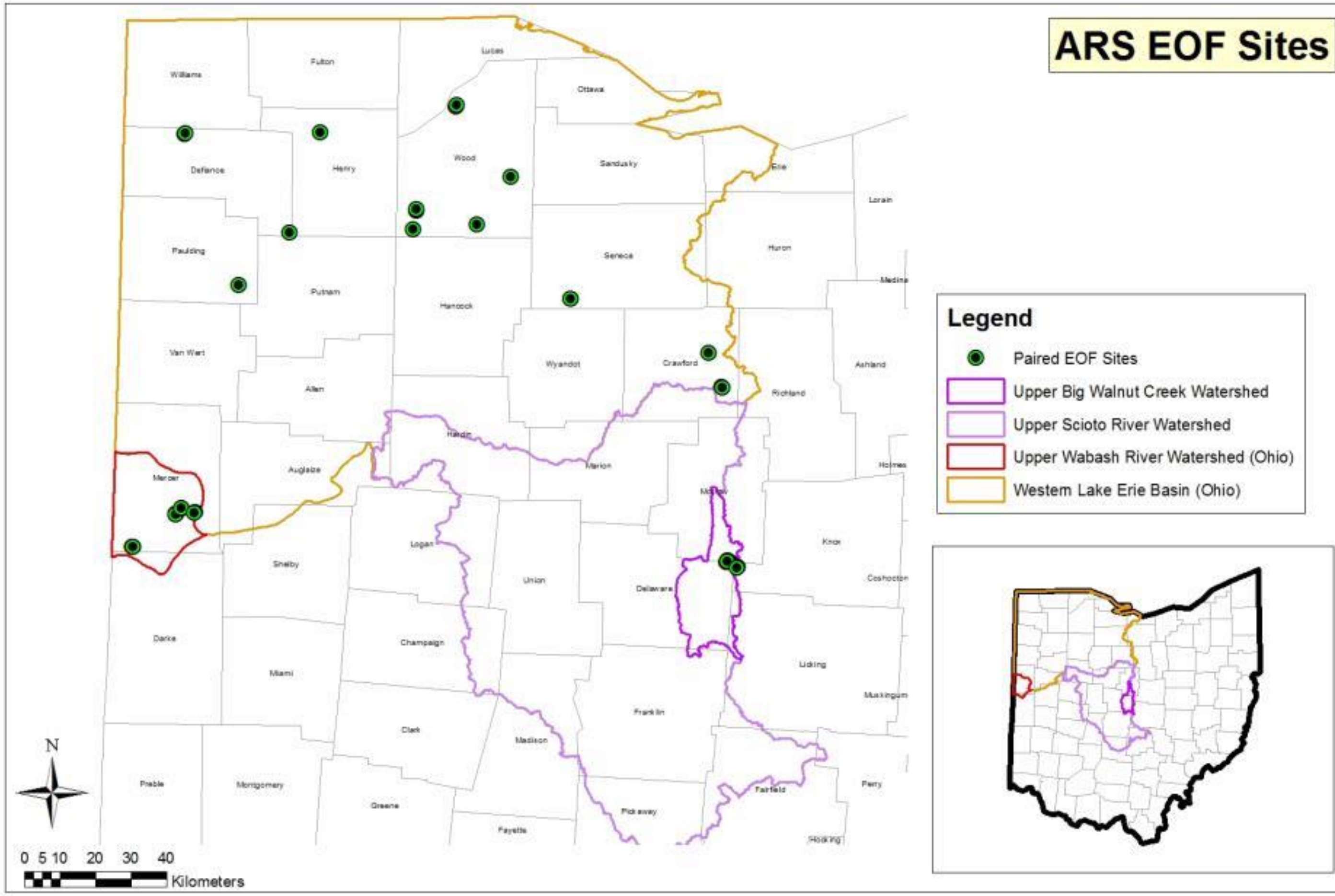
Phosphorus legacy differs by region



4R Research Fund LEW project:

Monitoring P loss at edge of field & in stream



Funding Sources:

