Rethinking Phosphorus Management Webinar Series
Hosted by Illinois Soybean Association
22 March 2016

IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Sustainable Thinking 4R Phosphorus

Tom Bruulsema, Phosphorus Program Director

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

Its mission is to promote scientific information on responsible management of plant nutrition.

Outline

1. 4R Nutrient Stewardship & Sustainability
2. Key phosphorus issues in agricultural sustainability
    1. Crop yield limitation (productivity)
    2. Optimum levels of soil P fertility (soil health)
    3. Natural resource consumption (nutrient use efficiency)
    4. Phosphorus loss (water quality)
3. Phosphorus management in 4R Implementation
    – Western Lake Erie Watershed 4R Certification
    – Certified Crop Adviser Specialties

- *Slides: available at **http://phosphorus.ipni.net***

nutrient stewardship

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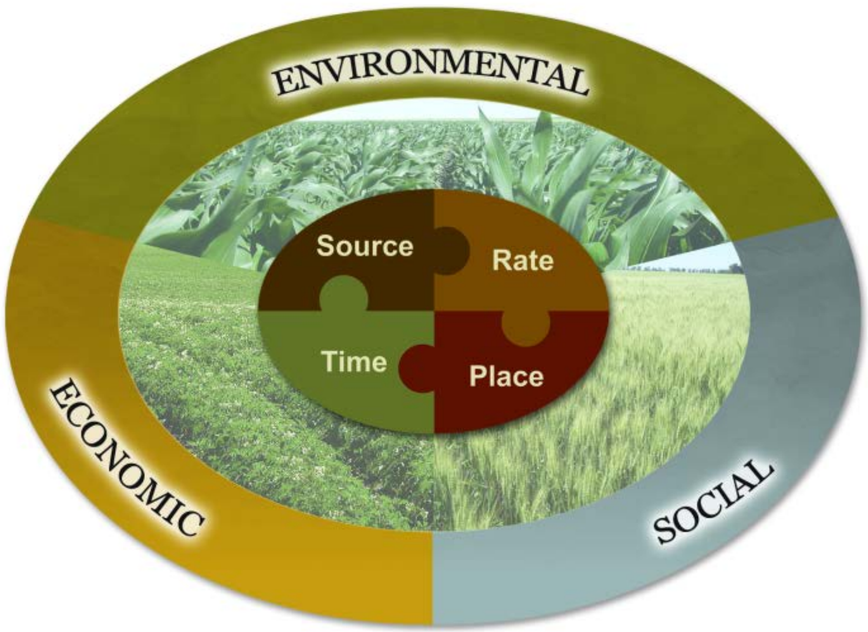
Ancaster, Ontario – 26 June 2009 – tilled corn
SOIL EROSION IS A REAL RISK

Northwest of Guelph, Ontario – 6 April 2014 – no-till
DISSOLVED P IN RUNOFF – AN INVISIBLE RISK

4R: "right" means sustainable

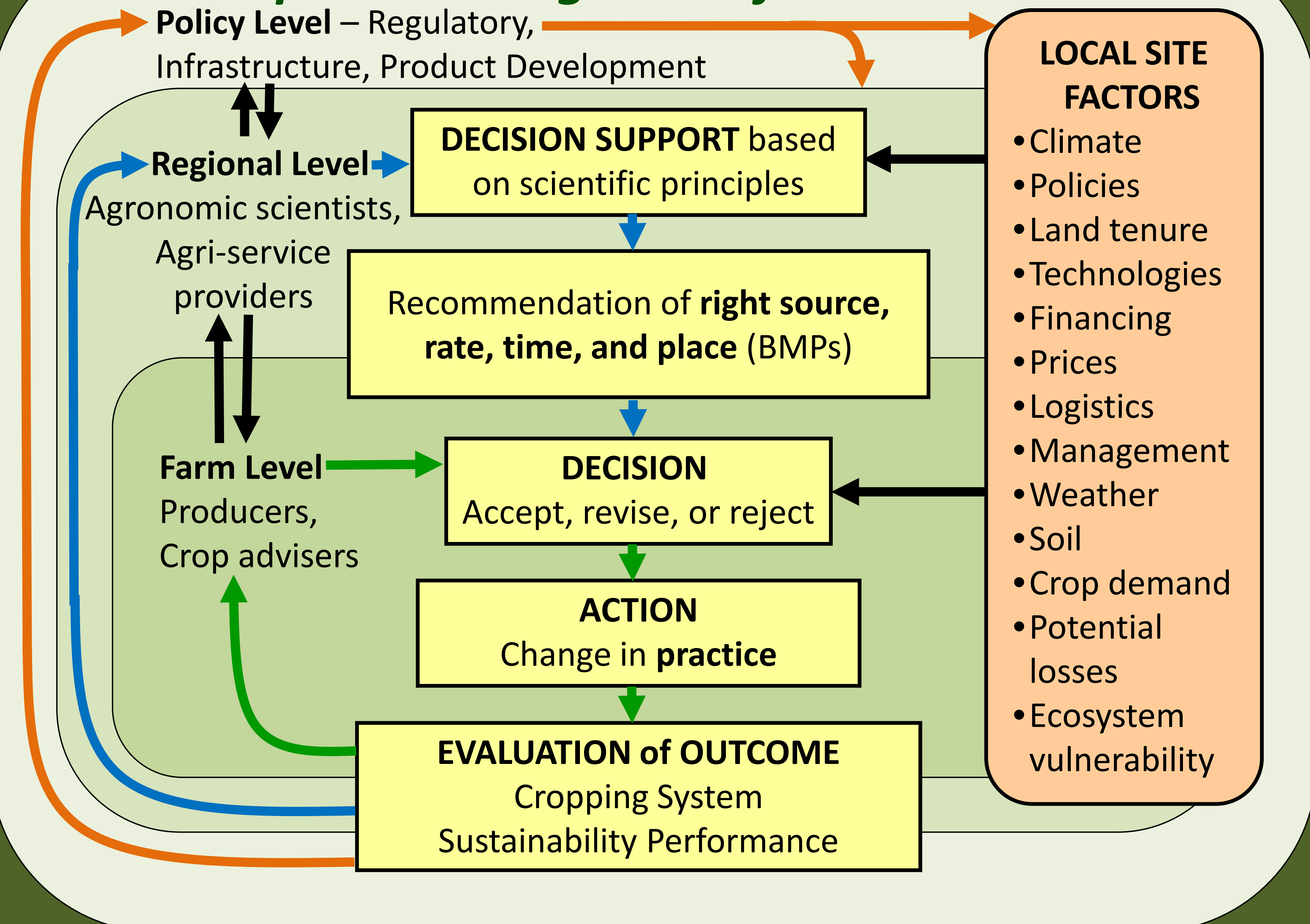


Field to Market®

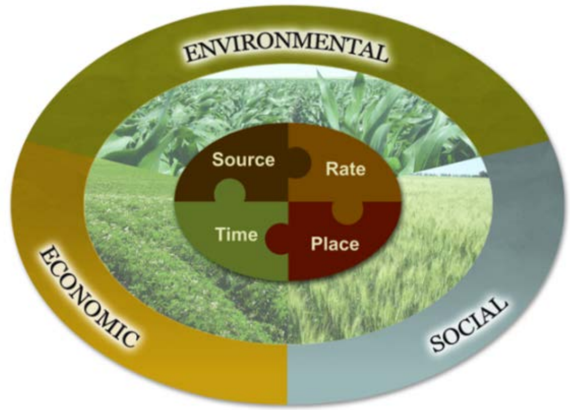
The Alliance for Sustainable Agriculture

"Building public trust"

4R Adaptive Management for Plant Nutrition



Nutrient Stewardship Metrics for Sustainable Crop Nutrition



Enablers (process metrics)

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

Actions (adoption metrics)

- [Require regional definition of 4R]
- Cropland area under 4R (at various levels)
- Participation in programs
- Equity of adoption (gender, scale, etc.)

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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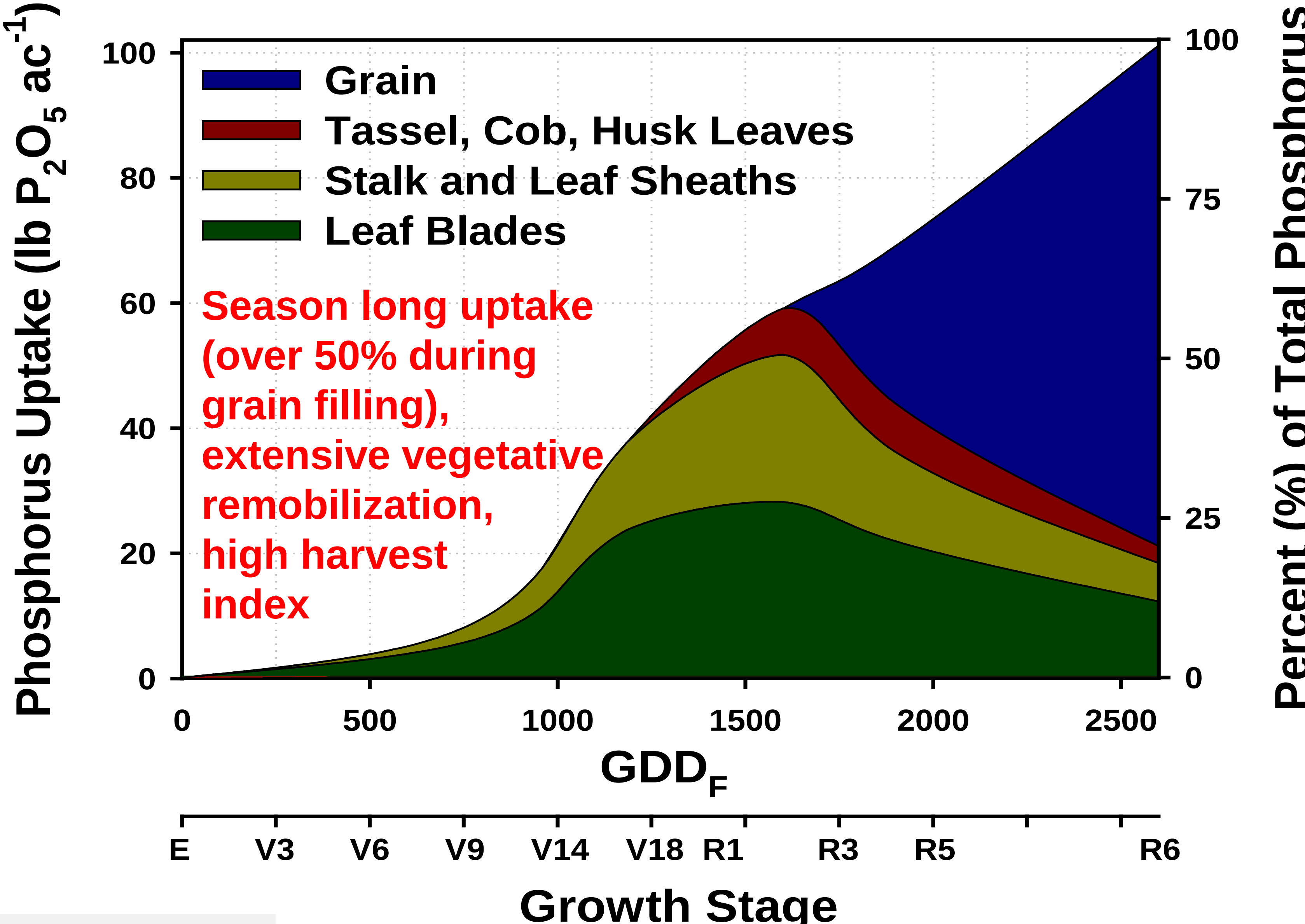
P Uptake & Partitioning for 230 Bushel Corn



Dr. F.E. Below,
University of Illinois

Average of 6 hybrids in Champaign and DeKalb IL in 2010

Agron. J. 105:161-170 (2013

Crop Physiology

Nutrition Needed for 230 Bushel Corn

Nutrient	Required to Produce	Removed with Grain	Harvest Index
	lbs/acre		%
N	256	148	58
P_2O_5	101	80	79
K_2O	180	58	32
S	23	13	57
Zn (oz)	7.1	4.4	62
B (oz)	1.2	0.3	23

Average of 6 hybrids in Champaign and DeKalb IL in 2010.

