IPNI Webinar Series
11 May 2016

IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Managing Phosphorus Sustainability

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.

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Outline

1. Sustainability
    1. Phosphorus Cycle
    2. Agricultural (crop nutrition)
2. Key phosphorus issues in agricultural sustainability
    1. Crop yields (productivity) require soil P fertility (soil health)
    2. Water quality (phosphorus loss reduction)
    3. Resource conservation (nutrient use efficiency)
3. Phosphorus in 4R Nutrient Stewardship

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

4R nutrient stewardship

IPNI

The emerging discipline of phosphorus sustainability science

"Phosphorus Footprint"

"Peak Phosphorus"

Phosphorus Sustainability Research Coordination Network

Summary: The Phosphorus Sustainability Research Coordination Network (P-RCN) was funded by the U.S. NSF to identify solutions for P sustainability by sparking an interdisciplinary synthesis of data, perspectives, and understanding about phosphorus. The P-RCN has over 50 academic participants and meets annually to engage stakeholders and coordinate and integrate P sustainability research.

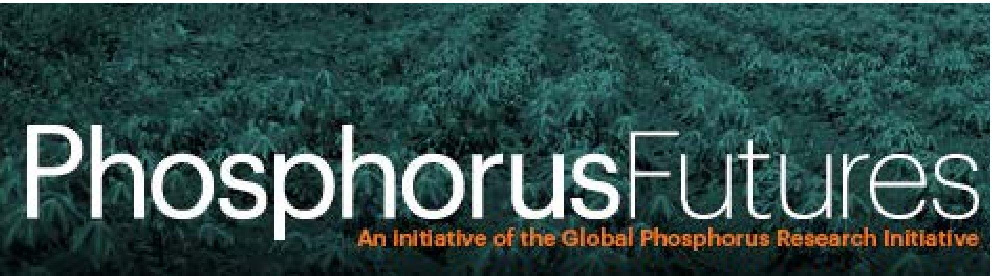
ELSEVIER

Global Environmental Change

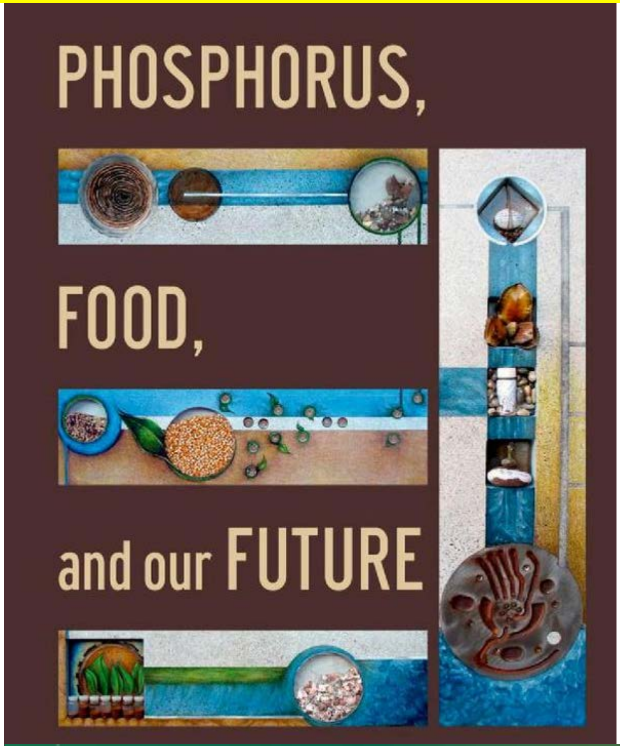
Volume 19, Issue 2, May 2009, Pages 292–305

Traditional Peoples and Climate Change

The story of phosphorus: Global food security and food for thought



GLOBAL PHOSPHORUS RESEARCH INITIATIVE



Roland W. Scholz · Amit H. Roy
Fridolin S. Brand · Deborah T. Hellums
Andrea E. Ulrich *Editors*