4R Research Fund USA-4RN09
USDA-ARS: USDA-Agriculture Research Service
CEAP: Conservation Effects Assessment Project
EPA: DW-12-92342501-0
Ohio Agri-Businesses
Ohio Corn and Wheat Growers

CIG: 69-3A75-12-231 (OSU)
CIG: 69-3A75-13-216 (Heidelberg University)
MRBI: Mississippi River Basin Initiative
The Nature Conservancy
Becks Hybrids/Ohio State University
Ohio Soybean Association

USDA ars

Soil Drainage Research Unit

Kevin King, USDA-ARS, Columbus, Ohio

Lake Erie Watershed 4R Research – findings to date

1. Incorporation ("right place") of broadcast fertilizer reduced P loss in tile drains by 45%
2. Soil test P in the top 5 cm of soil was up to 3 times higher than in the top 20 cm; on average, 1.5X.
3. Farmers express concern for their impact on the lake, and up to 90% are willing to change practices.
4. Collaborating brings rewards.

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http://research.ipni.net/project/IPNI-2014-USA-4RN09

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ISSUE REVIEW

Ref #17023

4R Phosphorus Management Practices for Major Commodity Crops of North America

By Tom Bruulsema, Phosphorus Program Director, IPNI

March 2017

Phosphorus plays a crucial role *in sustainable crop production. Made from finite natural resources, phosphorus fertilizers support high and increasing crop yields, but their use can also elevate the risk for reduced water quality. Increasing the adoption of 4R phosphorus application practices—applying the right source at the right rate, right time, and right place—has great potential to improve both crop yields and water quality. This paper reviews a science-based effort to describe such practices for five major commodity crops produced in North America.*

http://phosphorus.ipni.net/

Field to Market®

The Alliance for Sustainable Agriculture

Participating Scientists

1. **Brian Arnall**, Oklahoma State U
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3. **Don Flaten**, U of Manitoba
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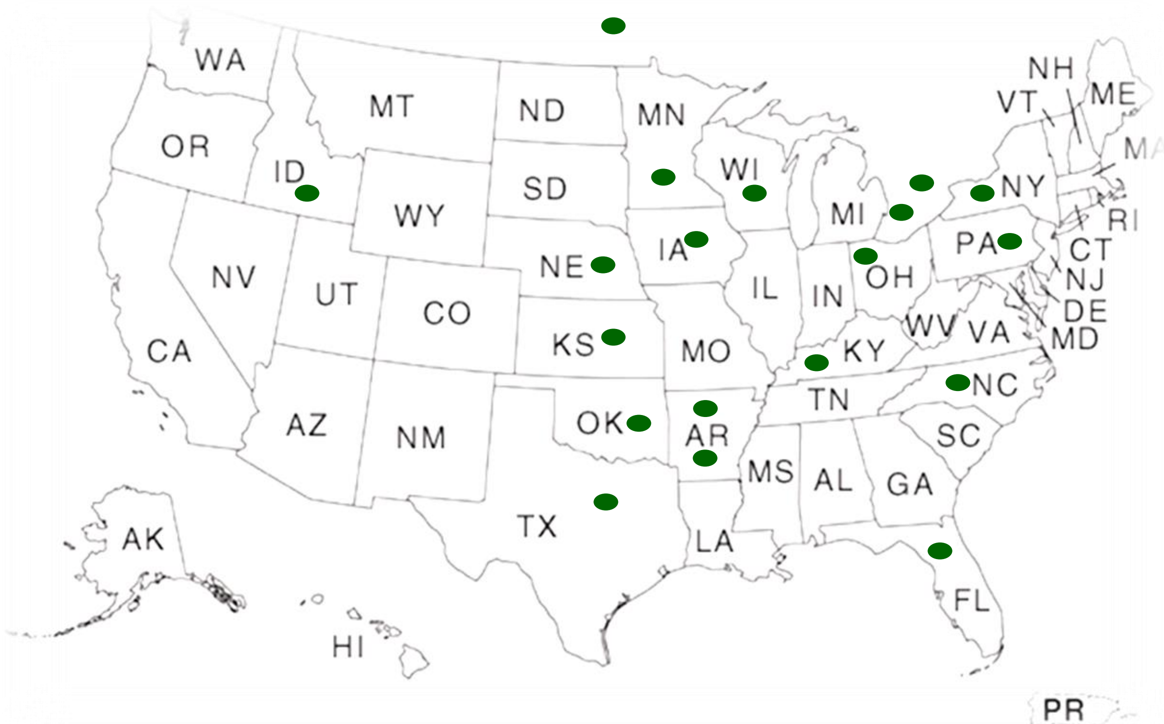
5. **Kevin King**, USDA-ARS, Columbus, OH
6. **Quirine Ketterings**, Cornell U
7. **Josh McGrath**, U of Kentucky
8. **Antonio Mallarino**, Iowa State U
9. **Rao Mylavarapu**, U of Florida with input from other colleagues.
10. **David Mulla**, U of Minnesota
11. **Nathan Nelson**, Kansas State U
12. **Keith Reid**, Agriculture and Agri-Food Canada
13. **Nathan Slaton**, U of Arkansas - with input from Bruce Linquist, UC-Davis, Bobby Golden, Mississippi State U, Dustin Harrell, Louisiana State U.
14. **Charles Shapiro**, U of Nebraska
15. **Andrew Sharpley**, U of Arkansas
16. **Doug Smith**, USDA-ARS, Temple, TX
17. **Ivan O'Halloran**, U of Guelph
18. **Deanna Osmond**, North Carolina State U
19. **David Tarkalson**, USDA-ARS, Kimberly, ID - with input from Bryan Hopkins, Brigham Young U, and others.