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University of Illinois

Agron. J. 105:161-170 (2013)

Crop Physiology

Banding Fertilizer 4-6 Inches Deep Directly Under the Future Crop Row

Dr. F.E. Below,
University of Illinois

Improved Growth with Banded Fertility

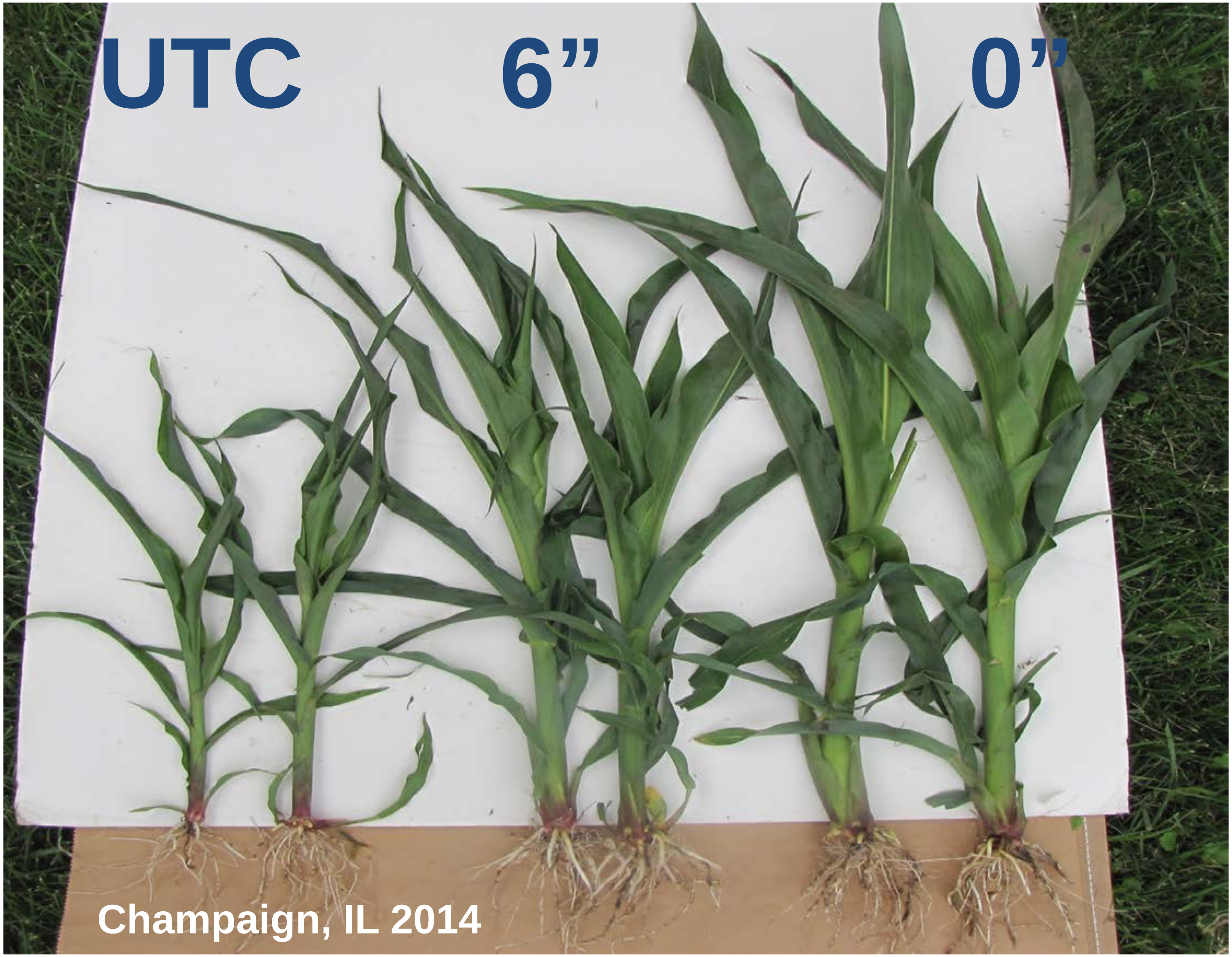
35 N, 100 P_2O_5, 25 S, and 2.5 Zn in pounds per acre

