IFCA ANNUAL CONVENTION
& TRADE SHOW January 17 - 19, 2017
PEORIA CIVIC CENTER | PEORIA, ILLINOIS

IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Managing Phosphorus
4R
Crops and Environment

Tom Bruulsema, Phosphorus Program Director

4R nutrient stewardship

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

Formed in 2007 from the Potash & Phosphate Institute, its mission is to develop and promote science for responsible management of crop nutrition

Agrium Inc.	Arab Potash Company	BHP Billiton	CF Industries Holdings, Inc.
Compass Minerals Plant Nutrition	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	SQM
Uralchem, JSC	Uralkali	Yara International ASA	

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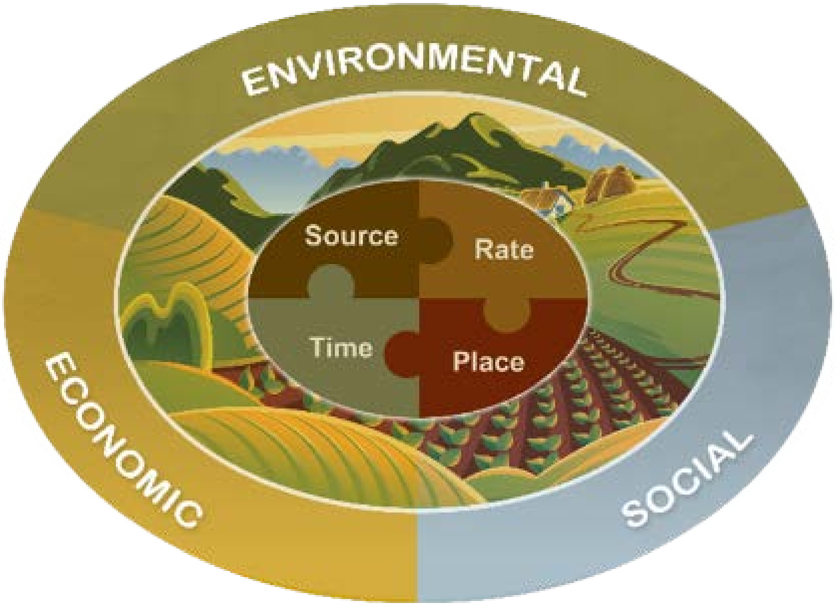
Outline

1. Sustainable Phosphorus
2. 4R
3. Effective Practices



nutrient stewardship

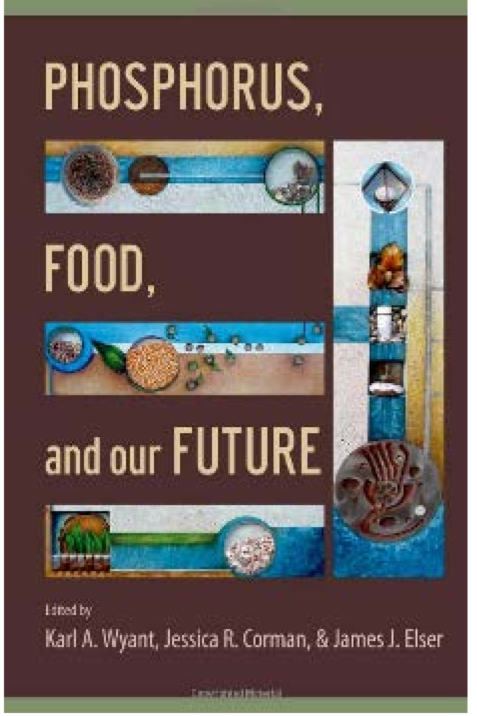
http://phosphorus.ipni.net

Phosphorus Sustainability Initiatives:

- resource consumption & use efficiency
- trace element loading
- water quality impacts

"Phosphorus Footprint"

"Peak Phosphorus"

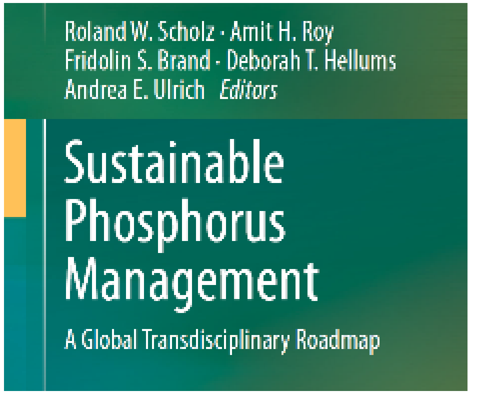


Sustainable Phosphorus Alliance

GPNM
Global Partnership on Nutrient Management

August 16-20, 2016
Kunming, Yunnan, China

5th Sustainable Phosphorus Summit 2016 (SPS 2016)



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Phosphorus Issues

- Eutrophication
- Hypoxia
- Harmful algal blooms
- Excess levels in soil, stratification
- Deficient levels in soil, crop yield limitation

- Finite resource, geopolitical distribution
- Declining quality of reserves
- Heavy metals, trace elements and cadmium
- Environmental impact of mining

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As a sustainability system, 4R Nutrient Stewardship needs METRICS.

crsc Canadian Roundtable for Sustainable Crops

Field to Market®
The Alliance for Sustainable Agriculture

4R nutrient stewardship

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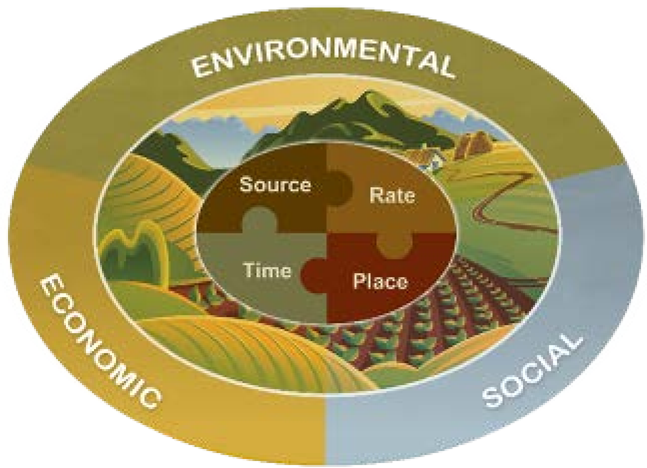
Nutrient Stewardship Metrics for Sustainable Crop Nutrition



Enablers (process metrics)

- Extension & professionals
- Infrastructure
- Research & innovation
- Stakeholder engagement

Actions (adoption metrics)

- Cropland area under 4R [Requires regional definitions of 4R practices]

Outcomes (impact metrics)

1. **Farmland productivity**
2. **Soil health**
3. **Nutrient use efficiency**
4. **Water quality**
5. Air quality
6. Greenhouse gases
7. Food & nutrition security
8. Biodiversity
9. Economic value

4R nutrient stewardship

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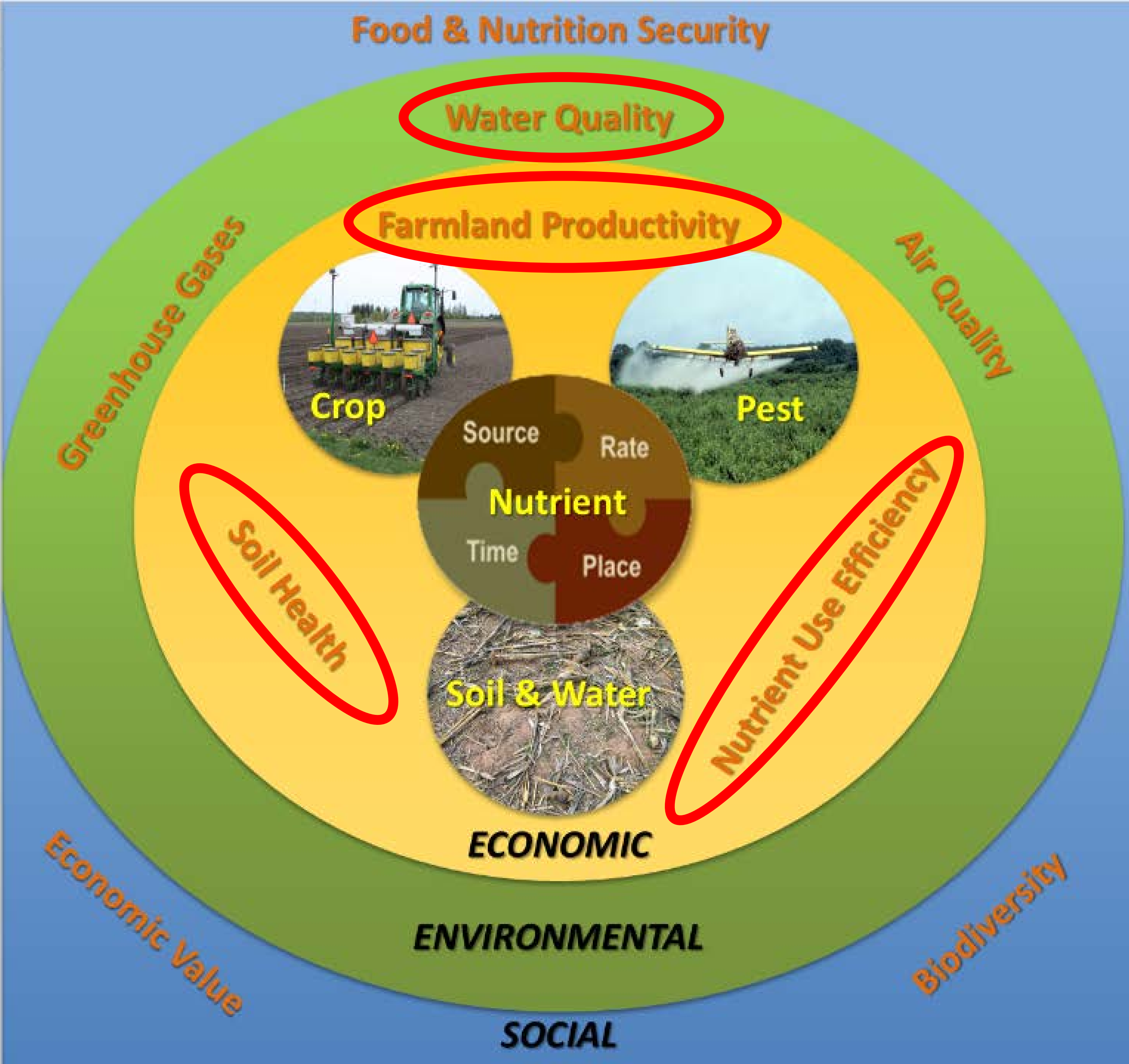
4R Outcome Metrics are influenced by 4R and more.

OUTCOMES

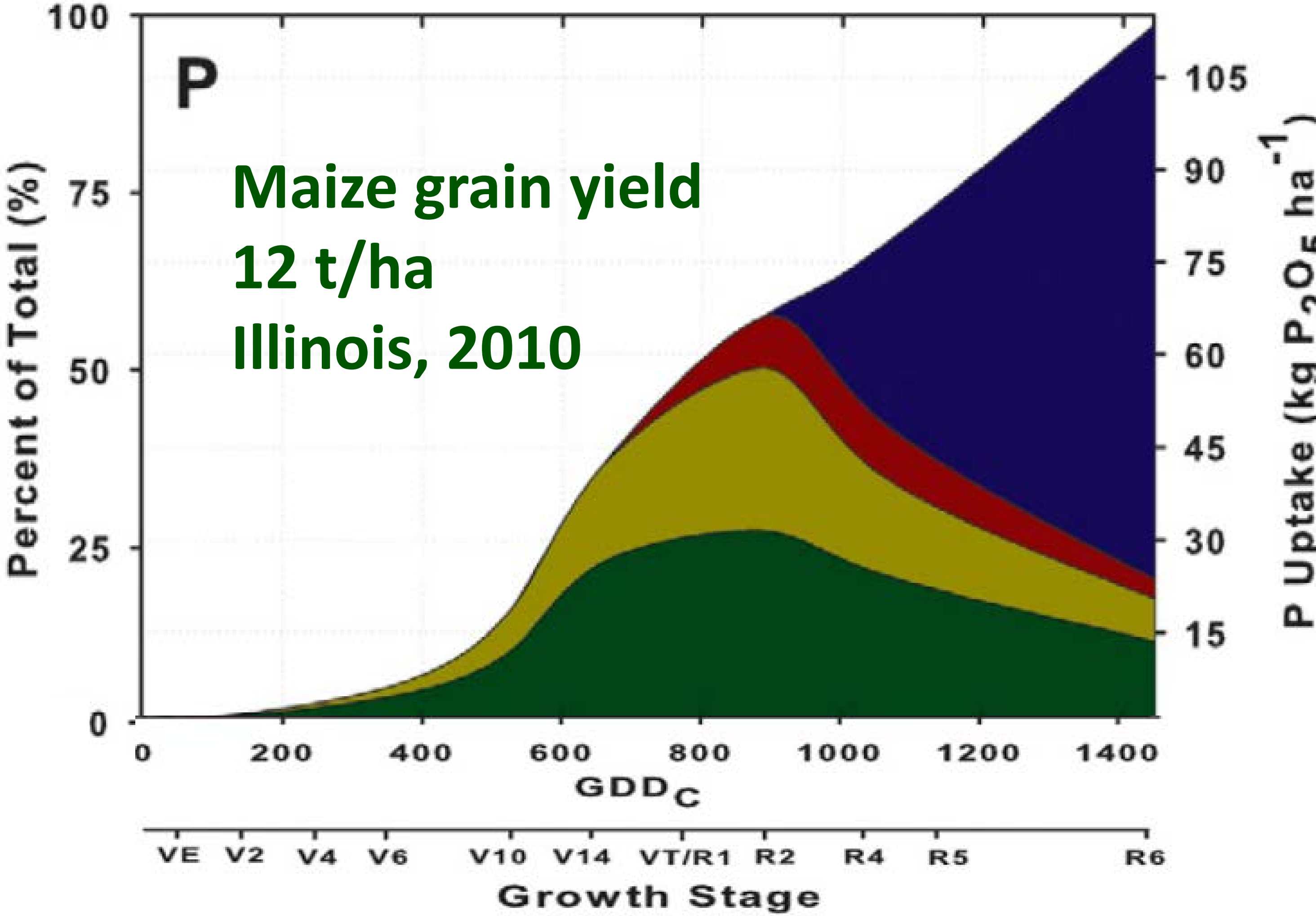
of

nutrient stewardship

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



High-yield crops take up large amounts of P. Most of it is removed with grain harvest.