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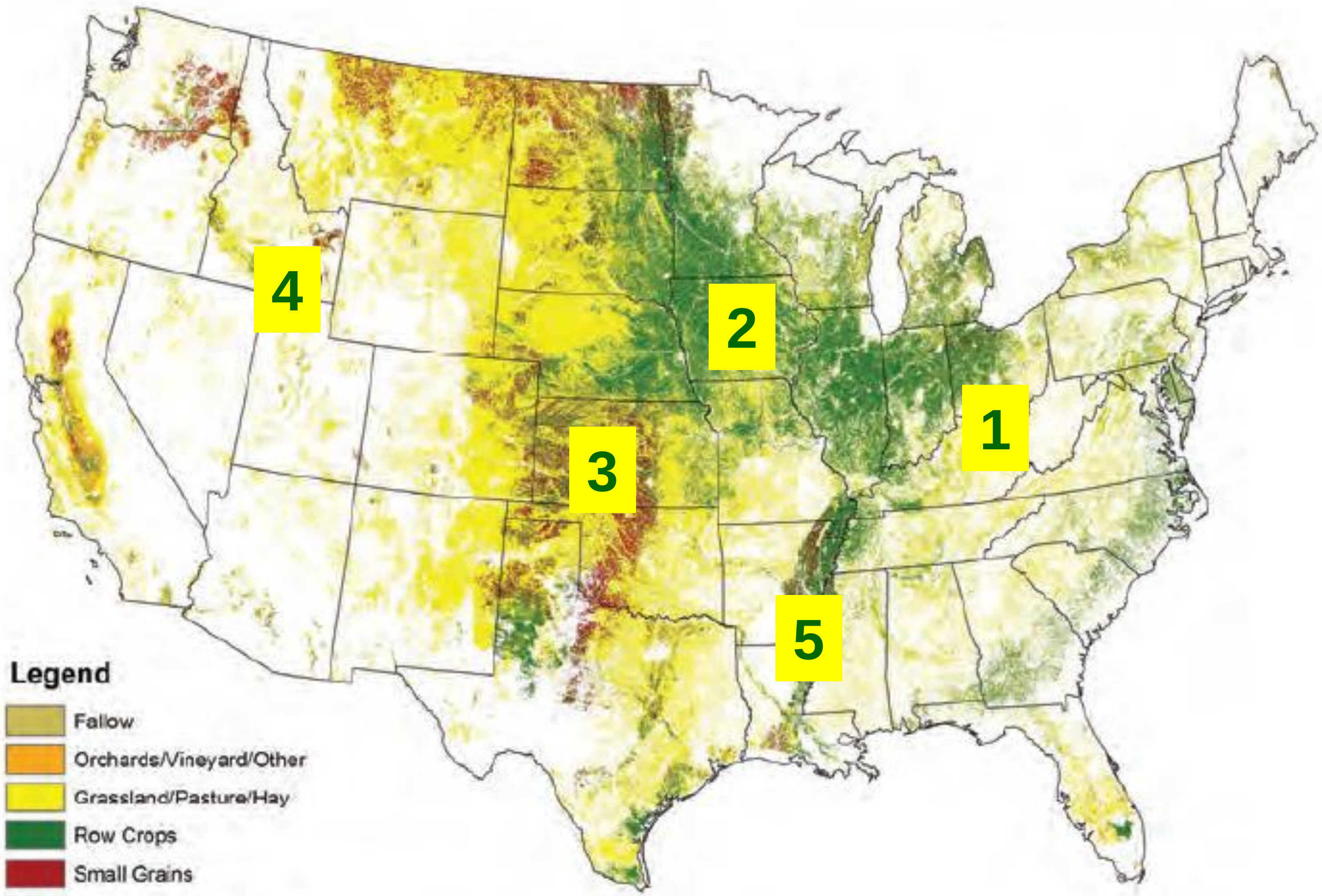
Regions and Cropping Systems