Dr. F.E. Below,
University of Illinois

Crop
Physiology

Growth Response to Banded Fertility

V6 growth stage

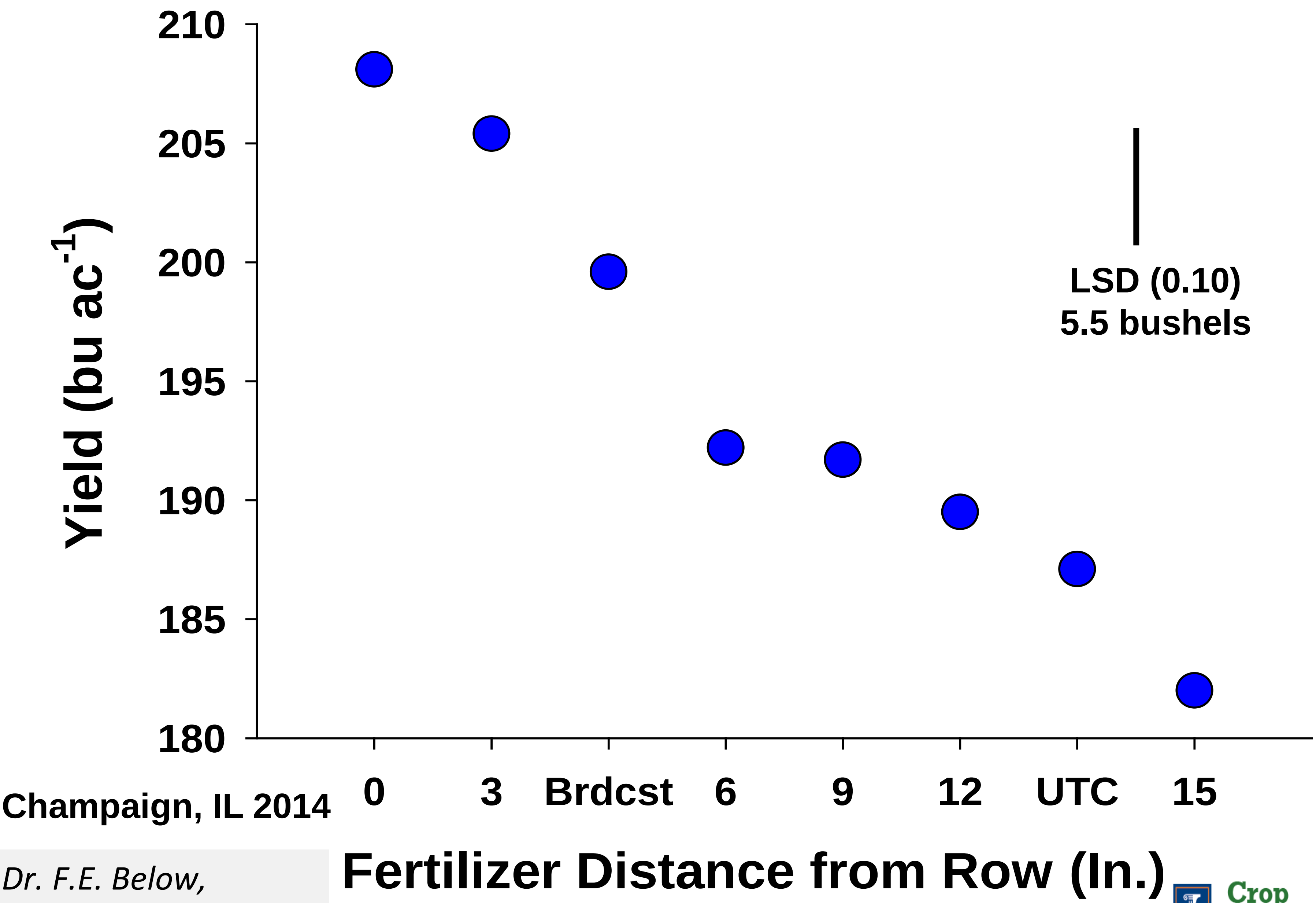


35 N, 100 P_2O_5, 25 S, and 2.5 Zn in pounds per acre

Dr. F.E. Below, University of Illinois

Crop Physiology

Corn Yield Response to Fertilizer Placement

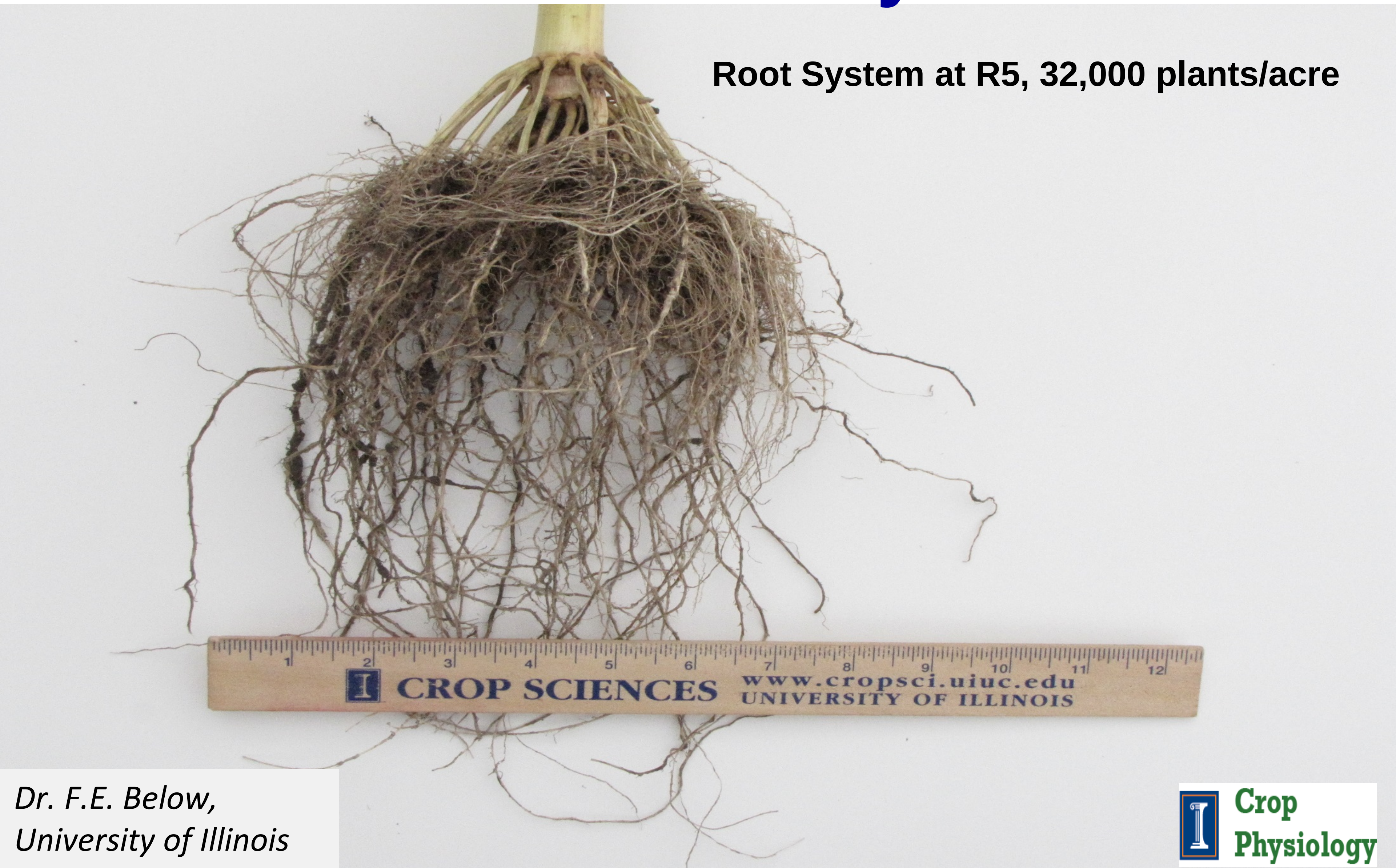


Dr. F.E. Below,
University of Illinois

Crop Physiology

Most Roots Expand Only 6 Inches Horizontally

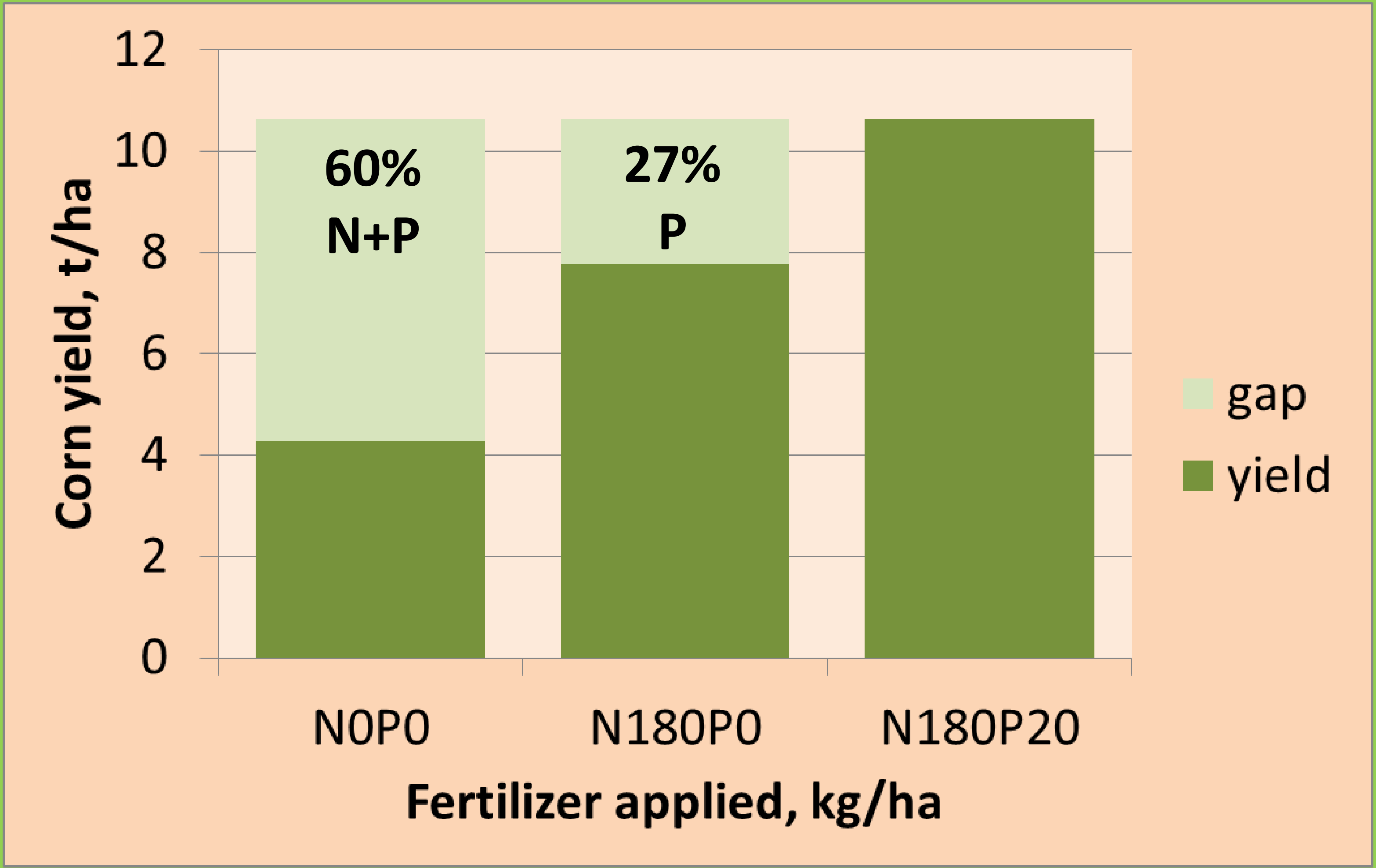
Root System at R5, 32,000 plants/acre



Dr. F.E. Below,
University of Illinois

Crop Physiology

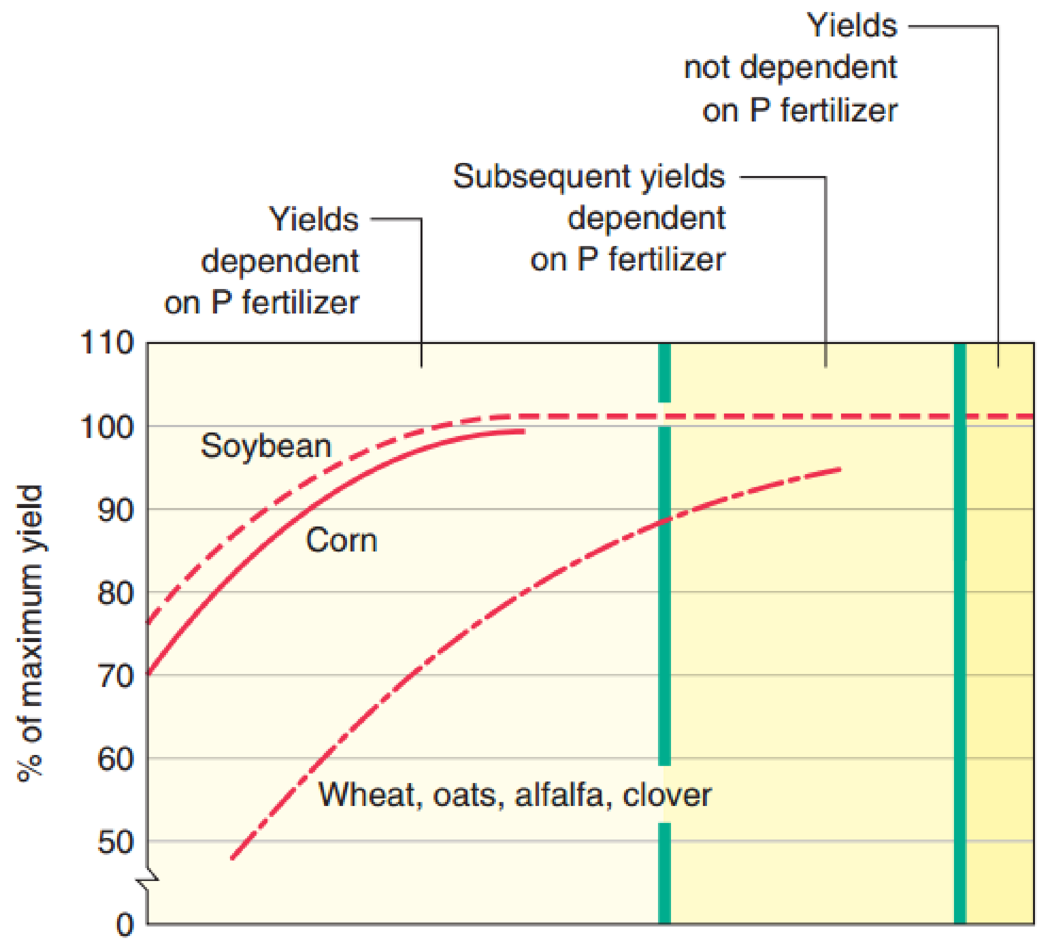
How much of crop yield can be attributed to P?



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)

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)

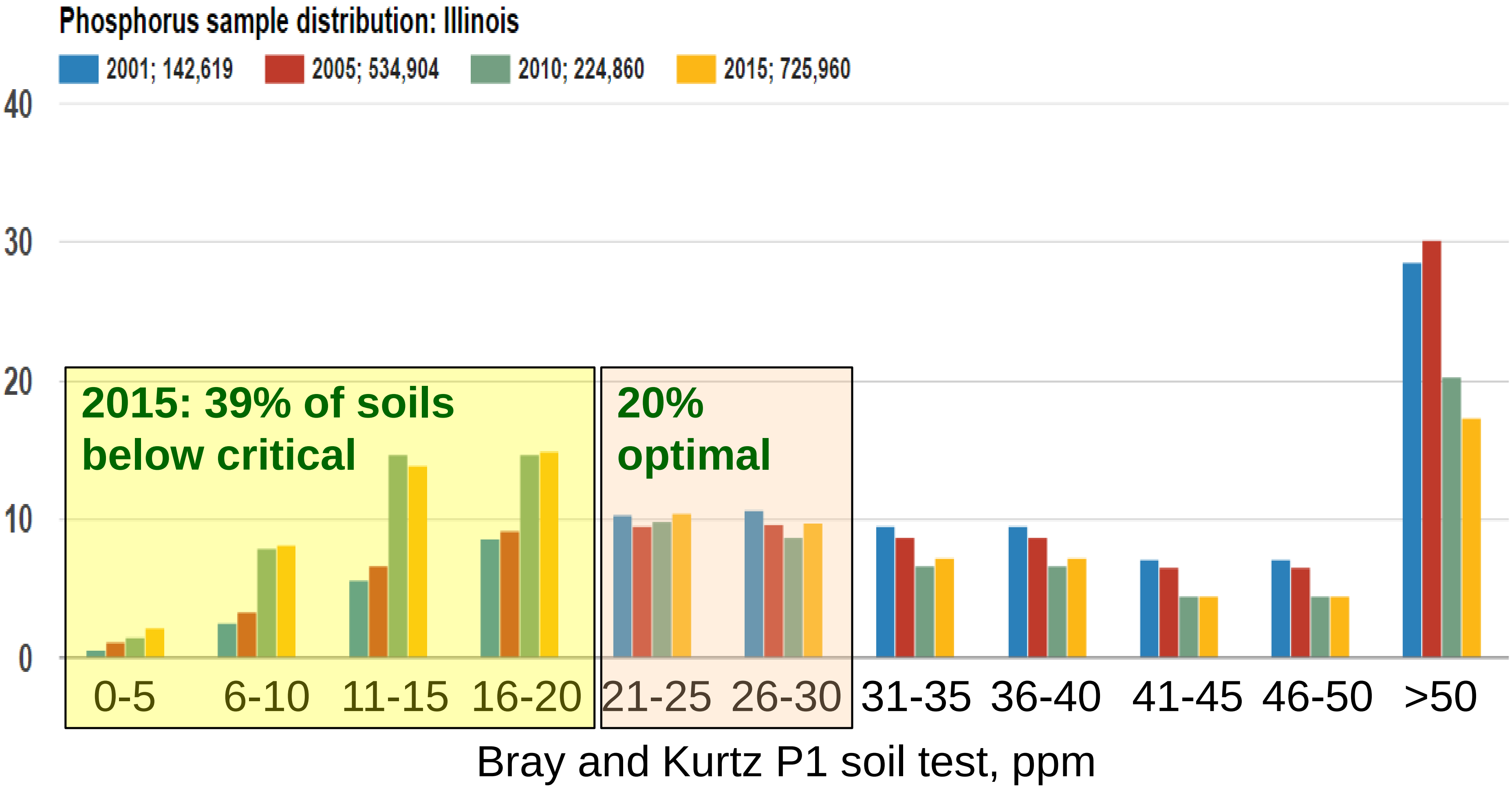


P test (lb/A) for different subsoil phosphorus-supplying power regions

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

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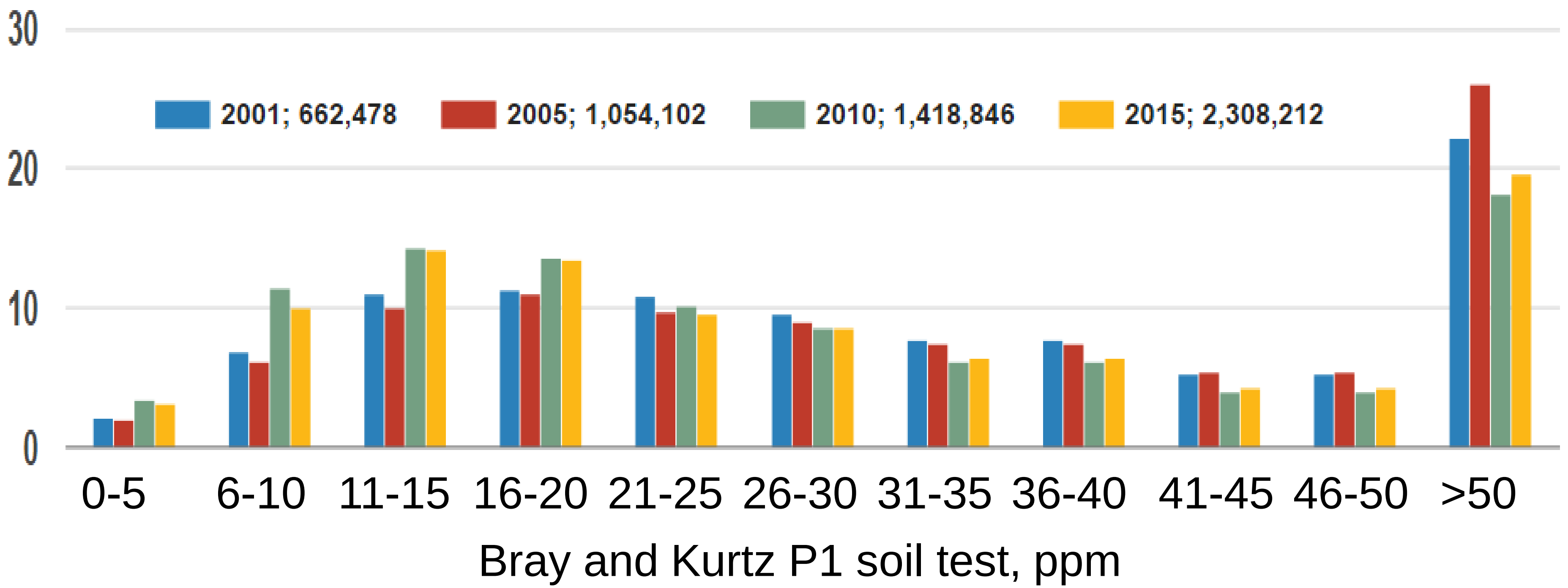
Indiana, Illinois & Iowa