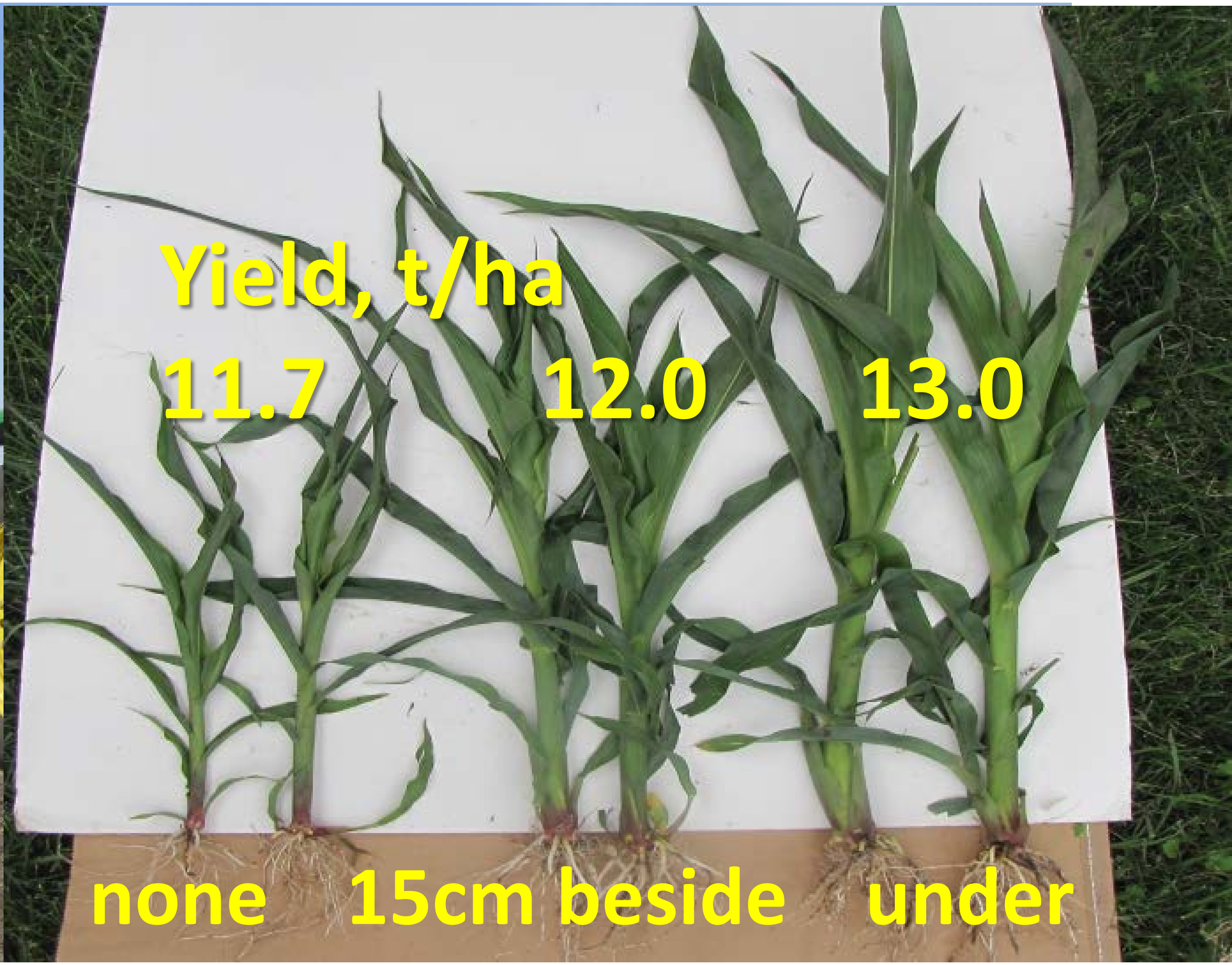


2010 data from two sites and six hybrids

Dr. F.E. Below, University of Illinois. Agron. J. 105:161-170 (2013)

Crop Physiology

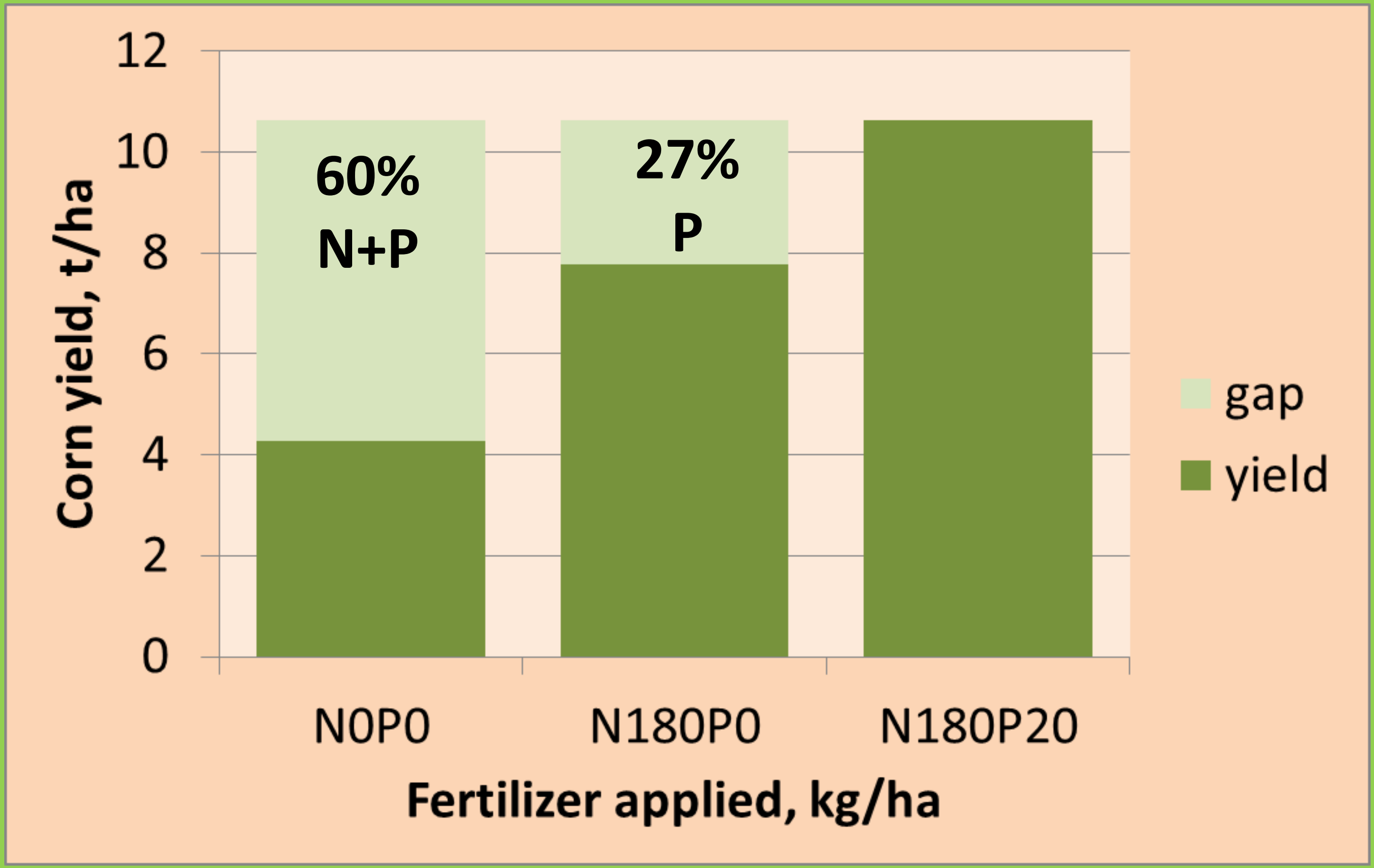
Research shows potential for altered P placement needs in high density high yield maize



Dr. F.E. Below, University of Illinois

Crop Physiology

Crop yield contribution from phosphorus use is very substantial in the long term



One example: Long-term contribution of P to yield of irrigated corn in Kansas – 40-year average, 1961-2000 (Stewart et al., 2005, Agron. J. 97:1–6)

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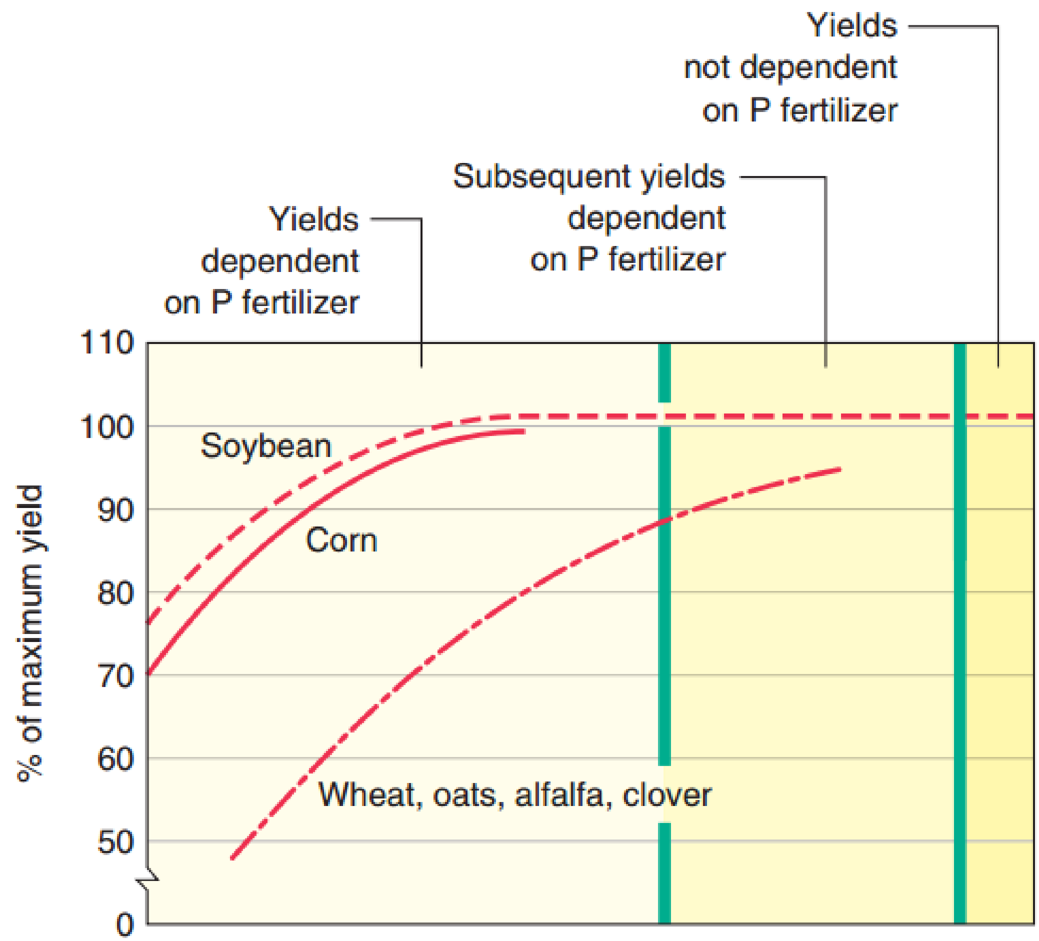
How much crop yield can be attributed to P in the short term (one year)?