1. Western Corn and Soybean
2. Eastern Cereals and Oilseeds
3. Wheat in the Great Plains
4. Irrigated Potatoes in the Northwest
5. Rice



2011 National Land Cover Database - http://www.mrlc.gov

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%	negligible
Time	41 to 42%	negligible
Place	20 to 98%	-60% to NS
Soil inversion	NS to 92%	-59% to NS
Conservation tillage	-308 to -40%	-33 to 96%

1. **Wide range of efficacies demands more site-specific focus.**
2. **Trade-off between dissolved and particulate is important.**

Dodd & Sharpley, 2015. Nutrient Cycling in Agroecosystems.

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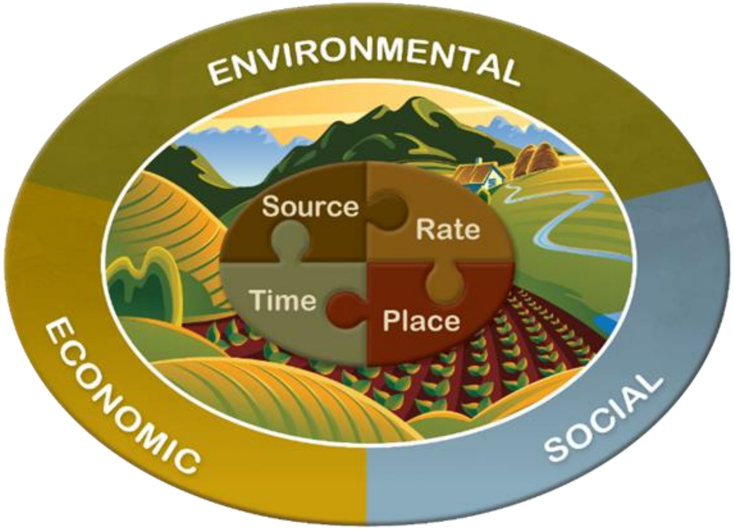
Summary

- Losses of P, small relative to inputs and outputs, impact water quality strongly.
- 4R management can reduce losses of dissolved P and optimize soil available P levels.
- Soil conservation practices are still important for managing particulate losses.
- Quantification of practice impacts on P losses is important to enabling sustainability investment decisions.

4R nutrient stewardship



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