% of samples at each level of soil test P



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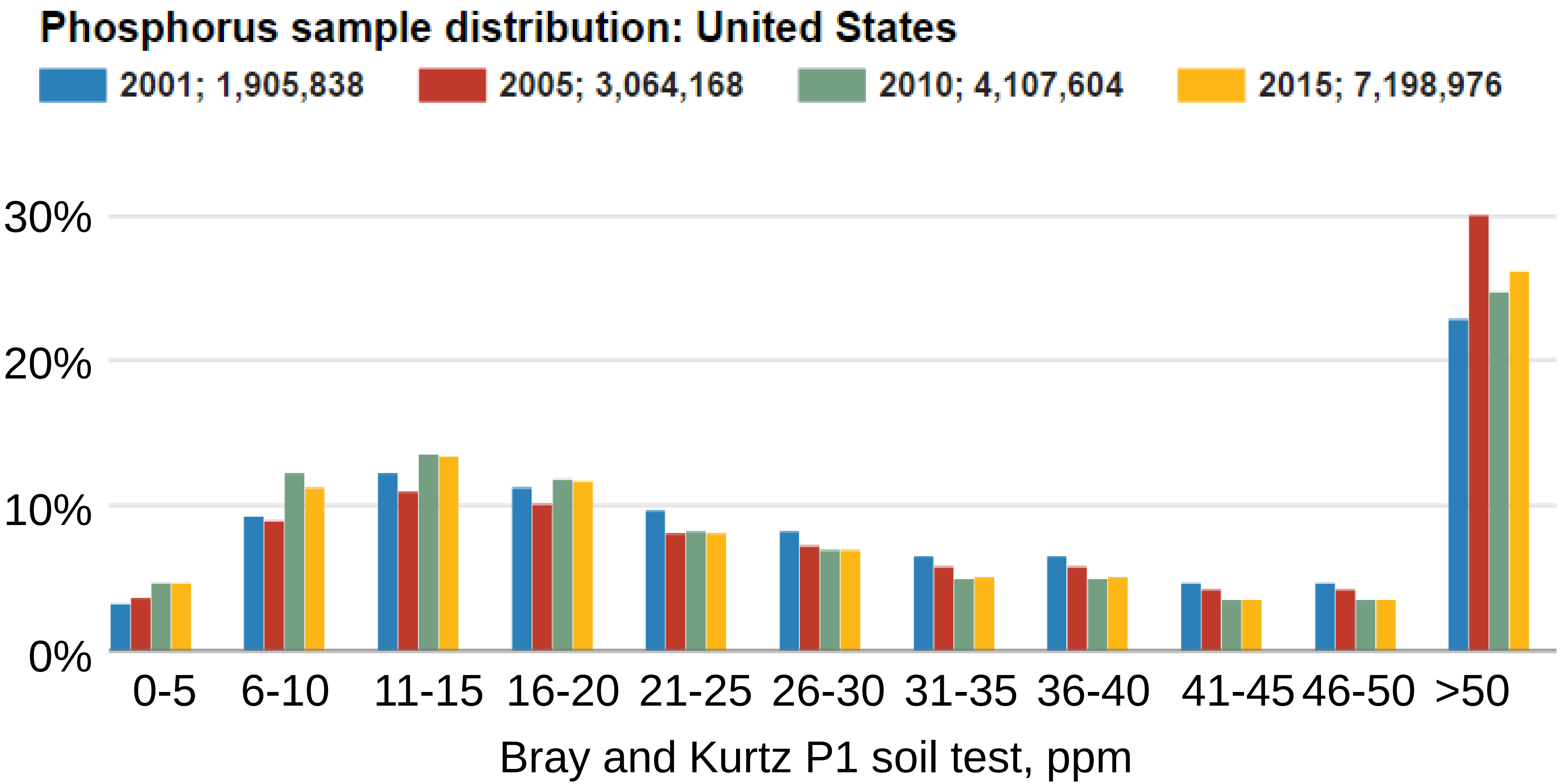
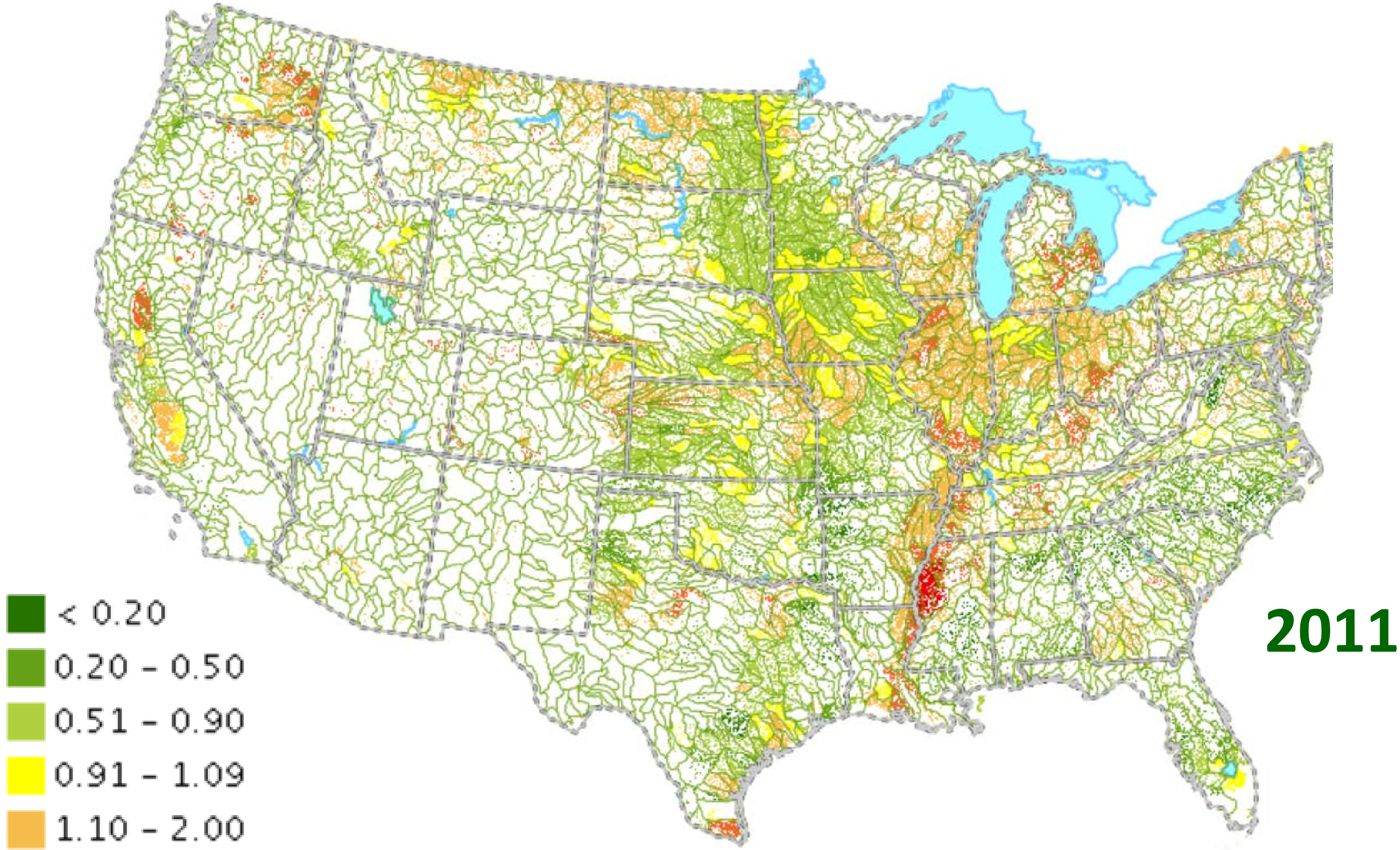


On average, soil test P changed little from 2001 to 2015.

http://soiltest.ipni.net

PUE: Ratio of removal to use varies across US cropland



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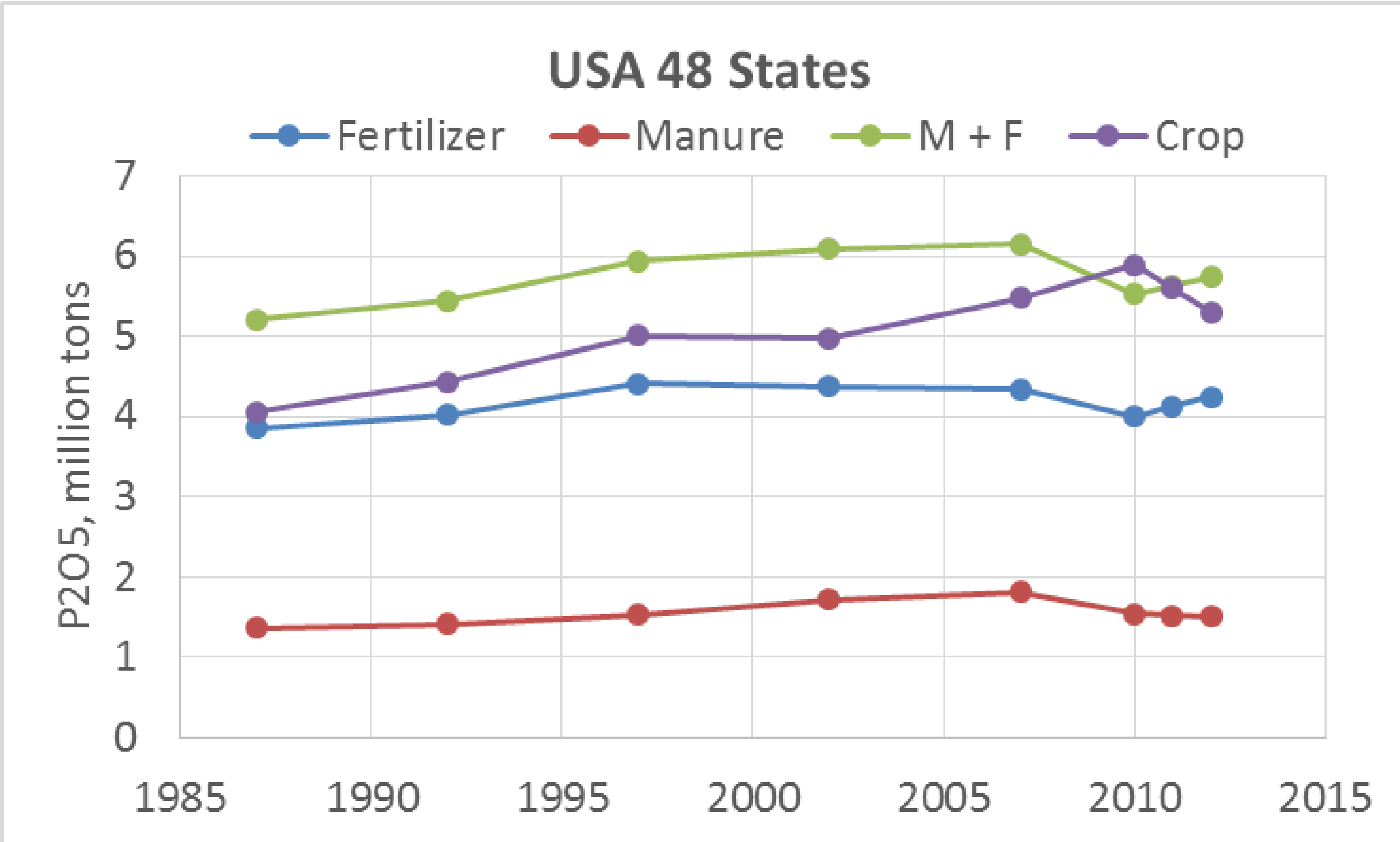
NuGIS
Nutrient Use Geographic Information System