- Expected to be zero, or very small, on soils with adequate P levels
- When soil test P is below critical levels:
  ~15% (0-23%) for soy
  ~20% (0-30%) for corn
  ~40% (10-50%) for wheat, oats, alfalfa and clover in Illinois (Figure 8.5, Illinois Agronomy Handbook)

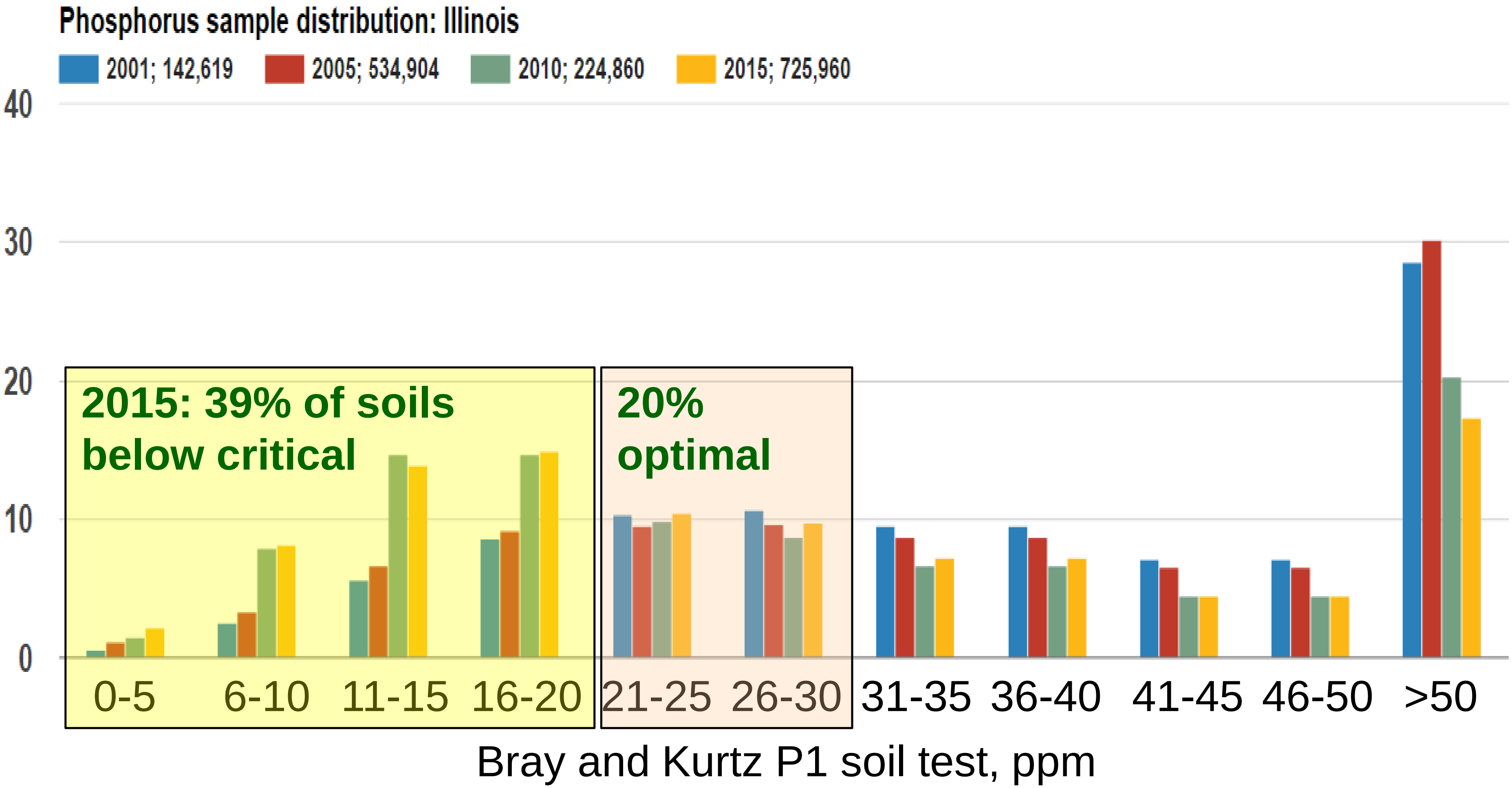


P test (lb/A) for different subsoil phosphorus-supplying power regions

High	7	15	20	40	60
Medium	10	20	30	45	65
Low	20	30	38	50	70

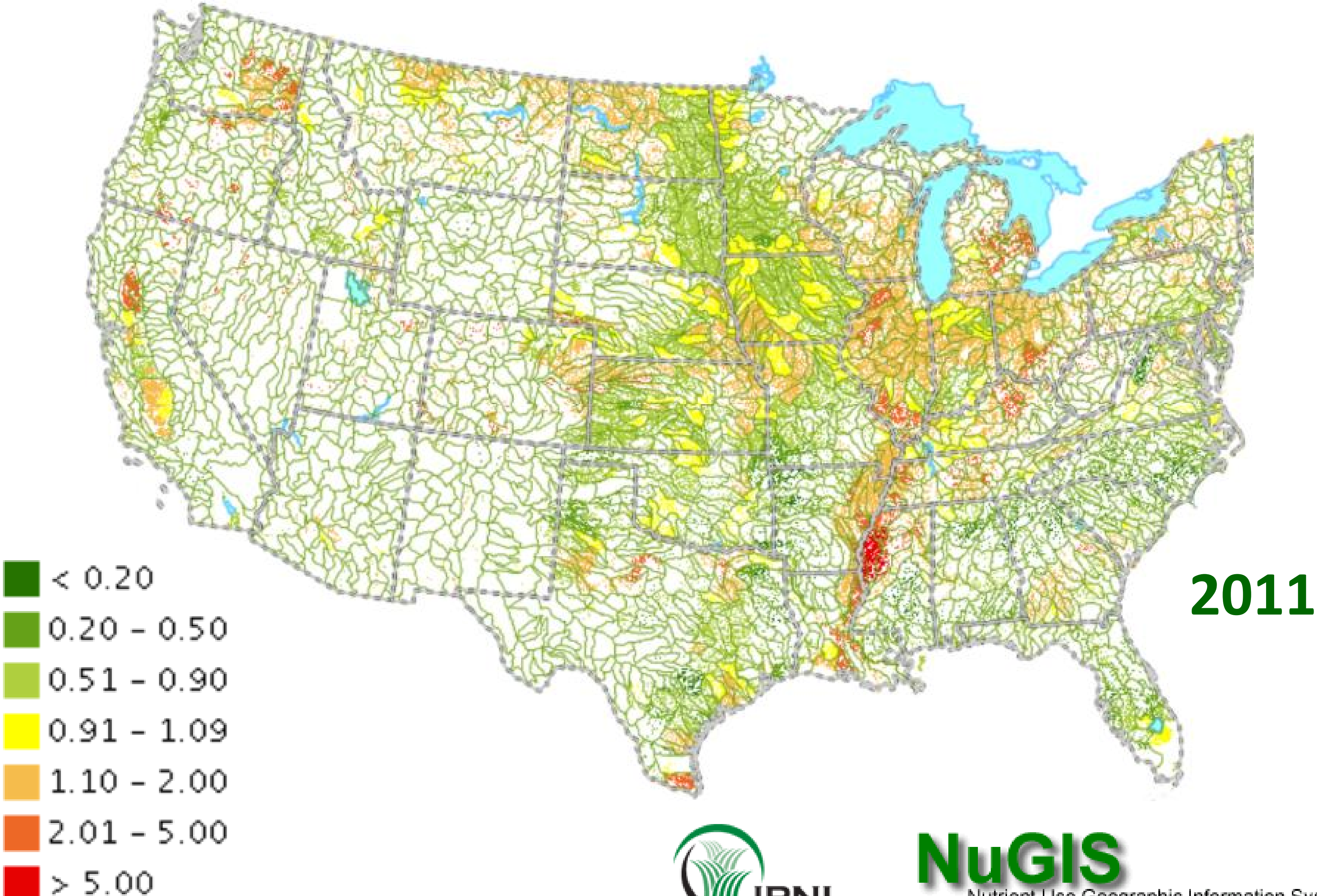
Figure 8.5. Relationship between expected yield and soil P, measured colorimetrically by the Bray P_I or Mehlich-3 procedures on neutral-to-acid soils, or by the Mehlich-3 procedure on soils with pH > 7.3.

Illinois soil test P declined from 2001 to 2015



http://soiltest.ipni.net

PUE: Ratio of removal to use varies across US cropland



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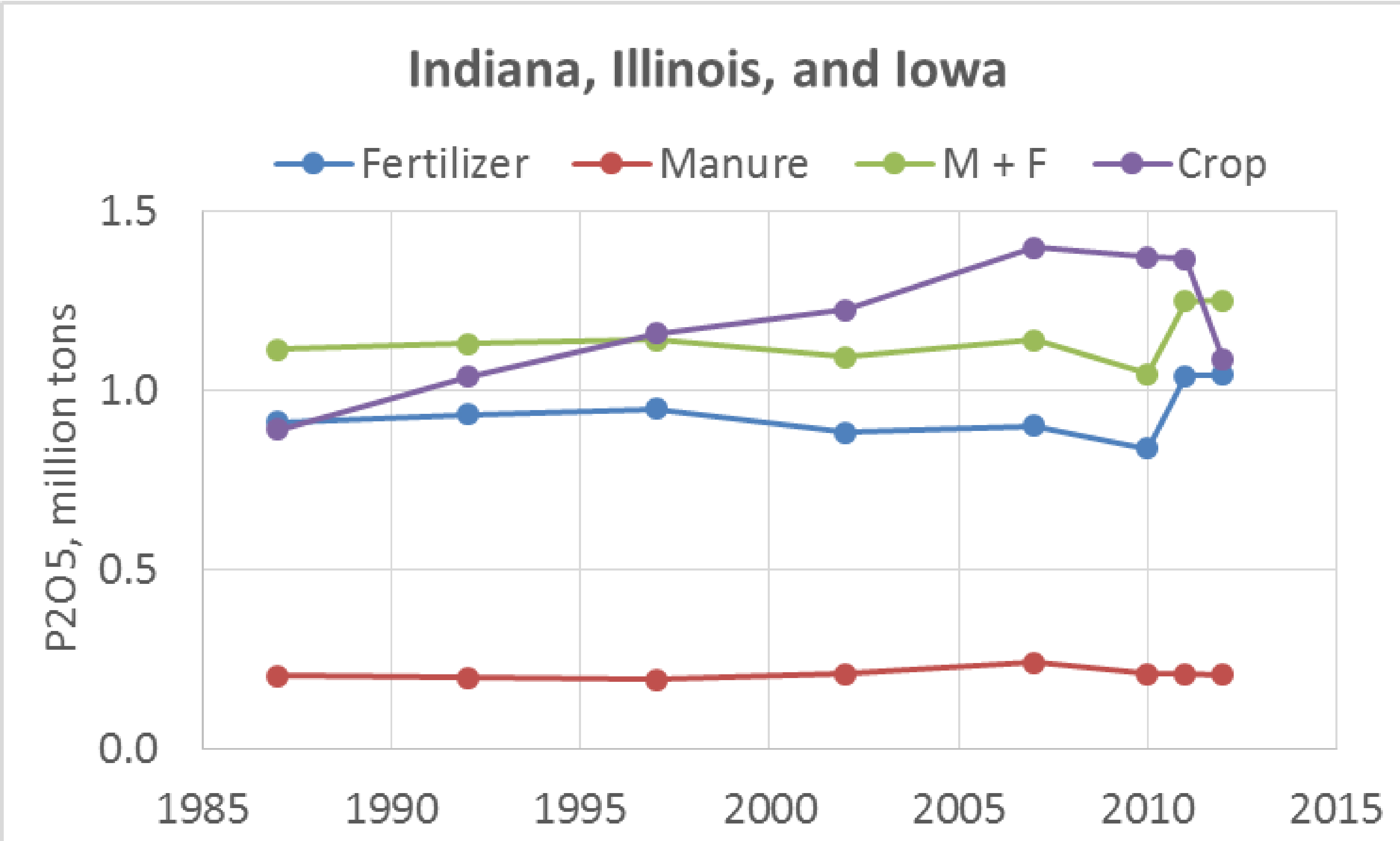
NuGIS
Nutrient Use Geographic Information System

Phosphorus Balance, corn belt – on average, seldom in surplus



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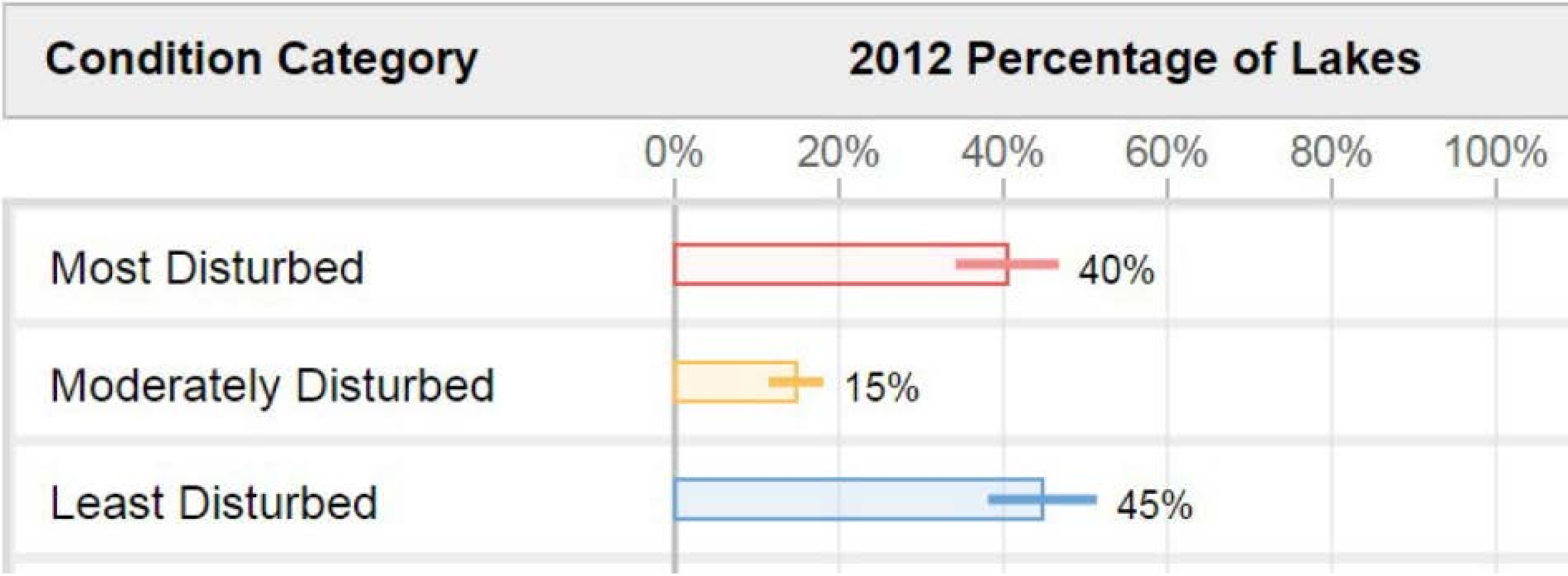
NuGIS
Nutrient Use Geographic Information System