Sustainable Phosphorus Management

A Global Transdisciplinary Roadmap

Phosphorus sustainability initiatives inform policy and the public

European Sustainable Phosphorus Platform

September 2015 n° 116

SCOPE NEWSLETTER

GPNM

Global Partnership on Nutrient Management

中国农业大学

CHINA AGRICULTURAL UNIVERSITY

1905

August 16-20, 2016

Kunming, Yunnan, China

5th Sustainable Phosphorus Summit 2016 (SPS 2016)

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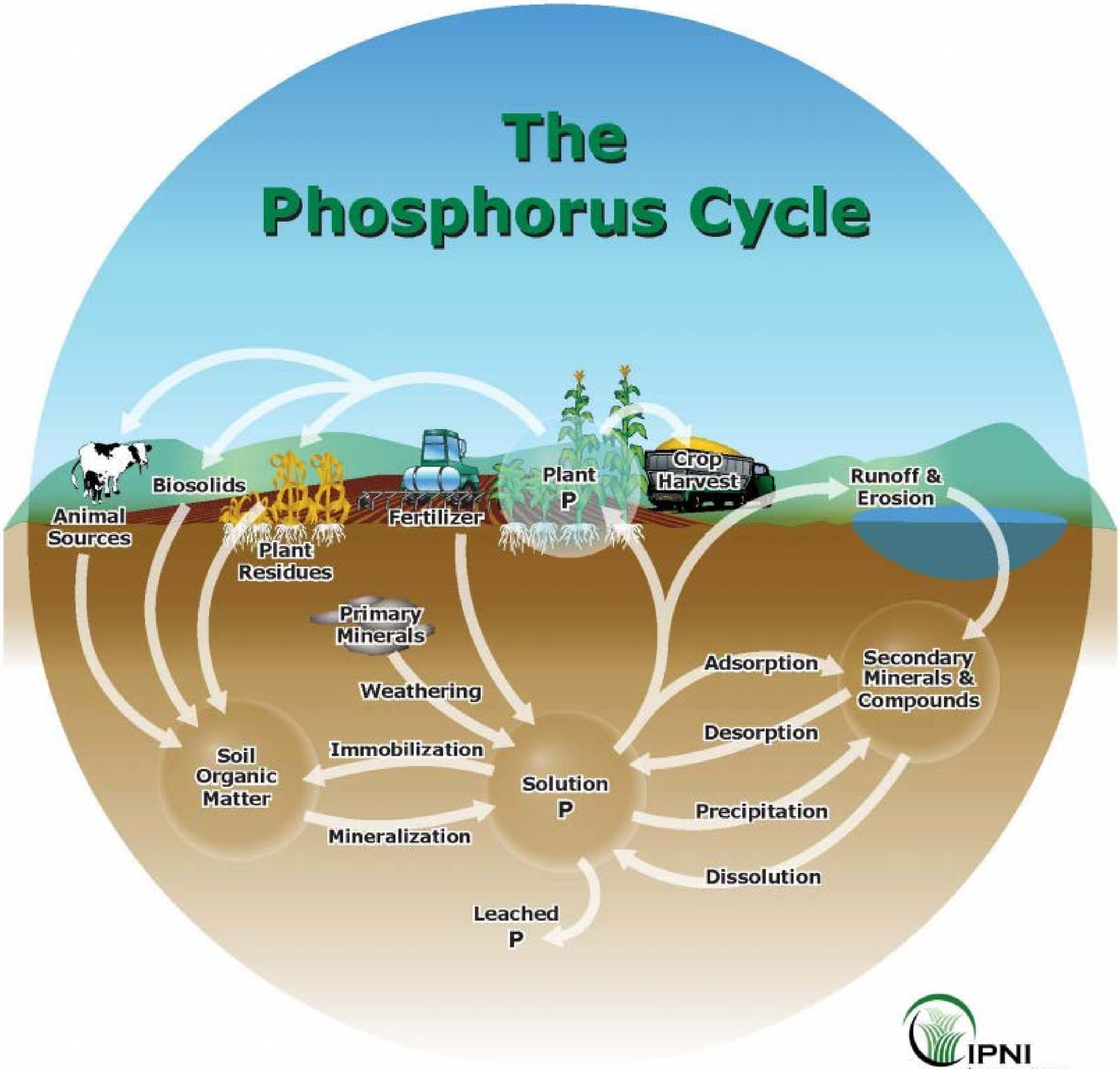
The farm perspective focuses on the soil and the crop