Phosphorus Balance, USA – on average, seldom in deficit



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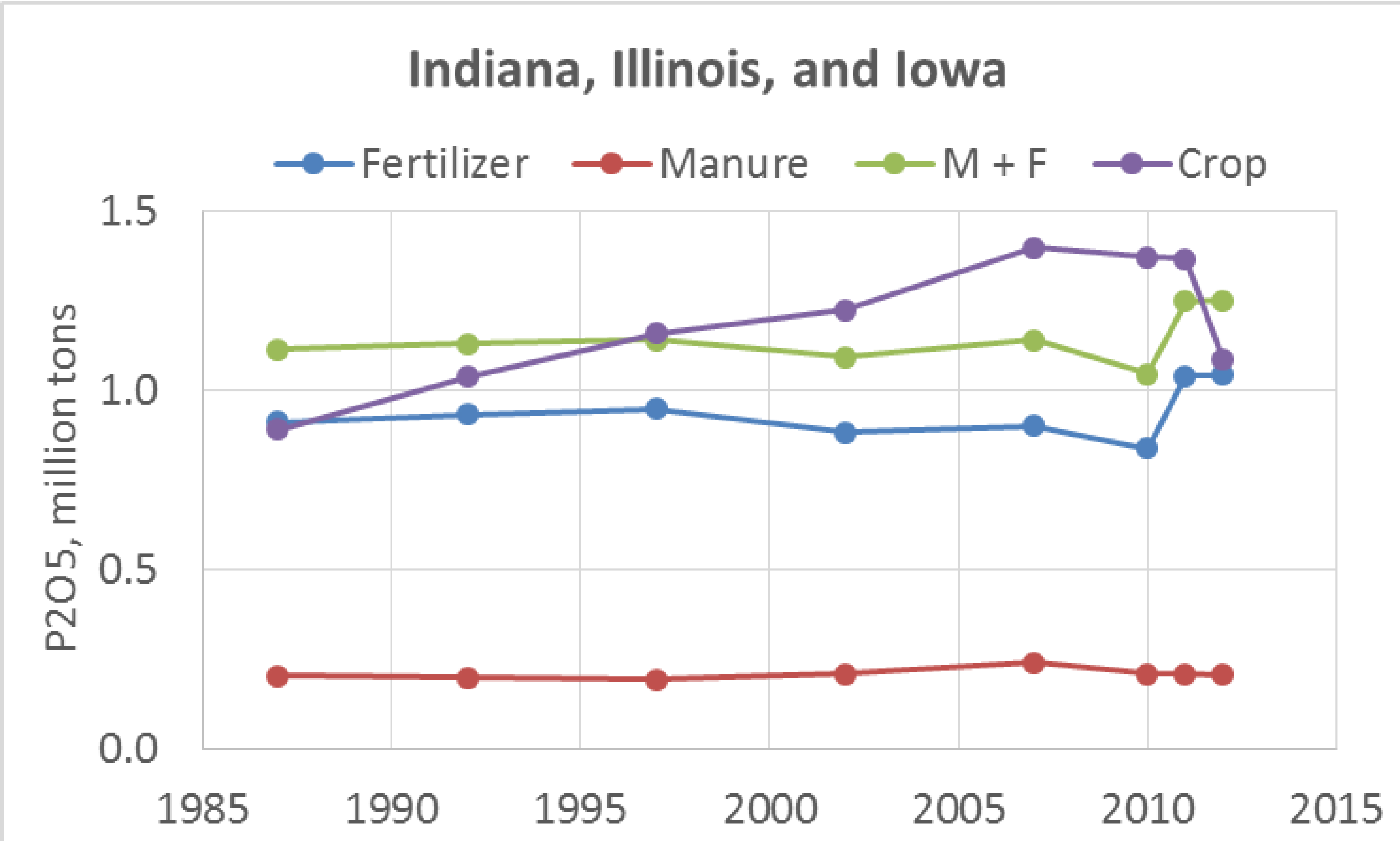
NuGIS
Nutrient Use Geographic Information System

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



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NuGIS
Nutrient Use Geographic Information System

Biosolids – a useful but small source of P

1. Amount of P in biosolids is roughly equal to dietary P supply.
2. Total biosolids from sewage treatment in North America contains an equivalent of 8% of crop P removal.
3. Currently, half the biosolids are land applied, to less than 1% of the cropland.
4. Good source of zinc.
5. Low analysis sources:
    1. Issues with bulk and transportability.
    2. Accuracy of reported nutrient analysis – “guaranteed minimum” does not apply well to bulk materials

World Phosphate Rock Reserves

P

Country	2014-15 Production	Reserves	Reserve Life
	Mt		Years
Algeria	1	2,200	2,200
China	100	3,700	37
South Africa	2	1,500	750
Jordan	7	1,300	186
Morocco	30	50,000	1,670
Russia	12	1,300	108
USA	26	1,100	42
World Total	**220**	**69,000**	**314**

Source: USGS, 2016 - http://minerals.usgs.gov/minerals/

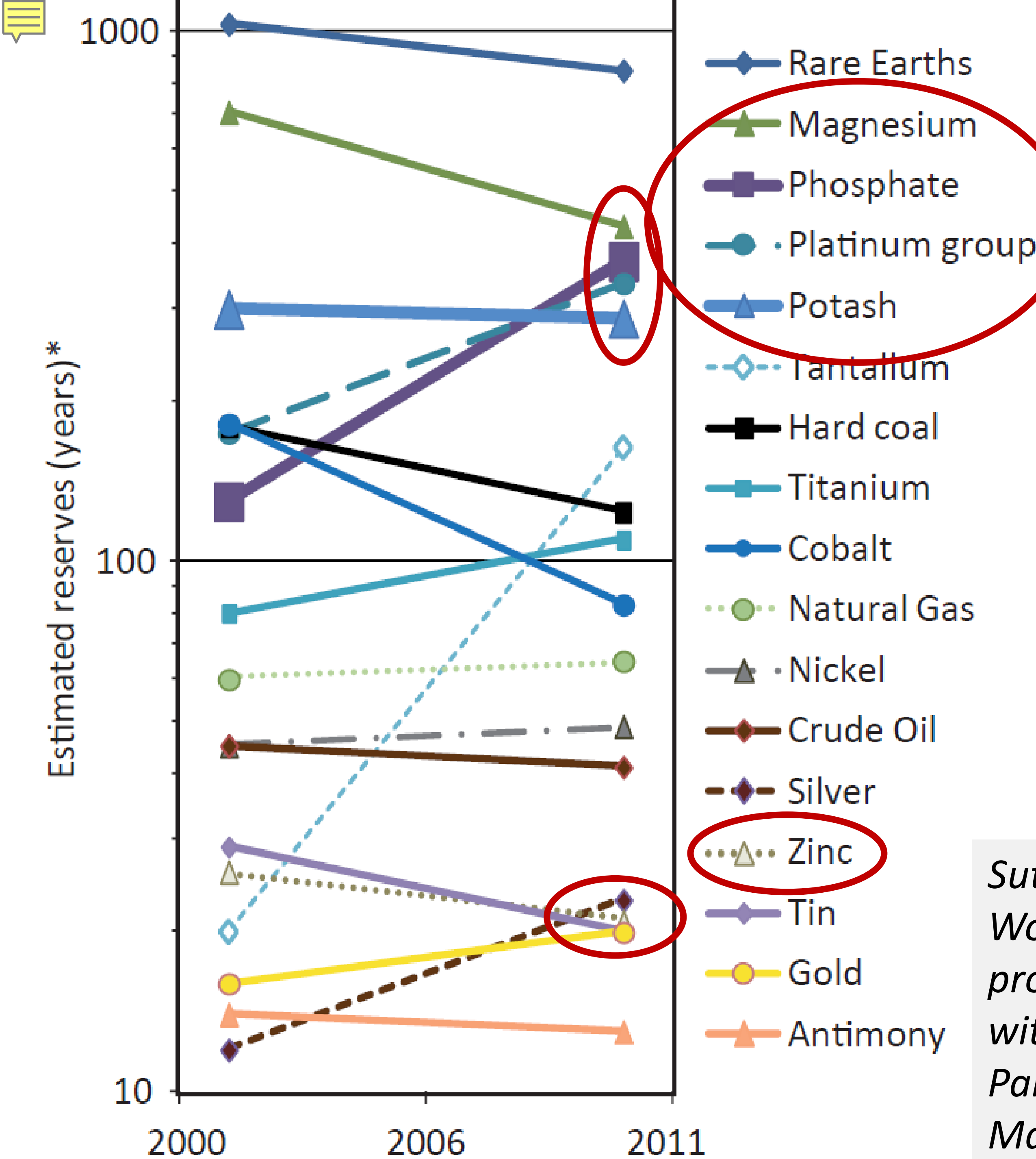
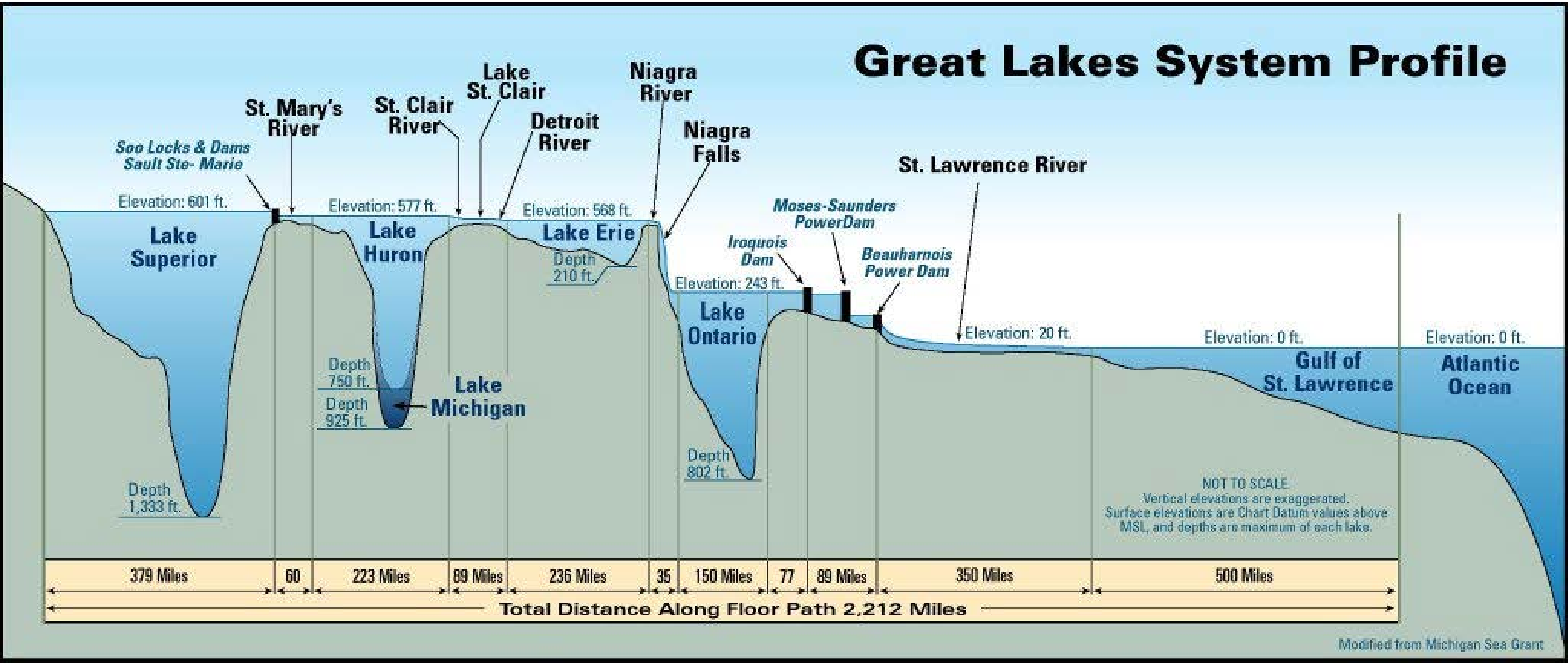


Figure 2.9 Putting phosphorus and potassium (potash) reserves into context.

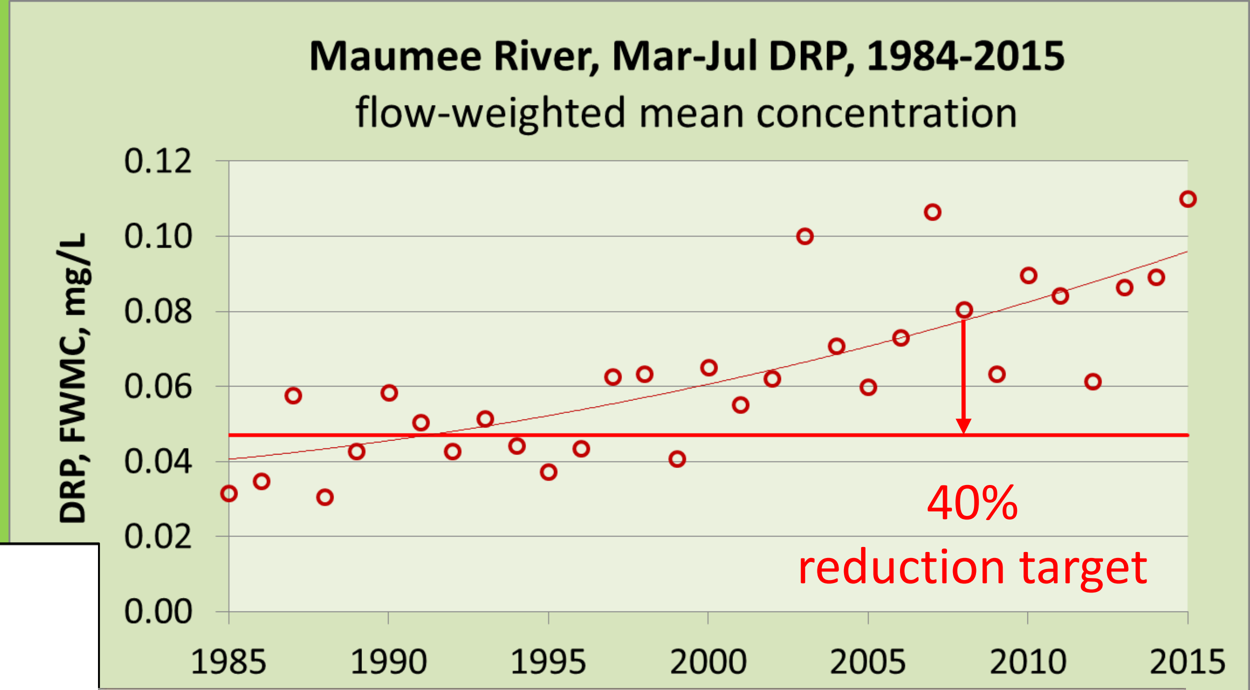
Zinc likely to run out long before phosphate.