Environmental Impact

- Eutrophication
- Hypoxia
- Harmful Algal Blooms

Photo credit: Carrie Vollmer-Sanders, The Nature Conservancy

Figure 4.3: Phosphorus (Total) | National Condition Estimates



National Lakes Assessment 2012

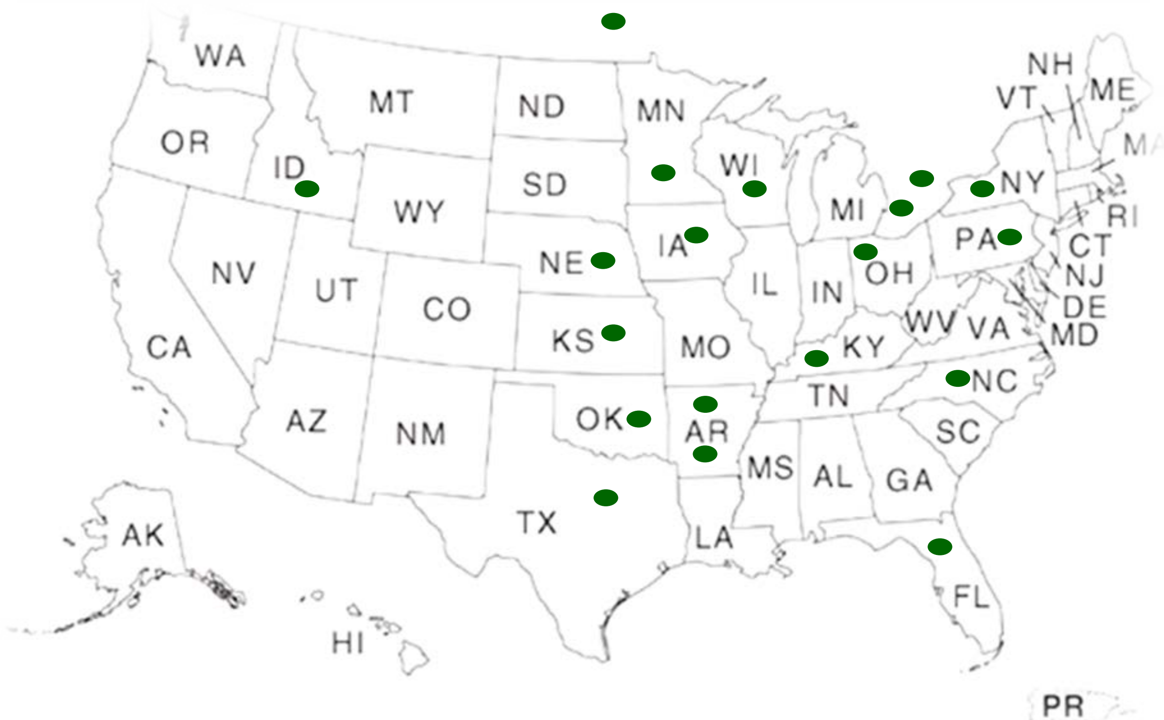
A Collaborative Survey of Lakes in the United States

USEPA 2016 National Lakes Assessment 2012 | A Collaborative Survey of Lakes in the United States

Defining 4R phosphorus practices at the continental scale.

4R P Practices - Participating Scientists

1. **Brian Arnall**, Oklahoma State U
2. **Doug Beegle**, Penn State U
3. **Don Flaten**, U of Manitoba
4. **Laura Good**, U of Wisconsin
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
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



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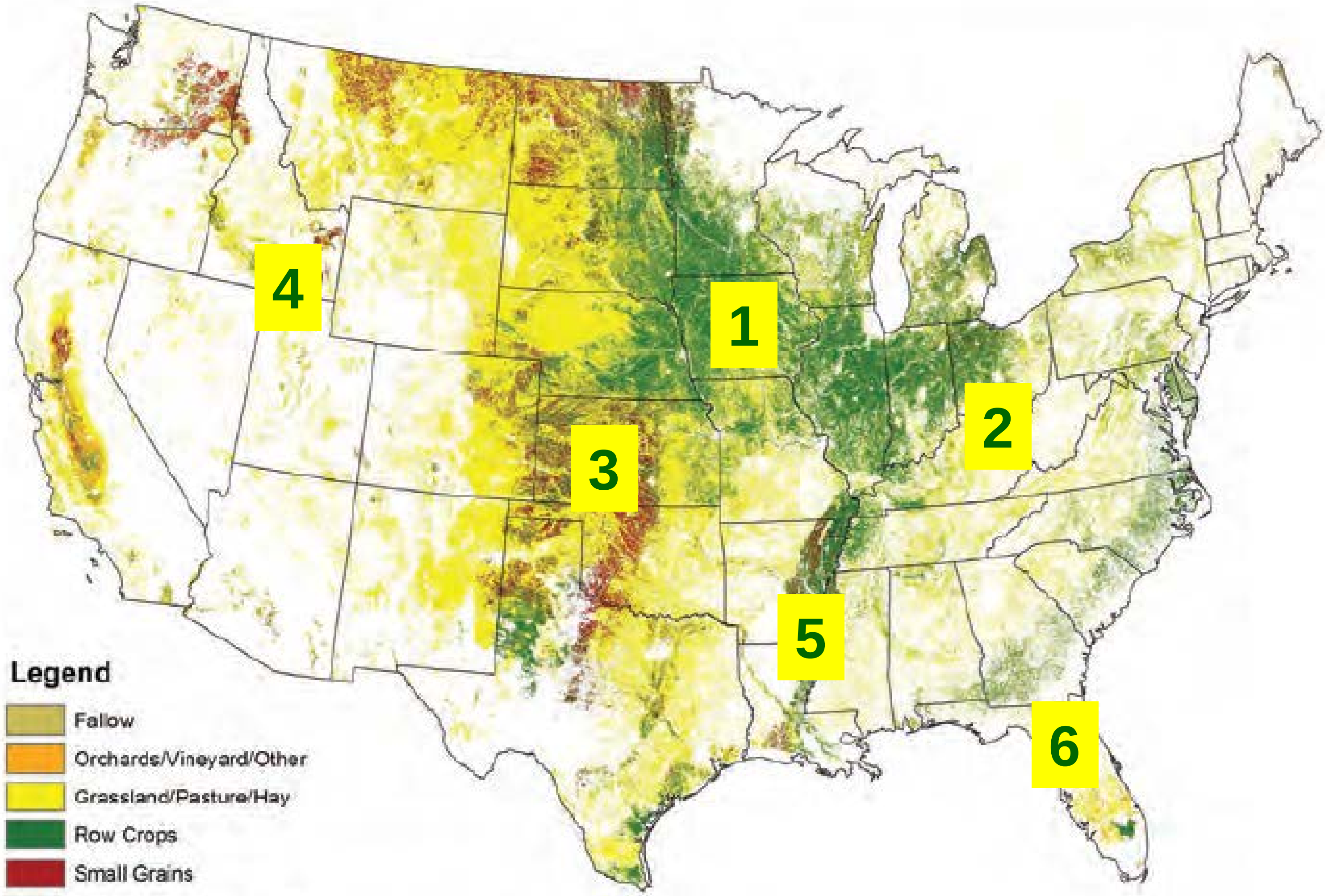
Regions and Cropping Systems

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



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

4R Phosphorus Practices for Western Crops (including Illinois)

- Basic
  - Source: known or guaranteed analysis
  - Rate: recommended soil sampling and soil test interpretation
  - Timing: avoid frozen and snow-covered soils, forecast rainfall
  - Placement: subsurface band encouraged; on surface only for no-till when risk index is low
- Intermediate
  - Source: manure sampled for nutrients
  - Rate: as in basic, plus: P index used
  - Timing: as in basic, & use P Index and avoid seasonal rainfall intensity
  - Placement: as in basic, plus avoid furrows of furrow-irrigated crops

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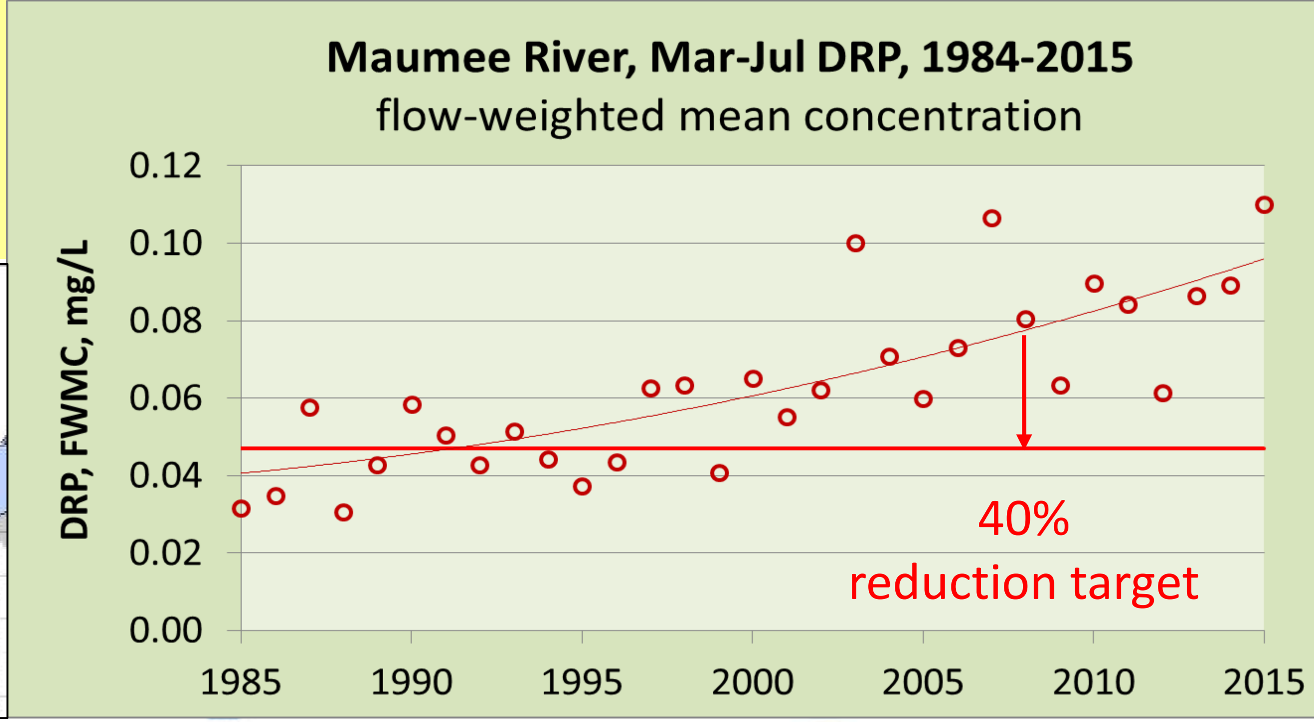
4R Phosphorus Practices for Western Crops (including Illinois)

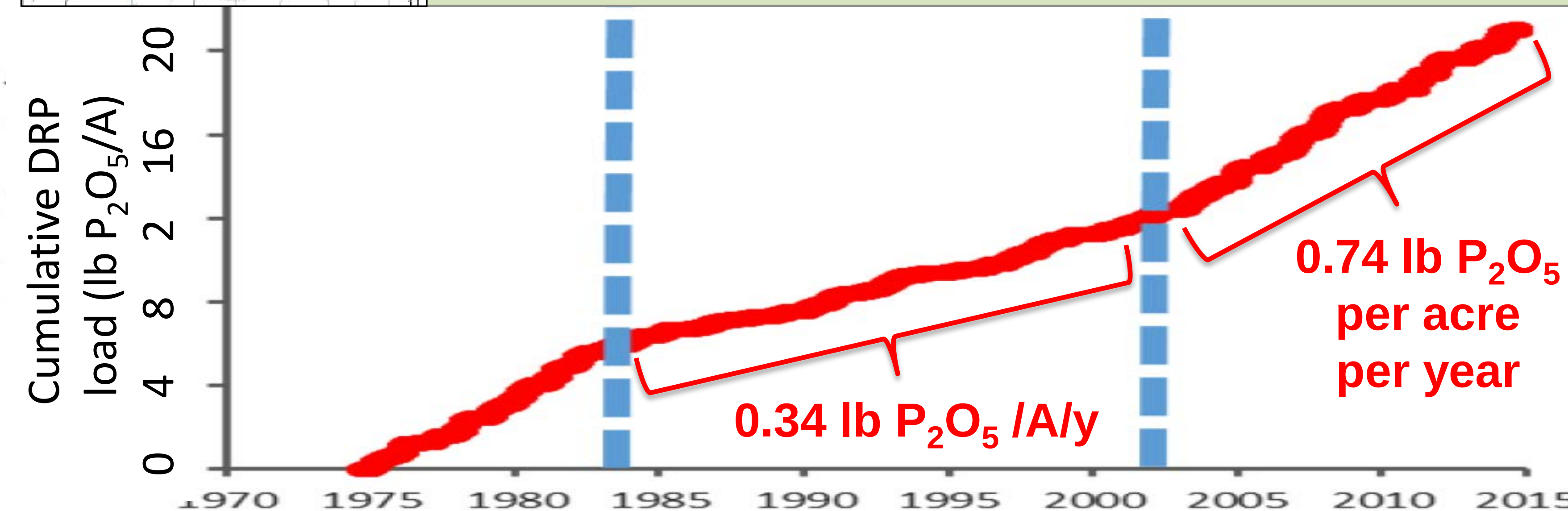
- Advanced
  - Source: as in intermediate
  - Rate: as in intermediate, plus: **zone-specific** based on soil sampling every 2 years, and crop yield maps
  - Timing: as in intermediate
  - Placement: as in intermediate, plus: terrain analysis to manage P loss

ADAPTIVE MANAGEMENT

- Decisions are site-specific and adaptive to changing conditions. Not everything can be written down.