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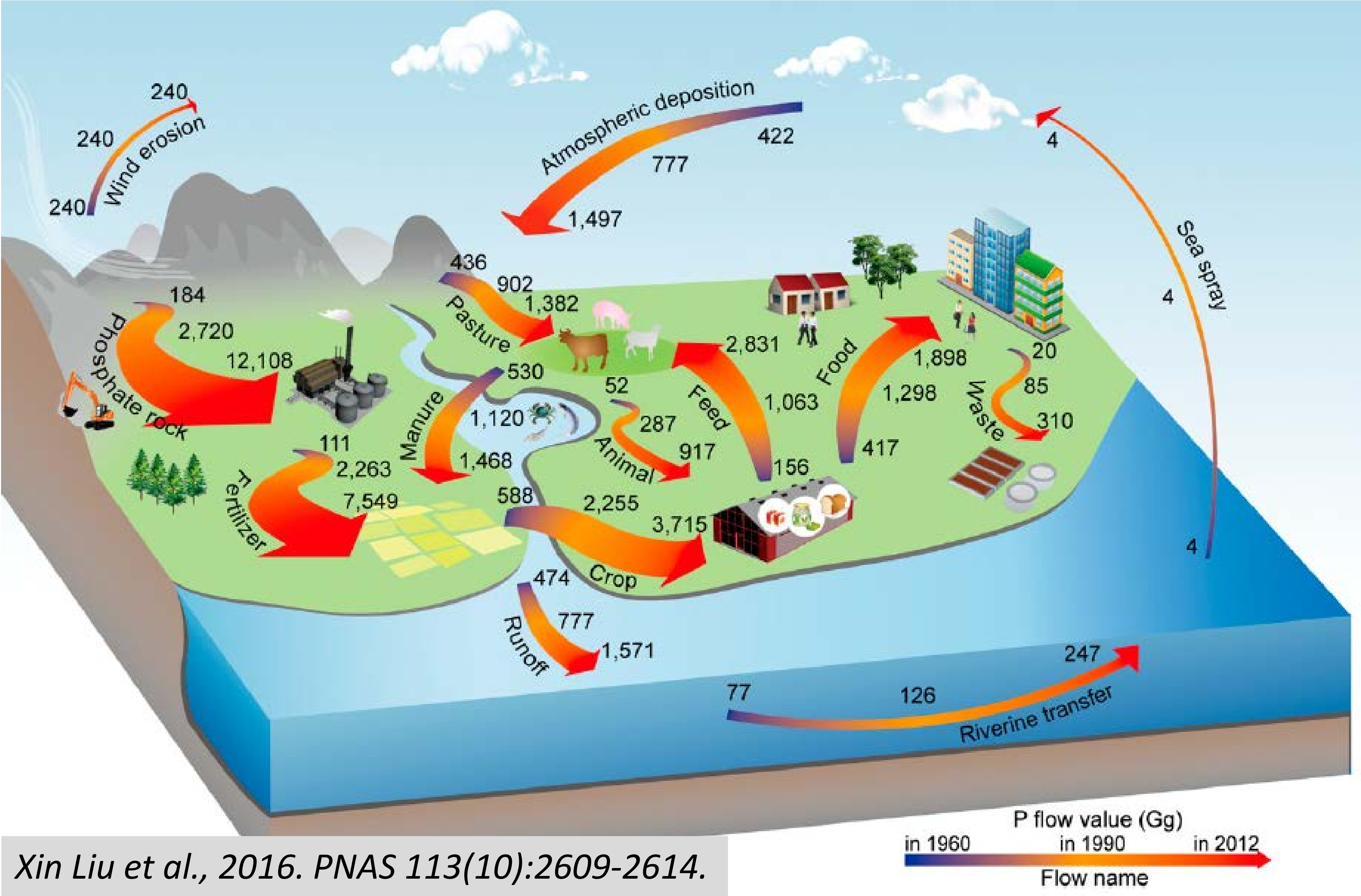