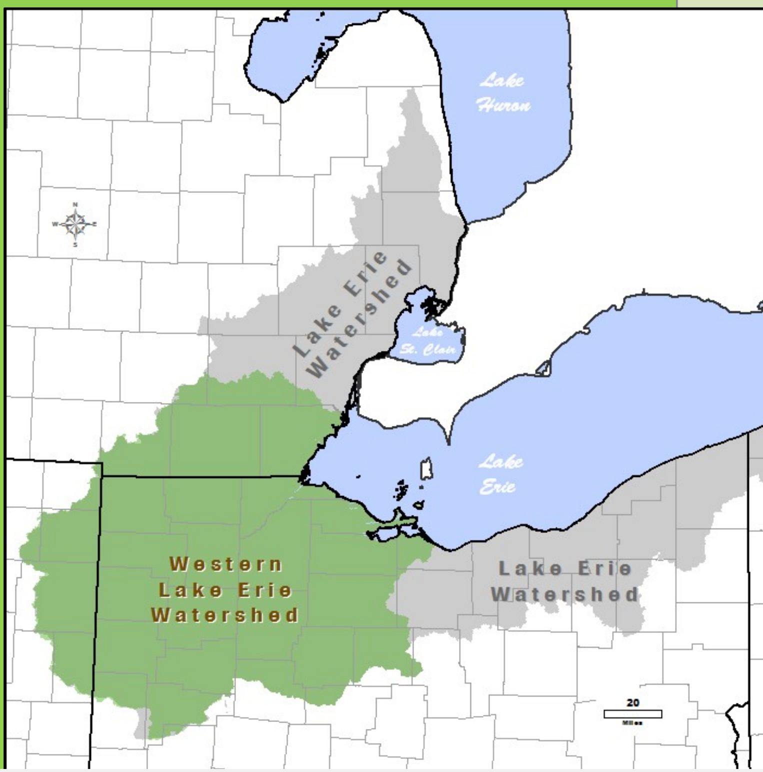
Sutton et al. 2013. Our Nutrient World: The challenge to produce more food and energy with less pollution. Global Partnership on Nutrient Management.

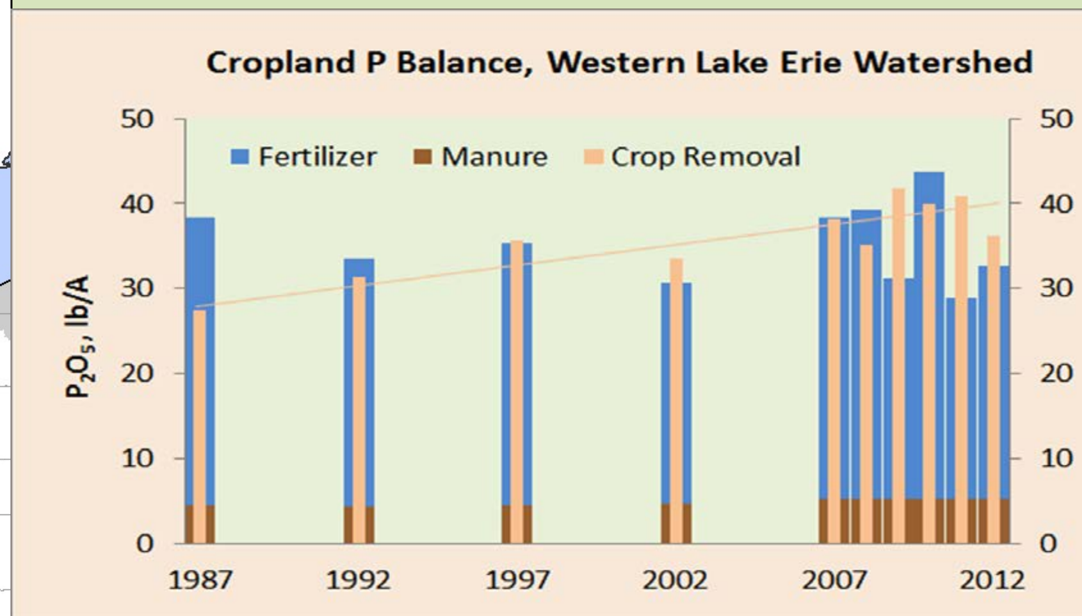
Lake Erie: prone to blooms because of its shallow depth



Western Lake Erie watershed: increasing trends in both crop yields and phosphorus in the rivers.







GLWQA Annex Nutrients Committee, May 2015. David Baker & Laura Johnson, National Center for Water Quality Research, Tiffin, OH. Cropland data from IPNI NuGIS.

WLEB 4R Certification Program

RIGHT SOURCE
Matches fertilizer type to crop needs

- Account for all sources of nutrients in recommendations

RIGHT RATE
Matches amount of fertilizer to crop needs

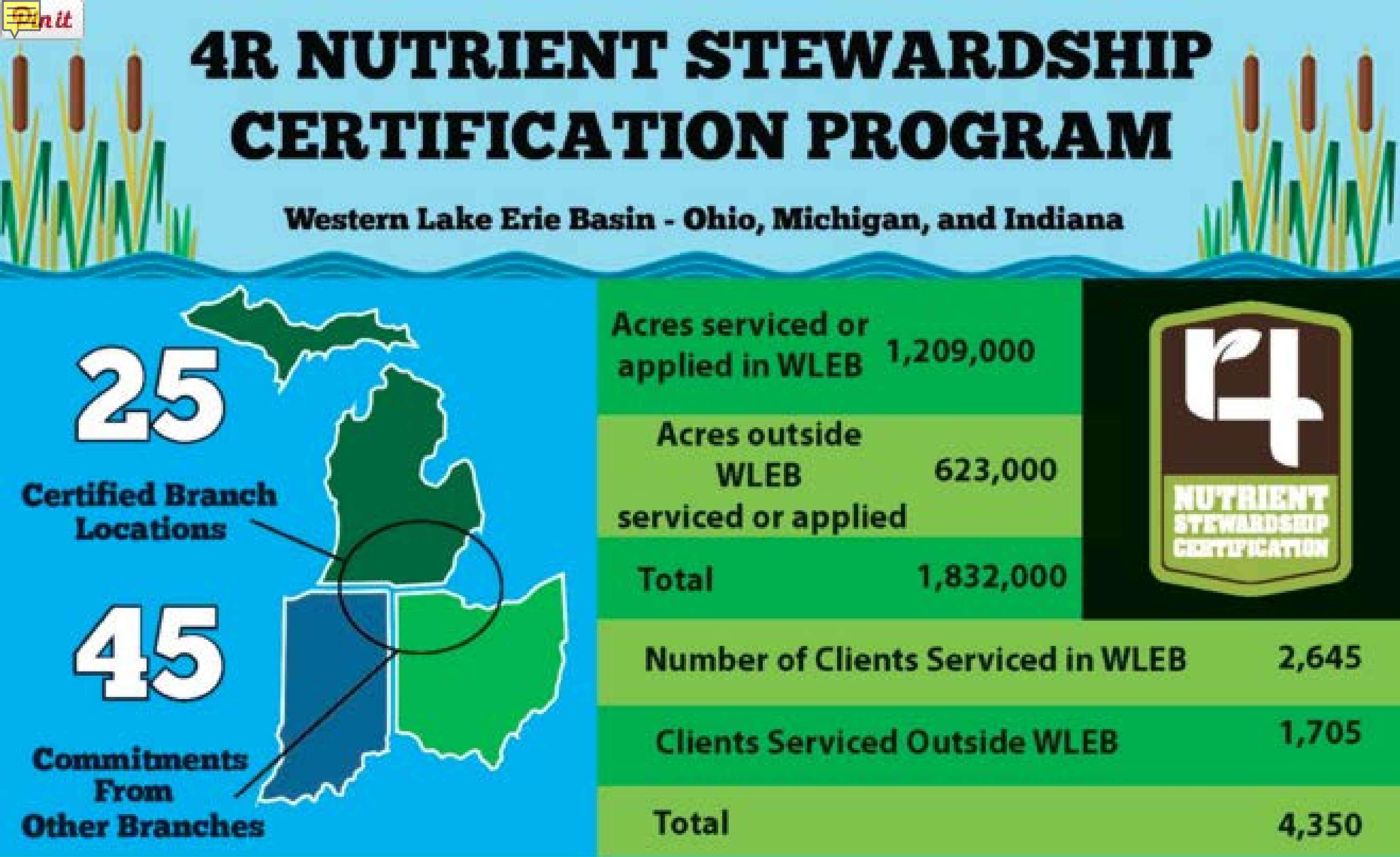
- Conduct soil tests regularly in uniform areas less than 25 acres
- Document crop yield goals based on crop history
- Base nutrient application on Tri-State recommendations or adaptive management using soil test and yield goals
- Calibrate nutrient application equipment annually

RIGHT PLACE
Keeps nutrients where crop can use them

- Utilize variable rate application
- Utilize phosphorus injection, subsurface banding or broadcasting with immediate incorporation
- Don’t broadcast apply nutrients without incorporation unless the risk of phosphorus loss is demonstrated to be low
- Apply nutrients using minimum setbacks from sensitive areas

RIGHT TIME
Makes nutrients available when crops need them

- Don’t apply phosphorus on frozen or snow covered ground
- Don’t apply phosphorus or nitrogen if a large rainfall is in the weather forecast



1.2M acres! http://4Rcertified.org/

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) No. 9

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

Edge-of-field comparison shows higher DRP loss with broadcast P on no-till

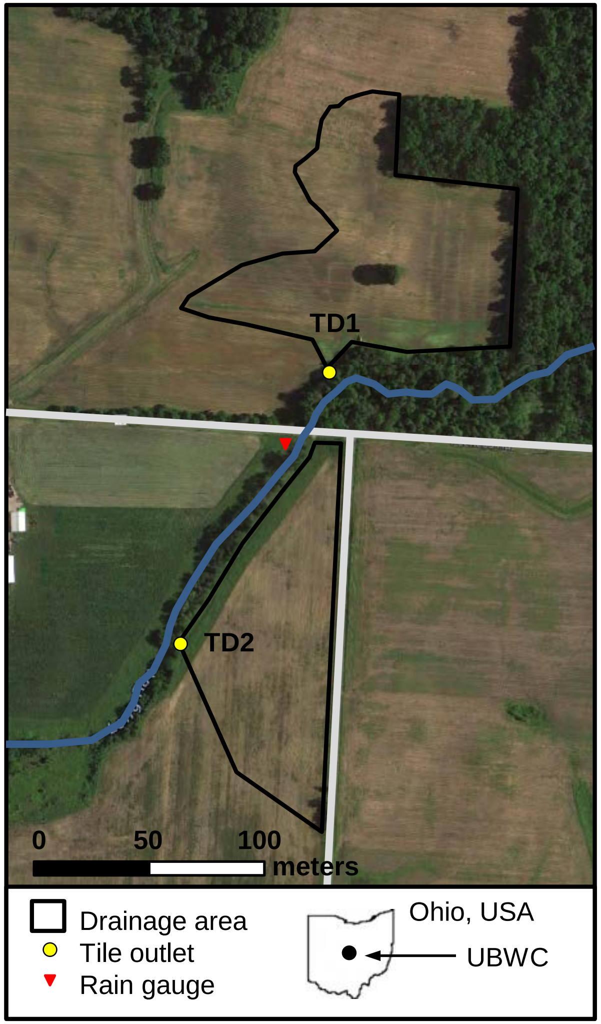
Soil type: Silt loam
Tile depth: 36”
Soil test P: 30 ppm Mehlich-3P
Tillage: No-till