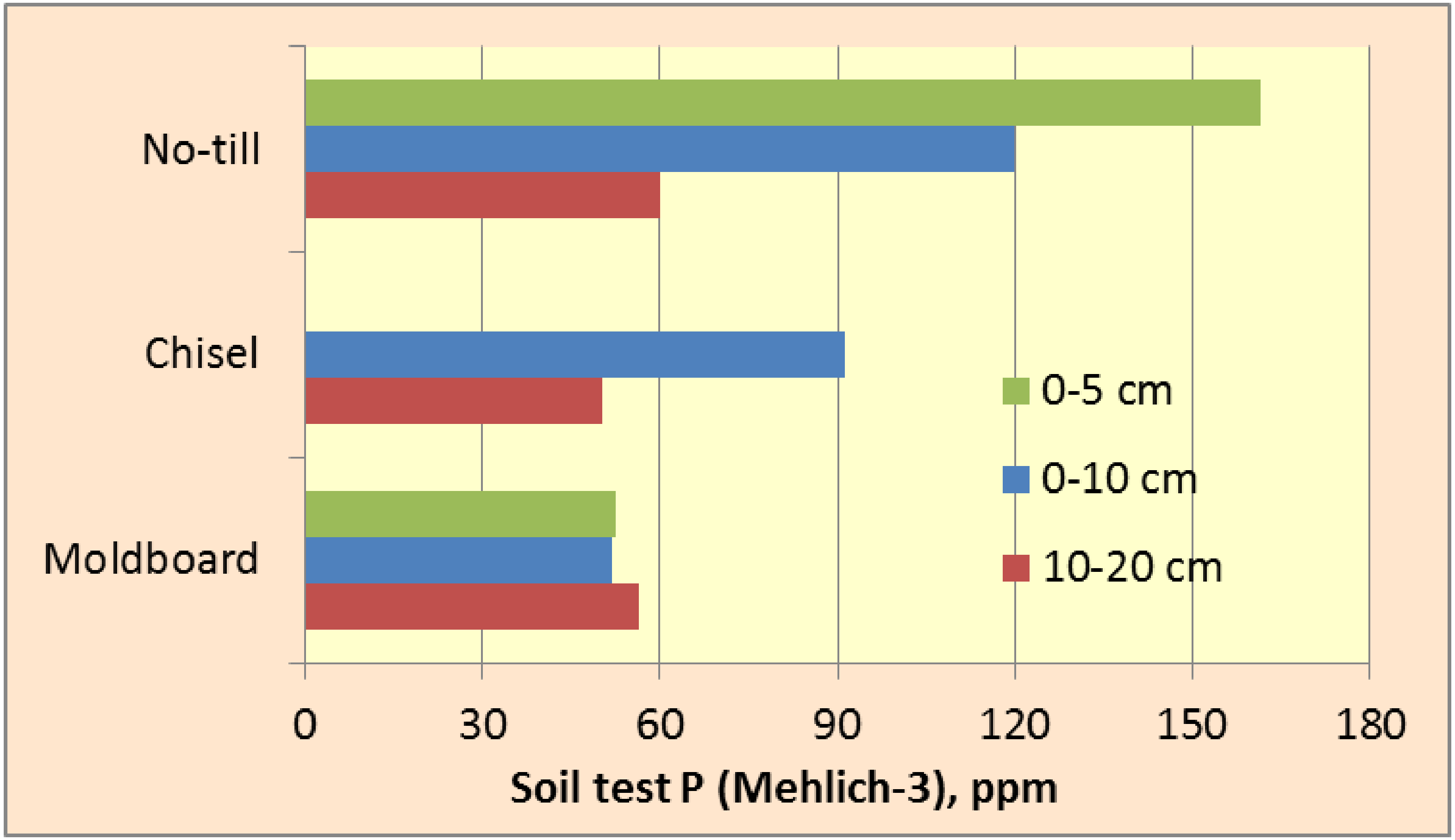
Western Lake Erie: dissolved P trends increasing since 2002





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

Soil test P stratifies when moldboard plowing stops

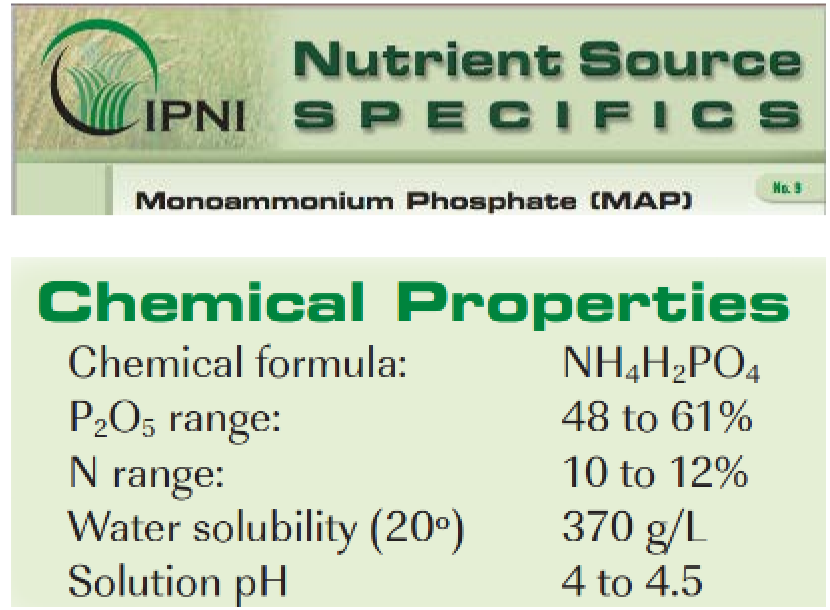


Soil test P distribution with depth in a long-term tillage experiment on a poorly drained Chalmers silty clay loam soil near West Lafayette, Indiana. Moldboard and chisel plots were plowed annually to a depth of 20 cm. Data from Gál (2005) and Vyn (2000). Fertilizer P applied broadcast.

Fertilizer P is Soluble P

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

- Maumee river target for DRP = 0.047 mg P per litre
- Targets for Lake Erie:
  Western Basin – 0.012 mg/L
  Central Basin – 0.006 mg/L
  Eastern Basin – 0.006 mg/L



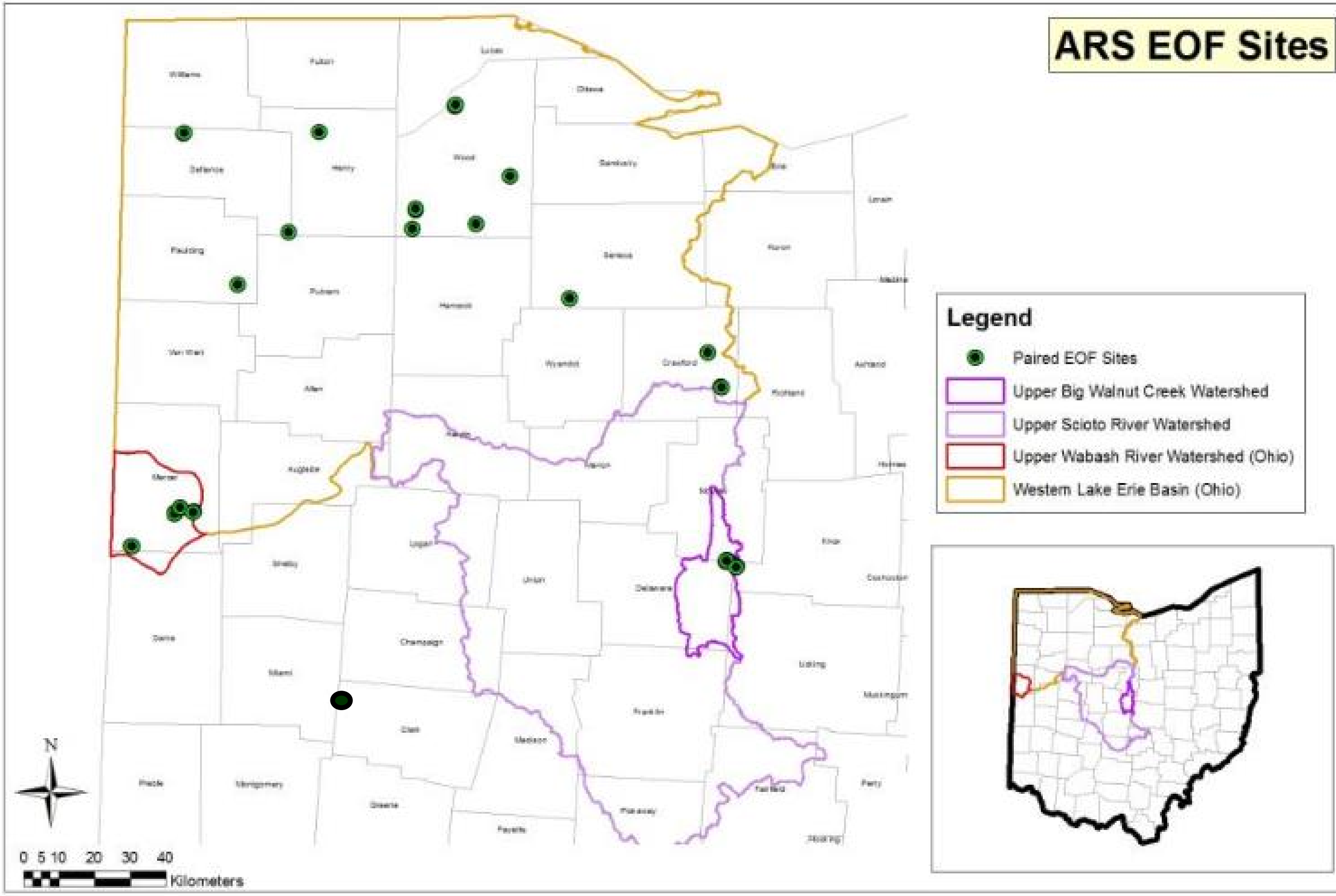
IPNI Nutrient Source SPECIFICS

Monoammonium Phosphate (MAP)