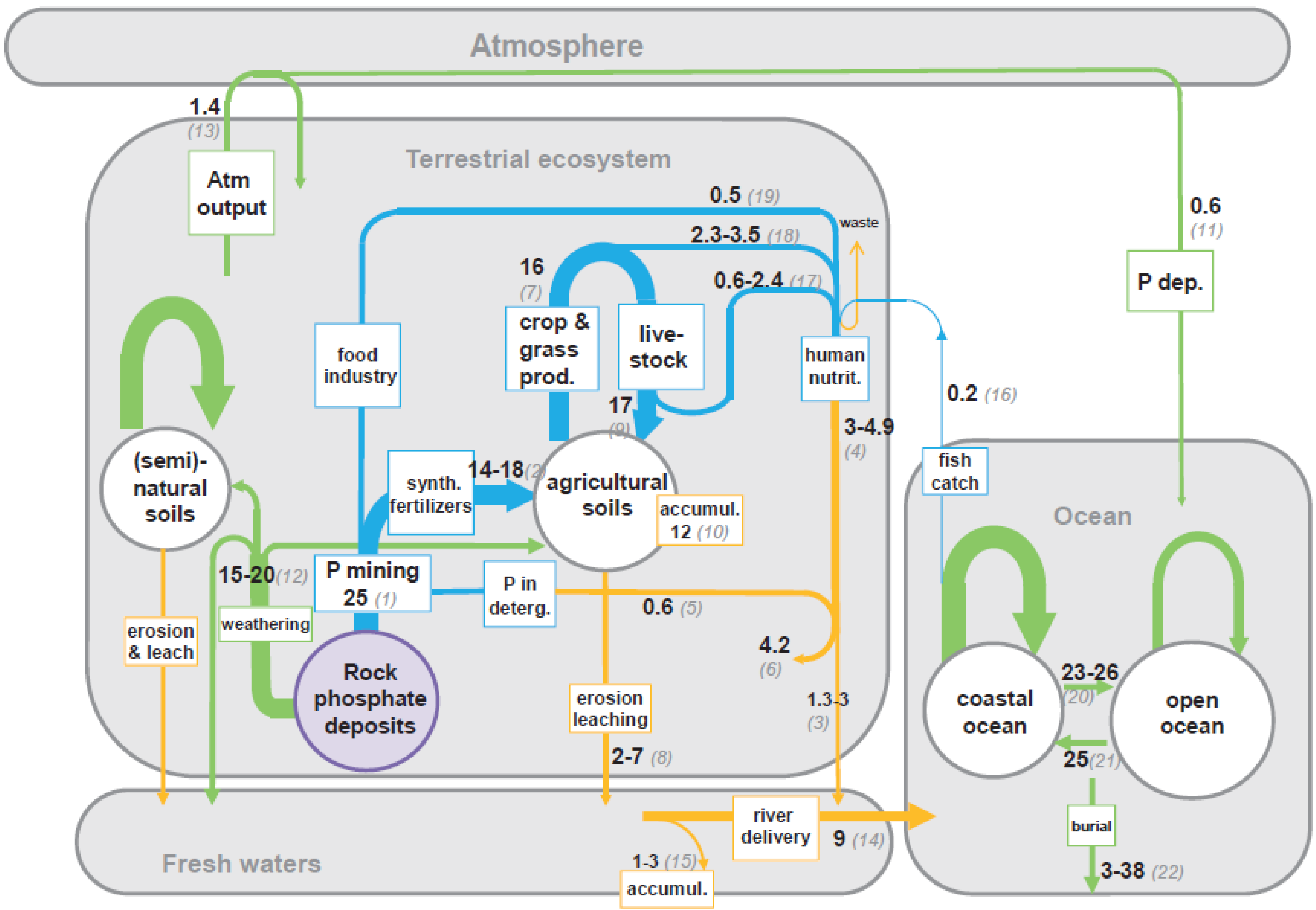
Phosphorus flows beyond the farm: China, 1960-2012