2014 management

May 6th – Applied MAP @ 180 lb/A
May 8th – Tilled field TD1 (disc)
(TD2 remained no-till)

Study Objective

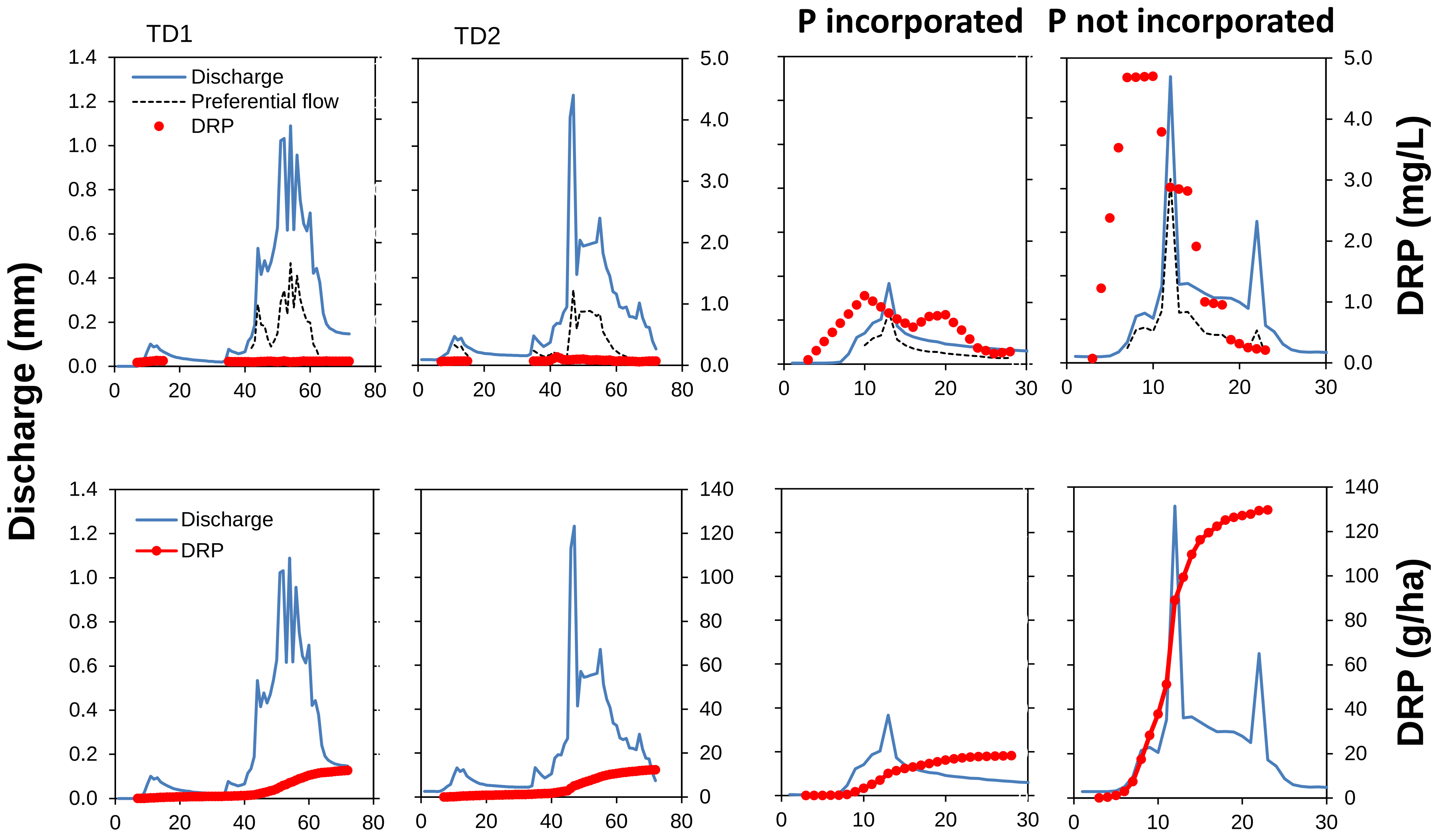
Compare P transport before and after tillage and between tilled and no-till fields



Williams and King, USDA-ARS, Columbus, Ohio

Before P application & tillage (April 28th)

After P application & tillage (May 12th)

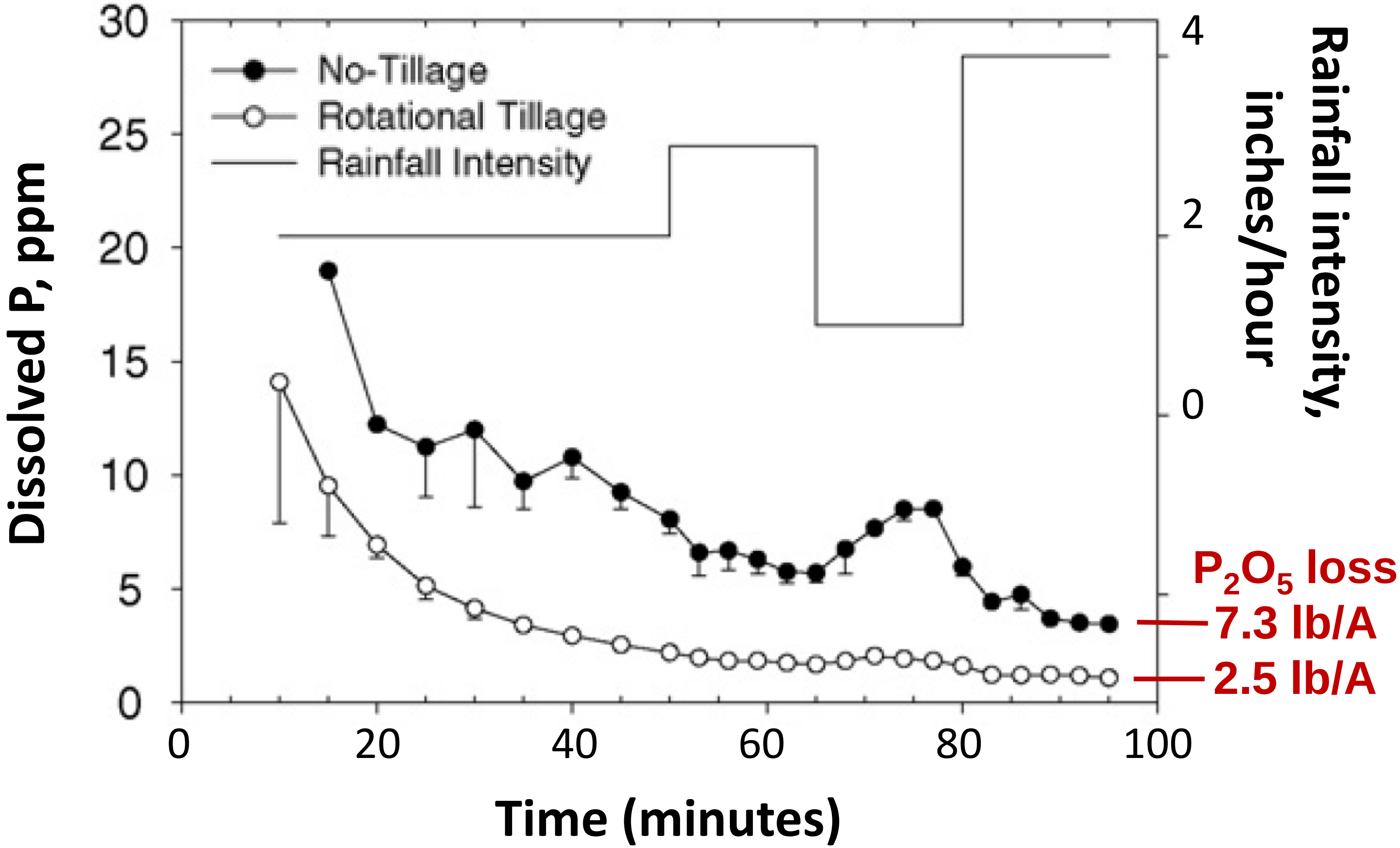


Incorporating P reduced DRP loss by 70% over 5 rain events (from 0.8 lb P_2O_5/A)

Williams and King, USDA-ARS, Columbus, Ohio

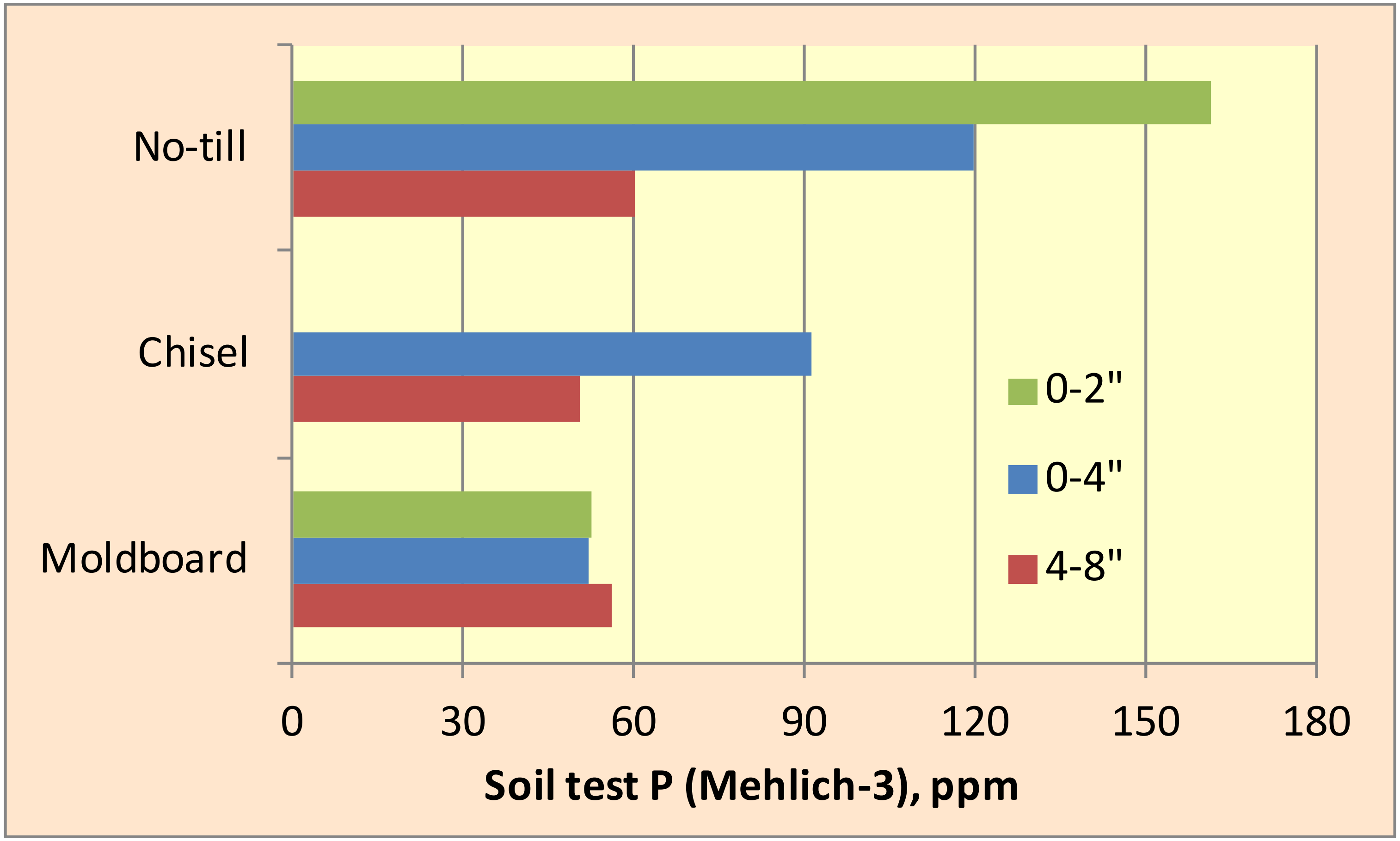
Rotational tillage & dissolved P – Waterloo, IN

one day after 0-46-0 fertilizer surface applied @ 100 lb/A P_2O_5



15-year no-till sites, corn-soybean rotation. Tillage 12 April with "finisher" chisel plow to 6" depth. Residue cover 57% for NT and 20% for RT. Rainfall applied 22 June to 2 July. *Smith et al. 2007. Soil & Tillage Research 95:11–18*

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 8”. Data from Gál (2005) and Vyn (2000). Fertilizer P applied broadcast.