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

Ohio
P loss monitoring at edge of field



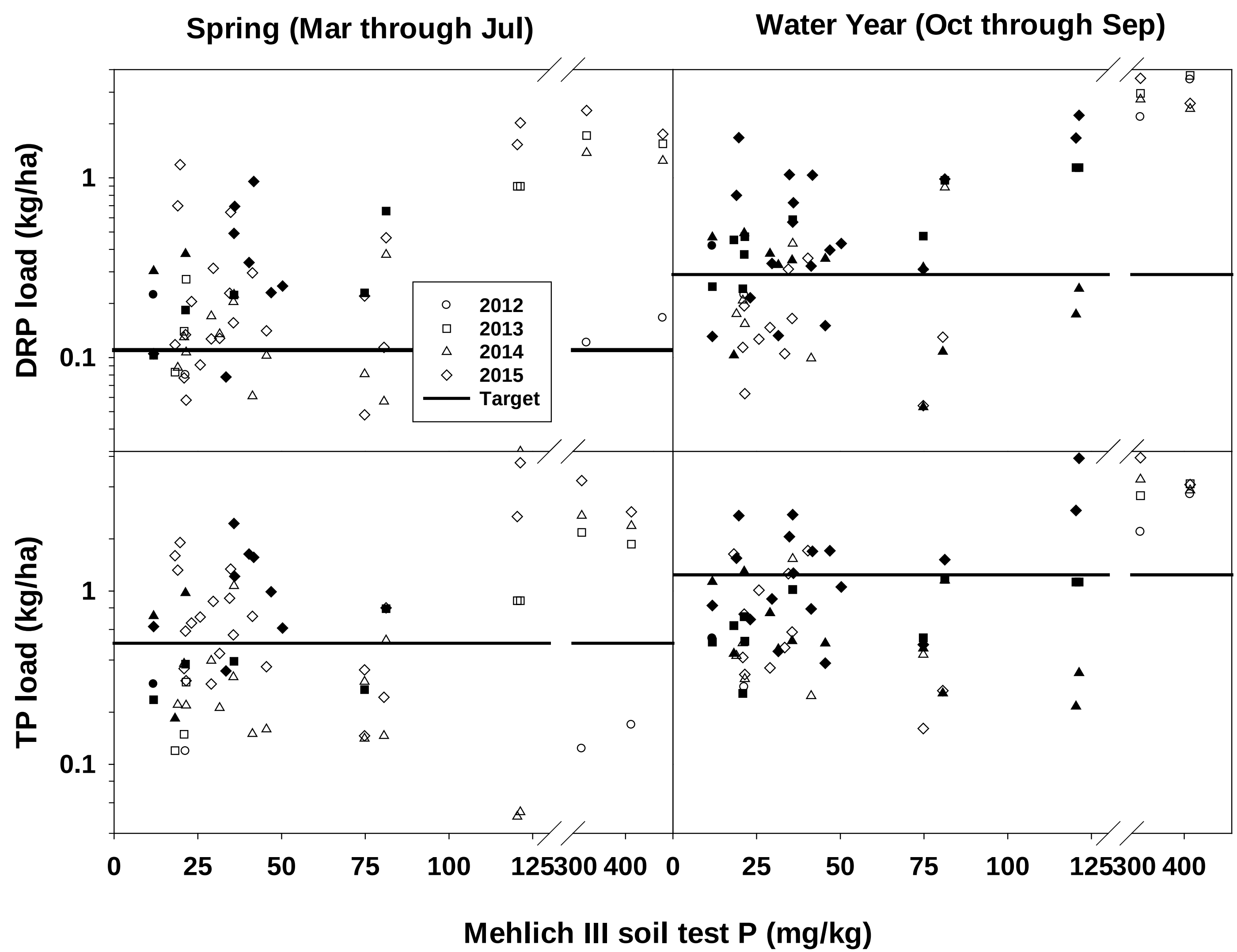
Funding Sources:

4R Research Fund
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

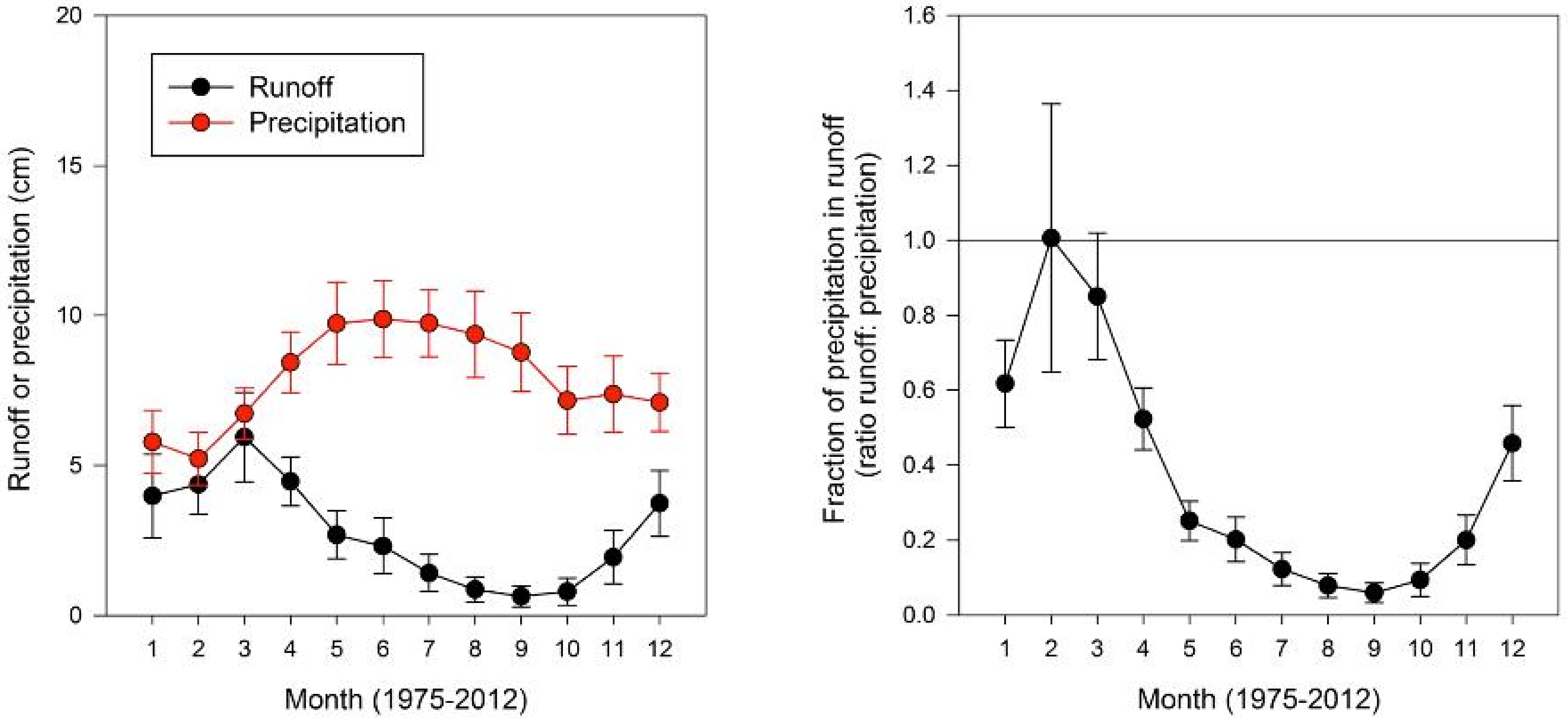
Kevin King, USDA-ARS, Columbus, Ohio

Right Rate



Kevin King, USDA-ARS, Columbus, Ohio

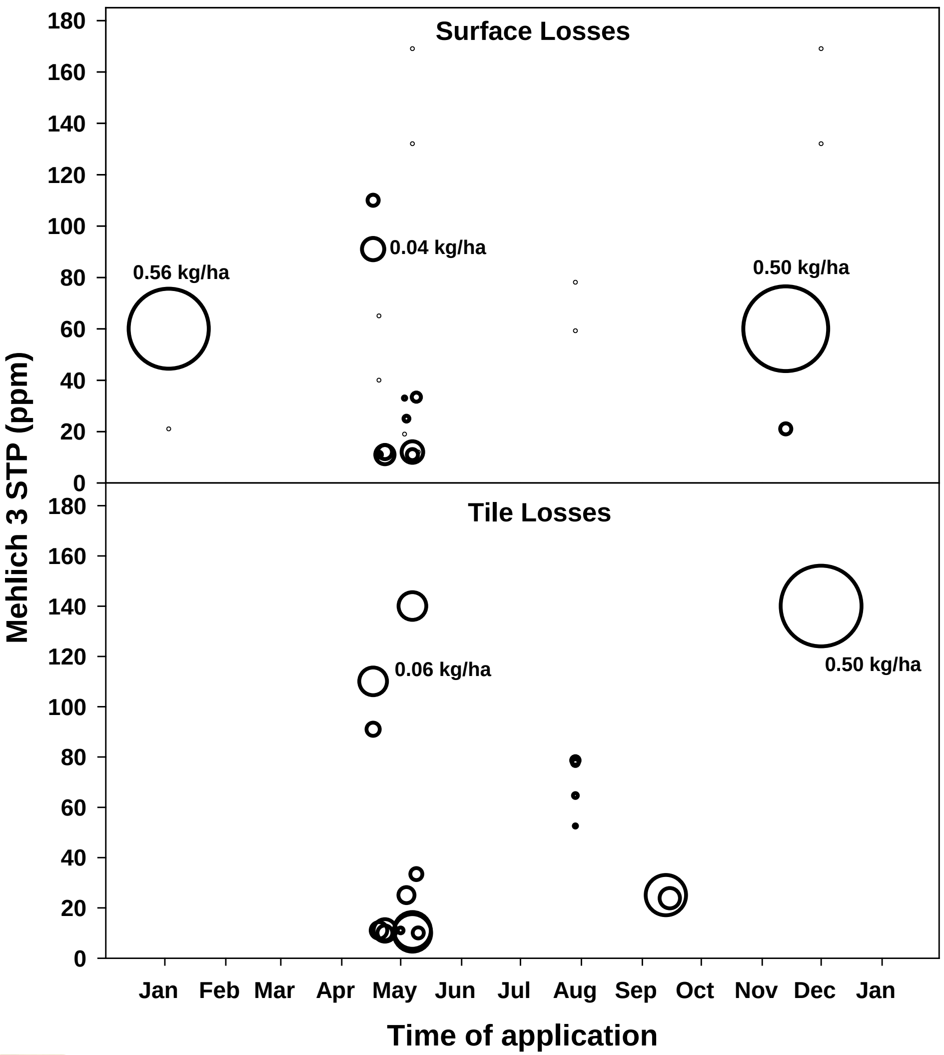
When is the right time?



Soil Drainage Research Unit

Kevin King, USDA-ARS, Columbus, Ohio

Right Timing



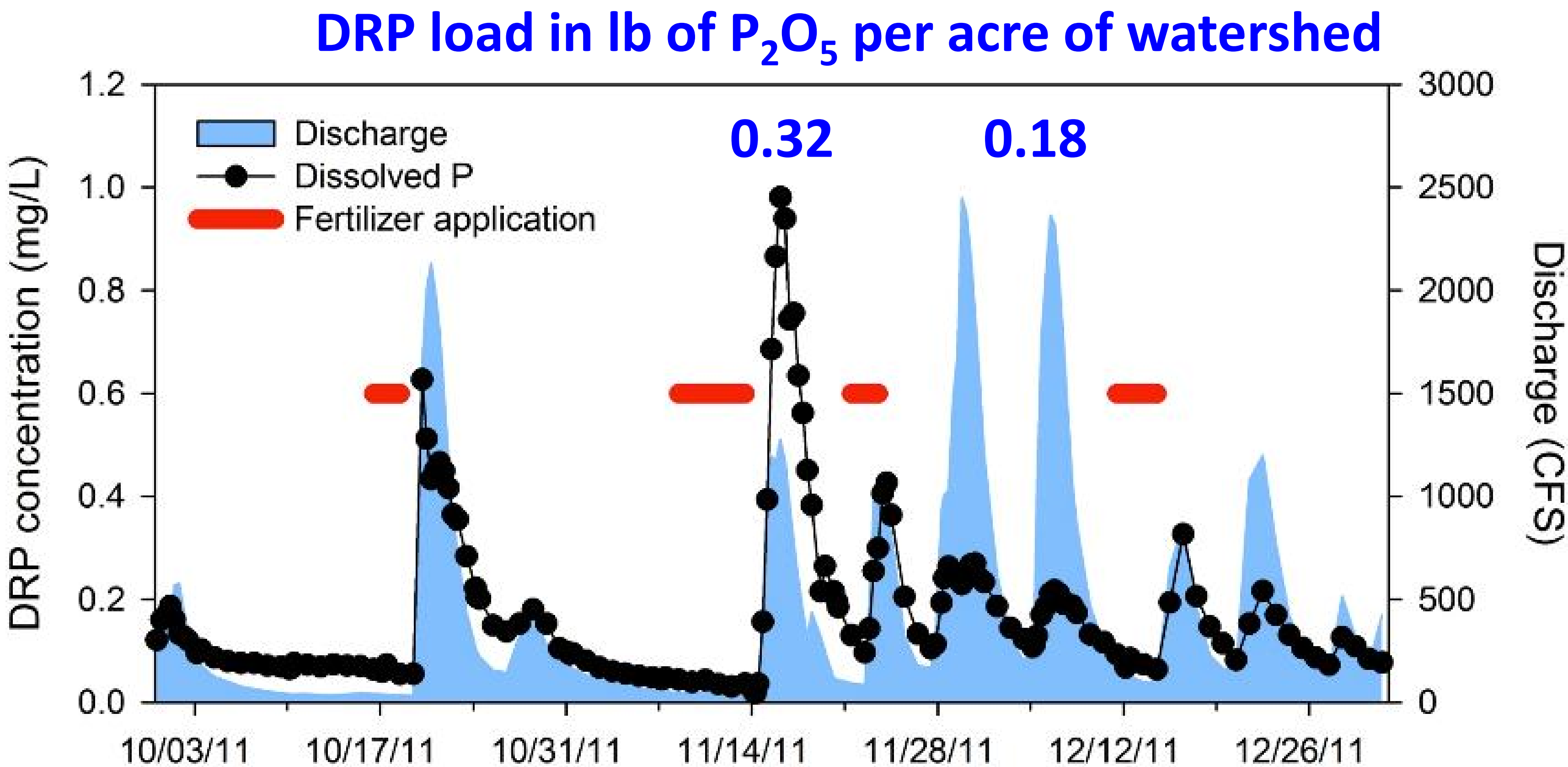
Time of Application

- Greatest potential for surface and tile losses occurs with fall and winter application
- Applying P in spring or after wheat harvest seems to minimize surface and tile losses

USDA ARS
Soil Drainage Research Unit

Kevin King, USDA-ARS, Columbus, Ohio

Right Time



1. Intense rainstorms following broadcast of P can generate high P concentrations in runoff even though losses are small relative to amount applied.
2. As the time intervals increase between surface broadcast P applications and runoff-producing rainfall events, DRP concentrations spike less.