Xin Liu et al., 2016. PNAS 113(10):2609-2614.

Global P Cycle: Large amounts mined and accumulating in soils



World, around 2000-2010, fluxes in TgP/yr

Sutton et al., 2013. Our Nutrient World. Center For Ecology and Hydrology, UK.

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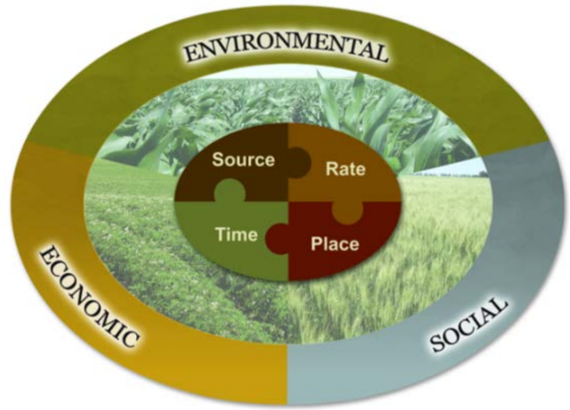
Nutrient Stewardship Metrics for Sustainable Crop Nutrition



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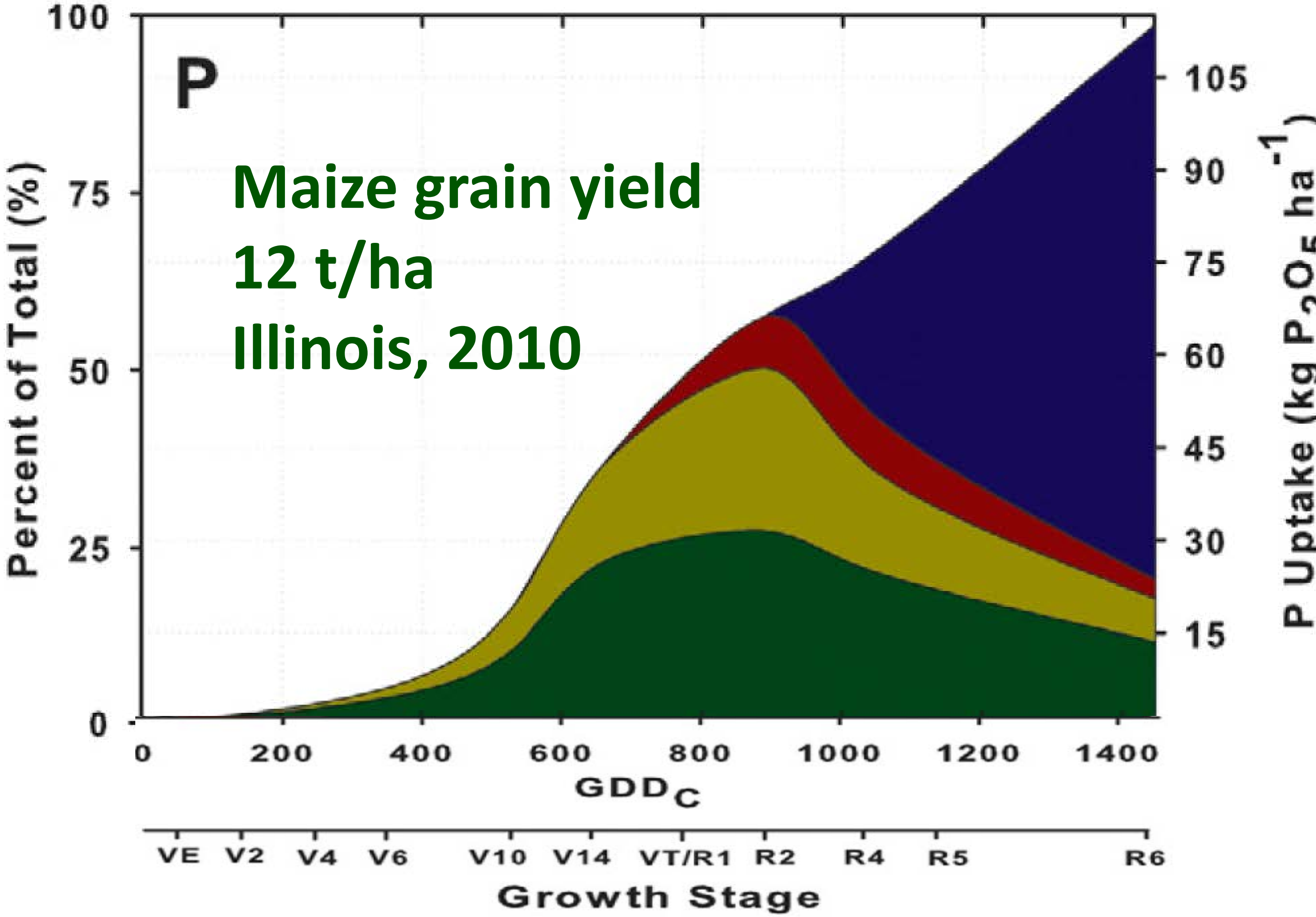
High-yield crops take up large amounts of P. Most of it is removed with grain harvest.