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Tillage increases erosion, but no-till can increase dissolved P

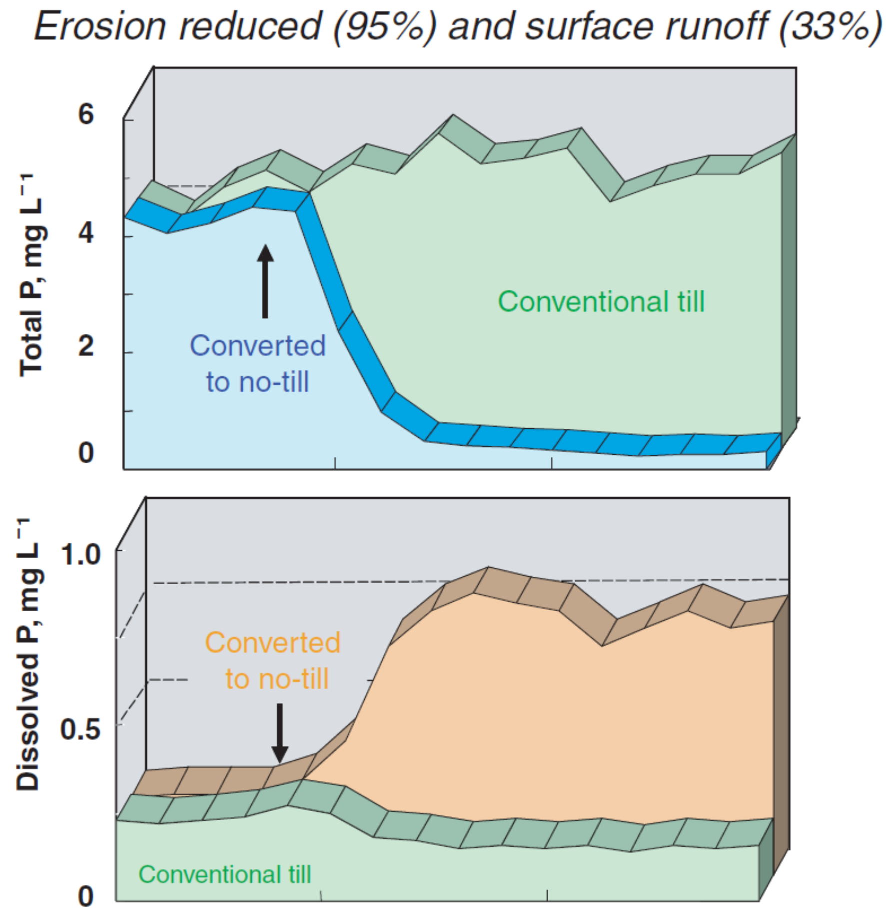
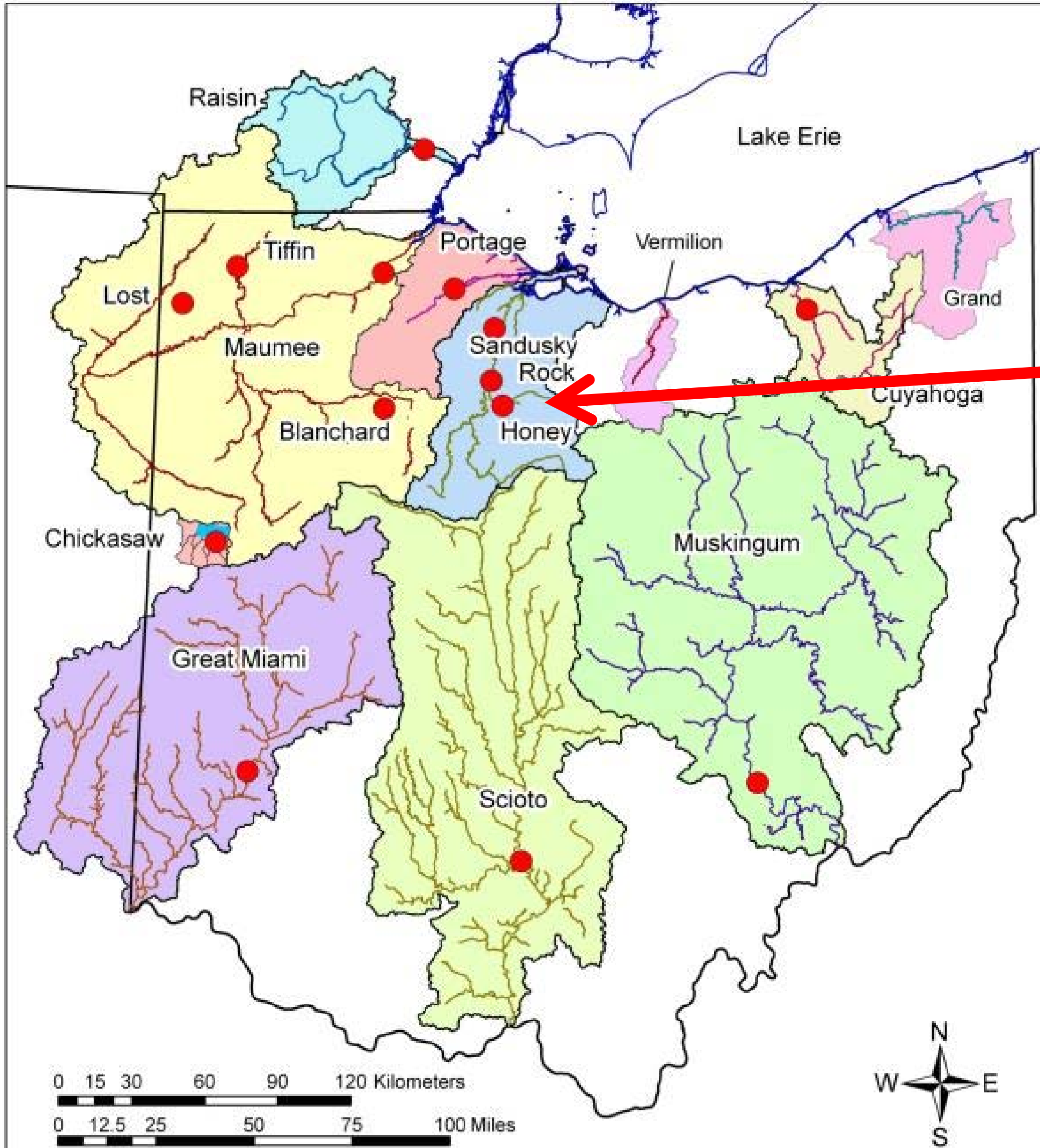


Figure 9. The conversion of conventional moldboard plow wheat to no-till wheat decreased total P transport in surface runoff but increased dissolved P in runoff and ground water nitrate (3 to 25 m) for several watersheds in Oklahoma. Data from Sharpley and Smith 1994.

USDA-ARS. 2006. Best Management Practices To Minimize Agricultural Phosphorus Impacts on Water Quality

P loss monitored at a watershed scale

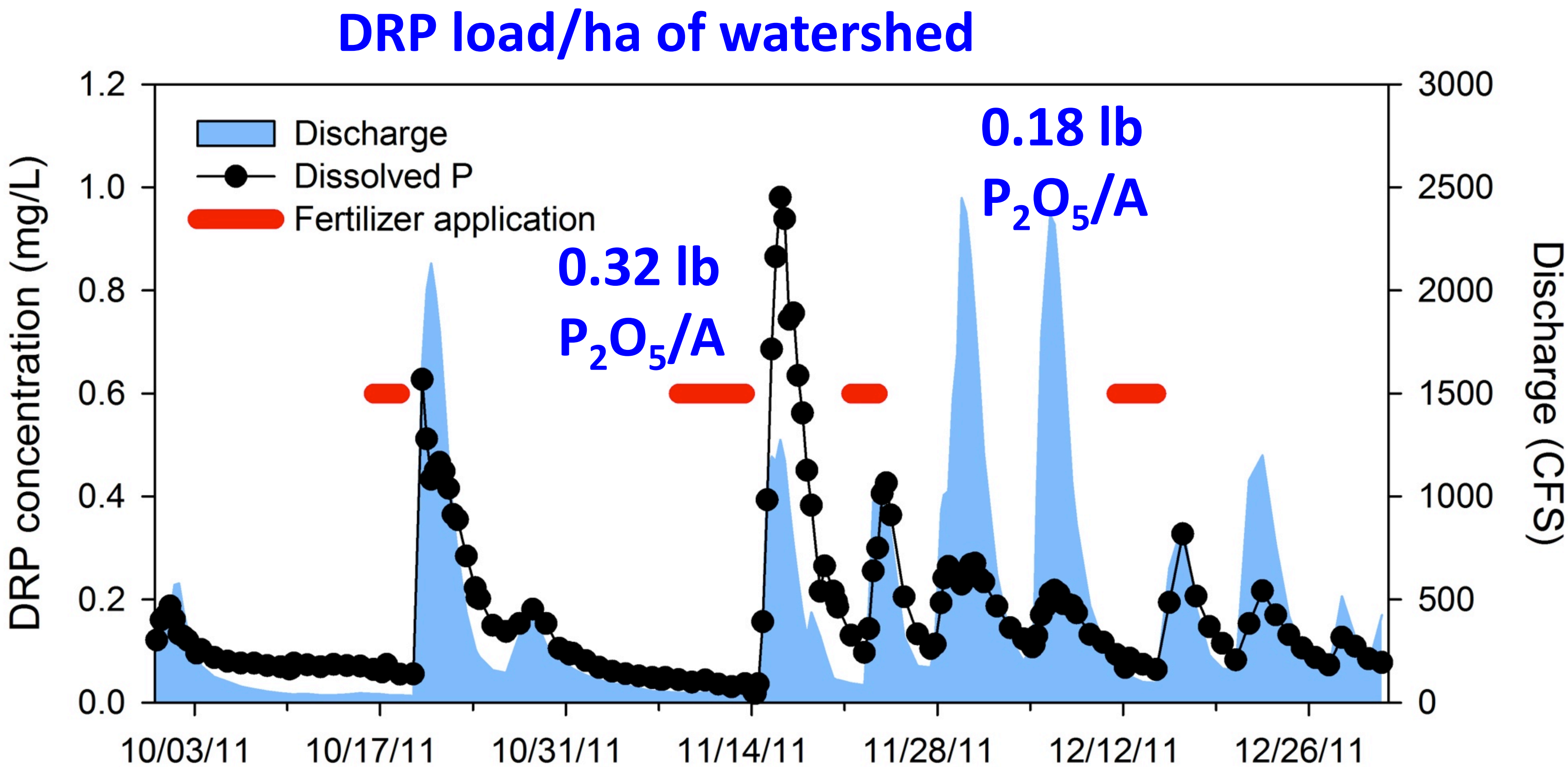


The Heidelberg University Tributary Loading Program

Honey Creek Watershed:

- **95,000 acres**
- **~80% row crops**
- **drains into the Sandusky River**

Right Time



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 and Laura Johnson, Heidelberg University

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

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Practice	Advantages (Benefits)	Limitations (Costs)
S – MAP or DAP R – rotation removal T – fall P – broadcast	Minimal soil compaction Allows timely planting in spring Low cost fertilizer form Low cost of application	Risk of elevated P in runoff in late fall and winter Low N use efficiency
S – MAP or DAP R – rotation removal T – spring P – broadcast	Minimal soil compaction Better N use efficiency Low cost fertilizer form Low cost of application	Risk of elevated P in spring runoff before incorporation Potential to delay planting Retailer spring delivery capacity
S – MAP or fluid APP R – one crop removal T – spring P – 2” x 2” band	Low risk of elevated P in runoff Most efficient use of N Less soil P stratification	Cost and practicality Potential to delay planting Retailer delivery capacity Cost of fluid versus granular P
S – MAP or DAP R – rotation removal T – fall P – banded in zone	Low risk of elevated P in runoff Maintain residue cover Allows timely planting in spring Less soil P stratification	Cost of RTK GPS guidance Cost of new equipment More time required than broadcast

Choice of 4R practice considers costs and benefits in terms of all key outcome metrics: yield, soil health, NUE, and water quality.

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Certified Crop Adviser Specialties

- 4R Nutrient Management Planning Specialist
  - Performance objectives effective May 2015
  - Over 60 people wrote August exam, ~50% pass rate
  - Ontario version in development (CCA Ontario and Fertilizer Canada)
- Sustainability Specialty Exam
  - Performance objectives effective May 2015
  - Launched November 2015 in Minneapolis, MN
  - First exam August 2016 (postponed from February)
  - References 4R Nutrient Stewardship

Summary – Sustainable 4R Phosphorus Thinking

- Sustainability thinking balances economic, environmental and social costs and benefits
- 4R "rights" consider consumer & public priorities in assessing impacts of management practices
- Source, rate, time & place for phosphorus application
  - Keeping P from limiting crop yields
  - Maintaining optimum soil P levels minimizing stratification
  - Efficiently using finite natural resources
  - Improving water quality by reducing P loss

http://phosphorus.ipni.net/

4R nutrient stewardship

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