David Baker and Laura Johnson, Heidelberg University

Broadcast? at the right time to avoid runoff

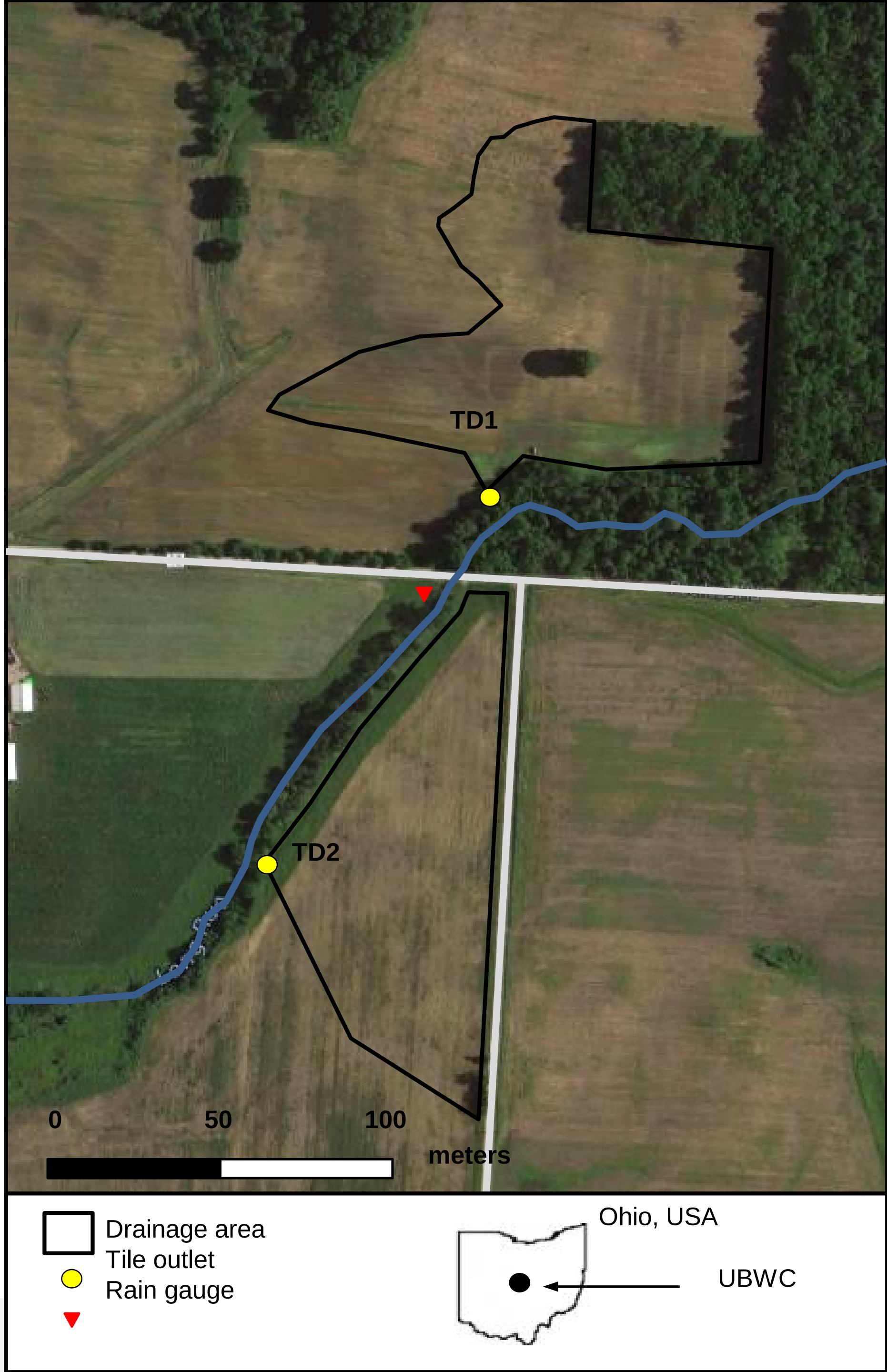
Right Place – in the soil, not on the soil

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

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

Compared P transport out of the tile drains

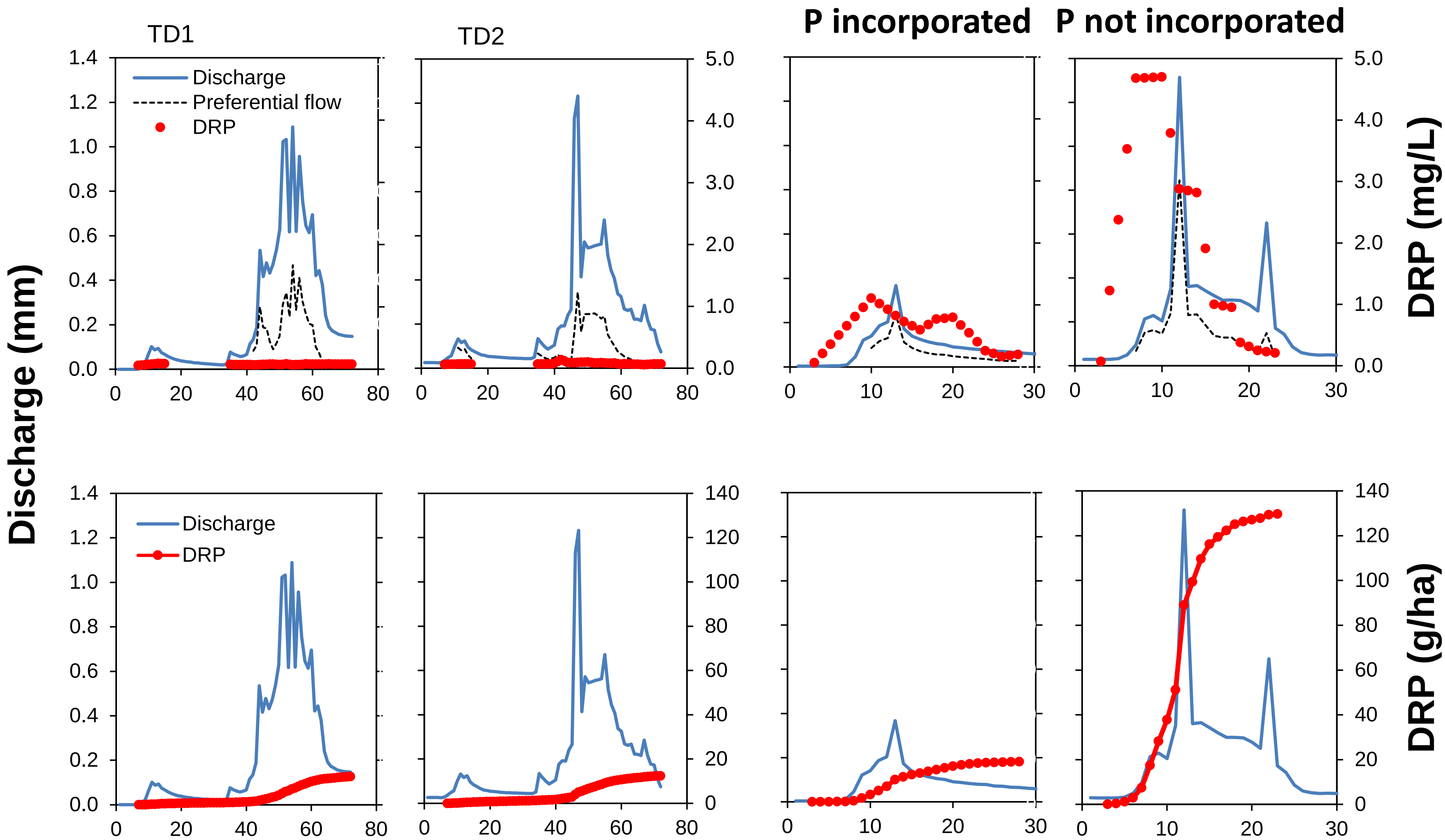
1. Broadcast P incorporated versus
2. Broadcast P not incorporated



Williams and King, USDA-ARS, Columbus, Ohio

Before P application & tillage (April 28th)

After P application & tillage (May 12th)



Incorporating reduced DRP loss from 0.27 to 0.04 lb P_2O_5 per acre

Williams and King, USDA-ARS, Columbus, Ohio

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

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

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

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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%

Dodd & Sharpley, 2015. Nutrient Cycling in Agroecosystems.

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

NUTRIENT STEWARDSHIP CERTIFICATION

4R NUTRIENT STEWARDSHIP CERTIFICATION PROGRAM

Western Lake Erie Basin - Ohio, Michigan & Indiana

Voluntary program for agricultural retailers & nutrient service providers implementing the 4Rs

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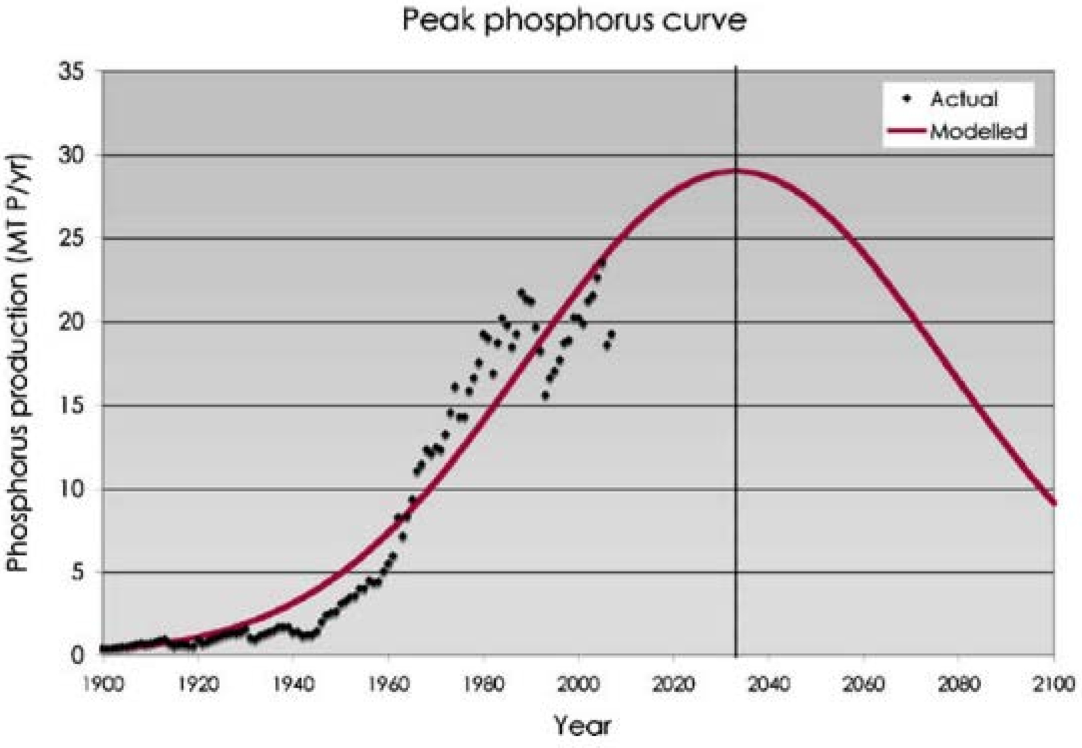
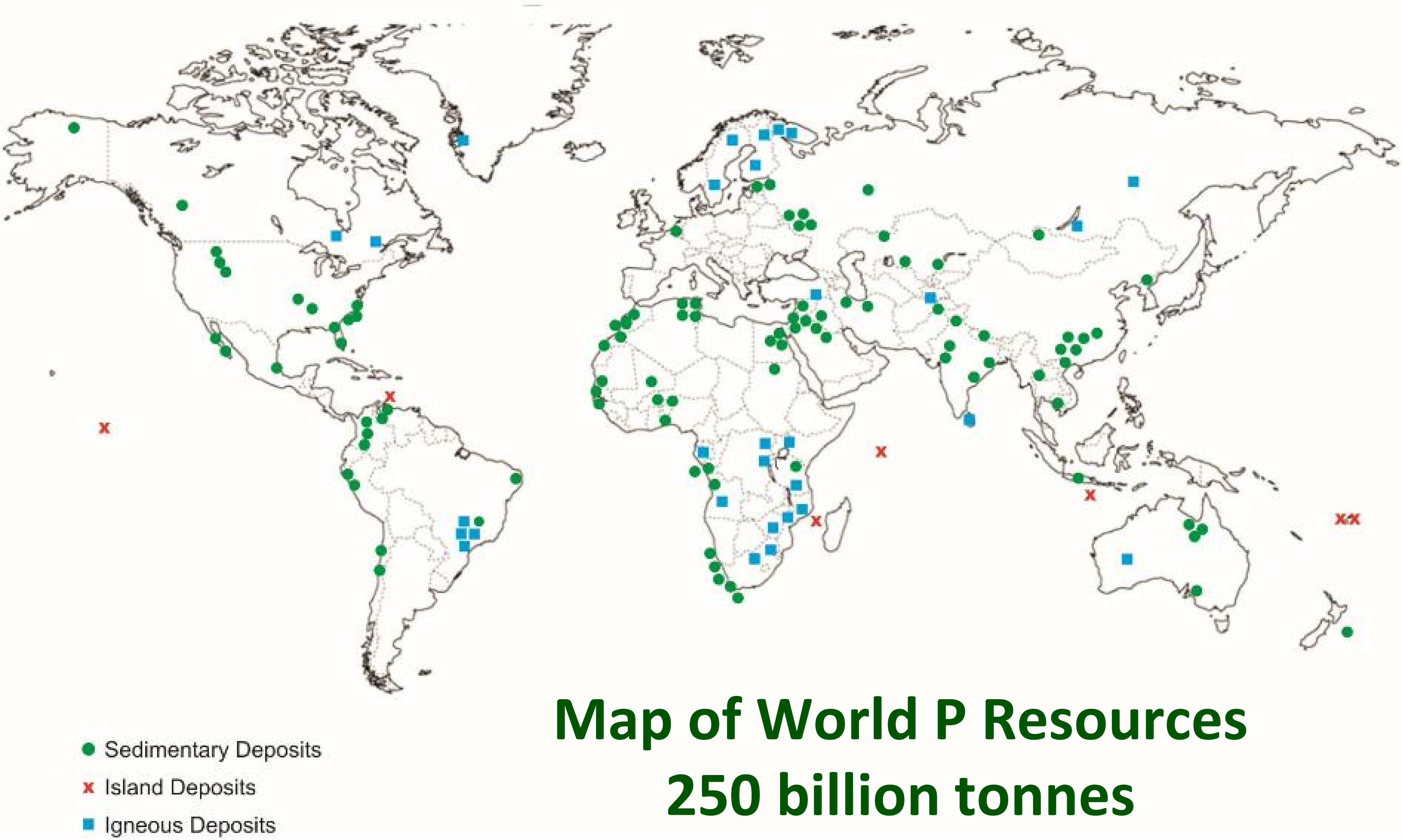
4R Ontario is Moving Forward…