2010 data from two sites and six hybrids

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

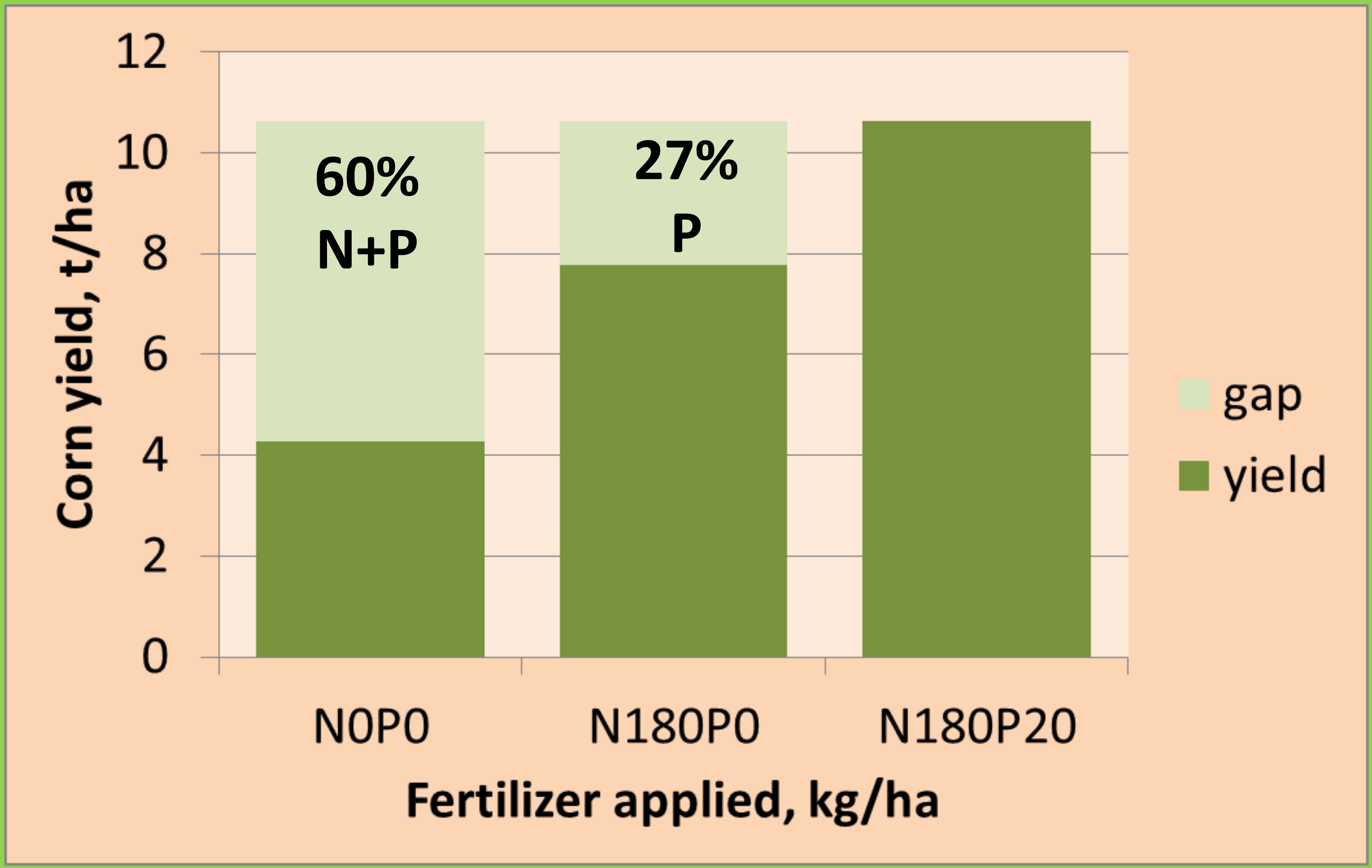
Crop Physiology