- **4R Ontario MOC: 2015-2018**
  - Continue to promote increased adoption of 4R; provide general retailer staff and farmer training; and develop affiliated resources
  - 4R Retailer Certification – focus on building capacity, industry accountability, relevant targets, program standards
  - Identify research gaps
  - Increased communication efforts

Phosphate Rock Reserves and Quality

- Grade, P_2O_5 content, trace elements
- Phosphogypsum
- Peak phosphorus by 2033? Cordell & White, 2009:





Map of World P Resources
250 billion tonnes
in >100 countries

Sources: IFDC; USGS (2002, 2013)

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Country	2014-15 Production	Reserves	R/P ratio
	Mt		Years
Morocco	**30**	**50,000**	**1670**
South Africa	**2**	**1,500**	**750**
Jordan	**7**	**1,300**	**186**
Russia	**12**	**1,300**	**108**
USA	**26**	**1,100**	**42**
China	**100**	**3,700**	**37**
World Total	**220**	**69,000**	**314**

Source: USGS, 2016

"No matter how much phosphate rock exists, it is a non-renewable resource"
IFDC, 2010

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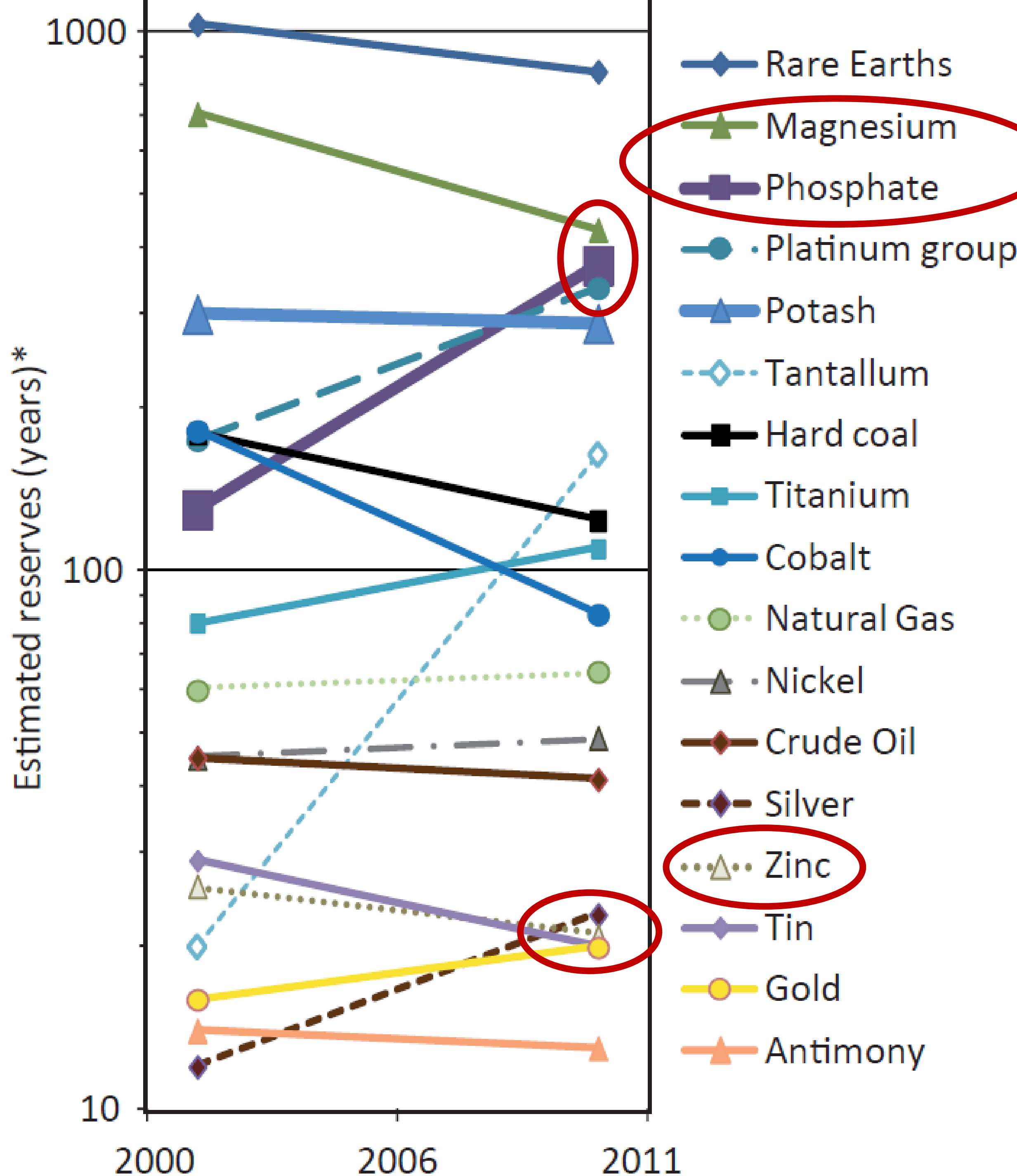
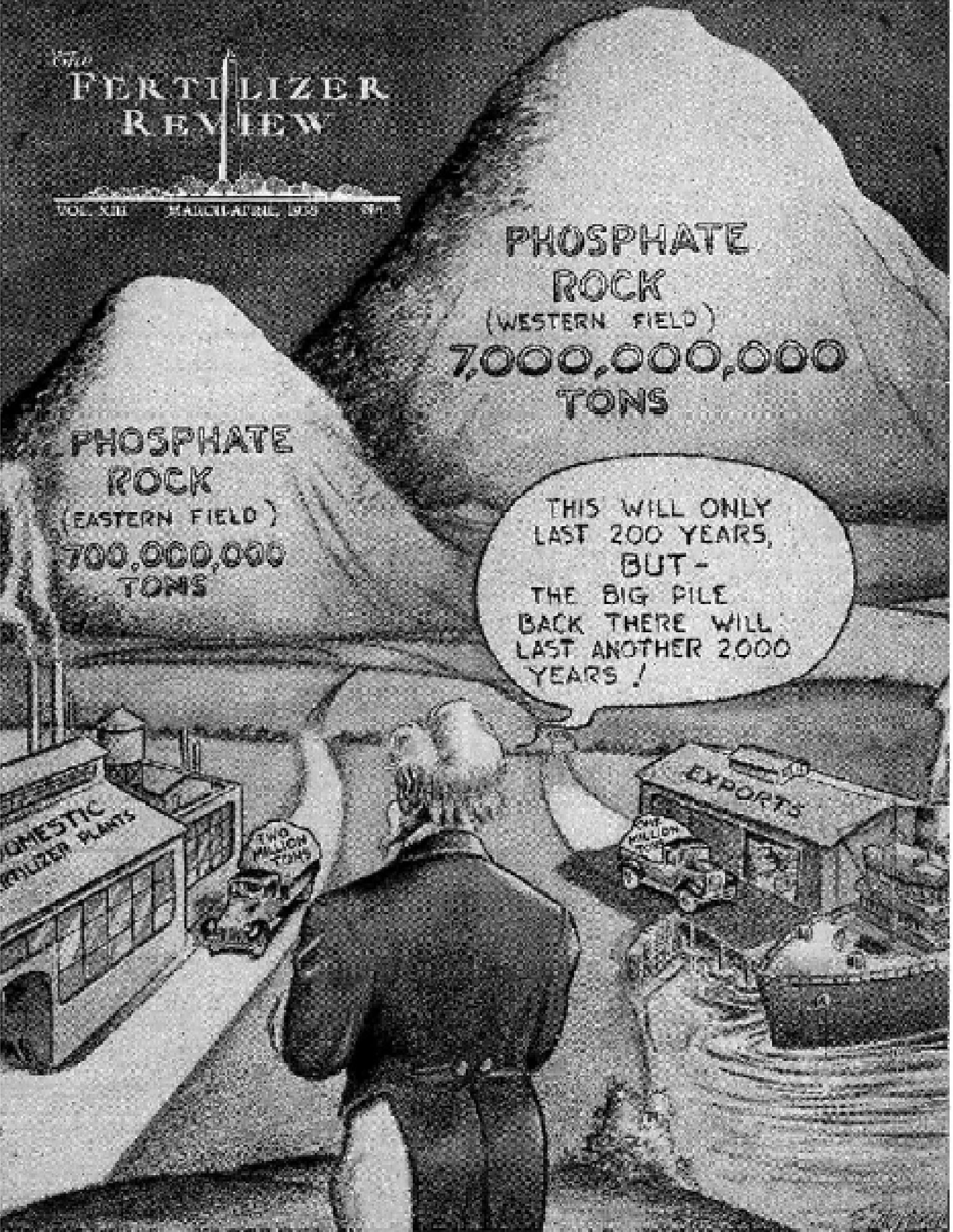


Putting phosphorus reserves into context: Changes in estimated reserves of different commodities as estimated in 2002/2003 and 2010 (Based on Scholz & Wellmer, 2013; U.S. Geological Survey, 2012a; U.S. Geological Survey, 2012c). *Ratio of estimated reserve to annual mine production.

Sutton et al. 2013. Our Nutrient World. Global Partnership on Nutrient Management.



Cover of The Fertilizer Review Vol. XIII, March–April 1938, No. 2, illustrating the role of the undeveloped Western phosphate deposits in U.S. phosphorus supply considerations. **Depletion concerns about national PR reserves were eminent at the time but could not be substantiated.**

Andrea E. Ulrich. 2016. Science of The Total Environment 542(B):1005-1168

Global ore tonnage and grade:

1983: 513 Mt @ 14.3% P_2O_5

2013: 661 Mt @ 17.5% P_2O_5

Steiner et al., 2015, CRU report.

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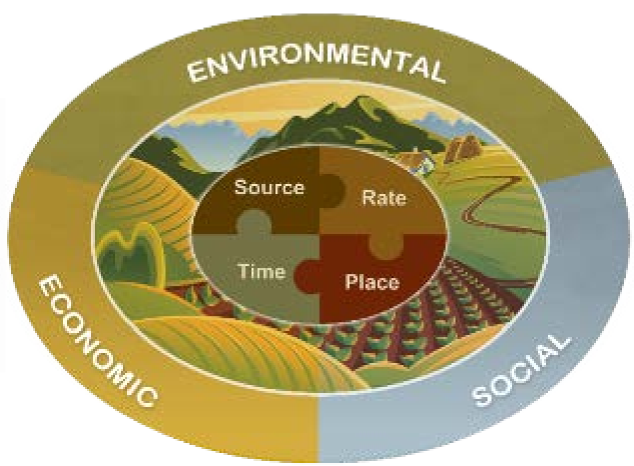
Summary

- With 4R, nutrient service providers can engage the sustainability movement to build social trust.
- Site-specific 4R phosphorus practices limit dissolved losses and need to be synergized with conservation practices controlling particulate losses.
- Opportunities to recycle phosphorus could reduce strain on finite natural resources, and can improve water quality where soil P is in surplus.

4R nutrient stewardship



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