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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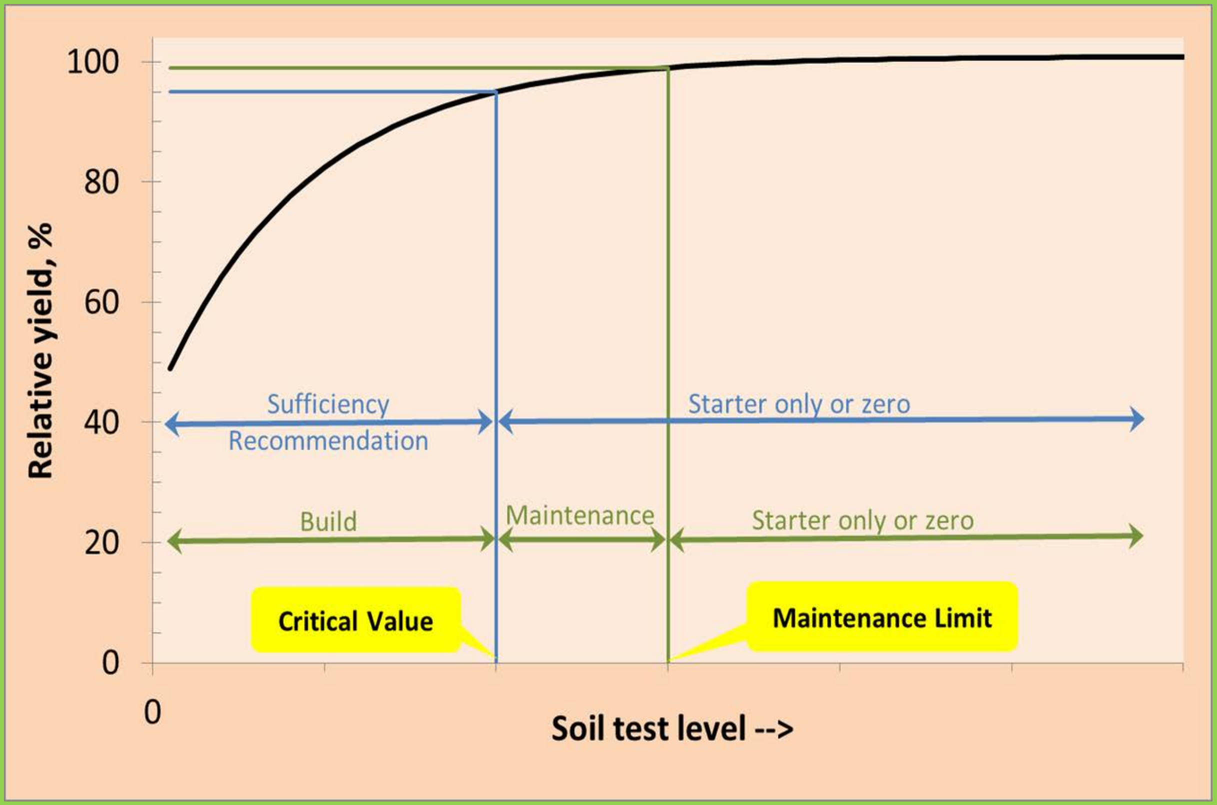
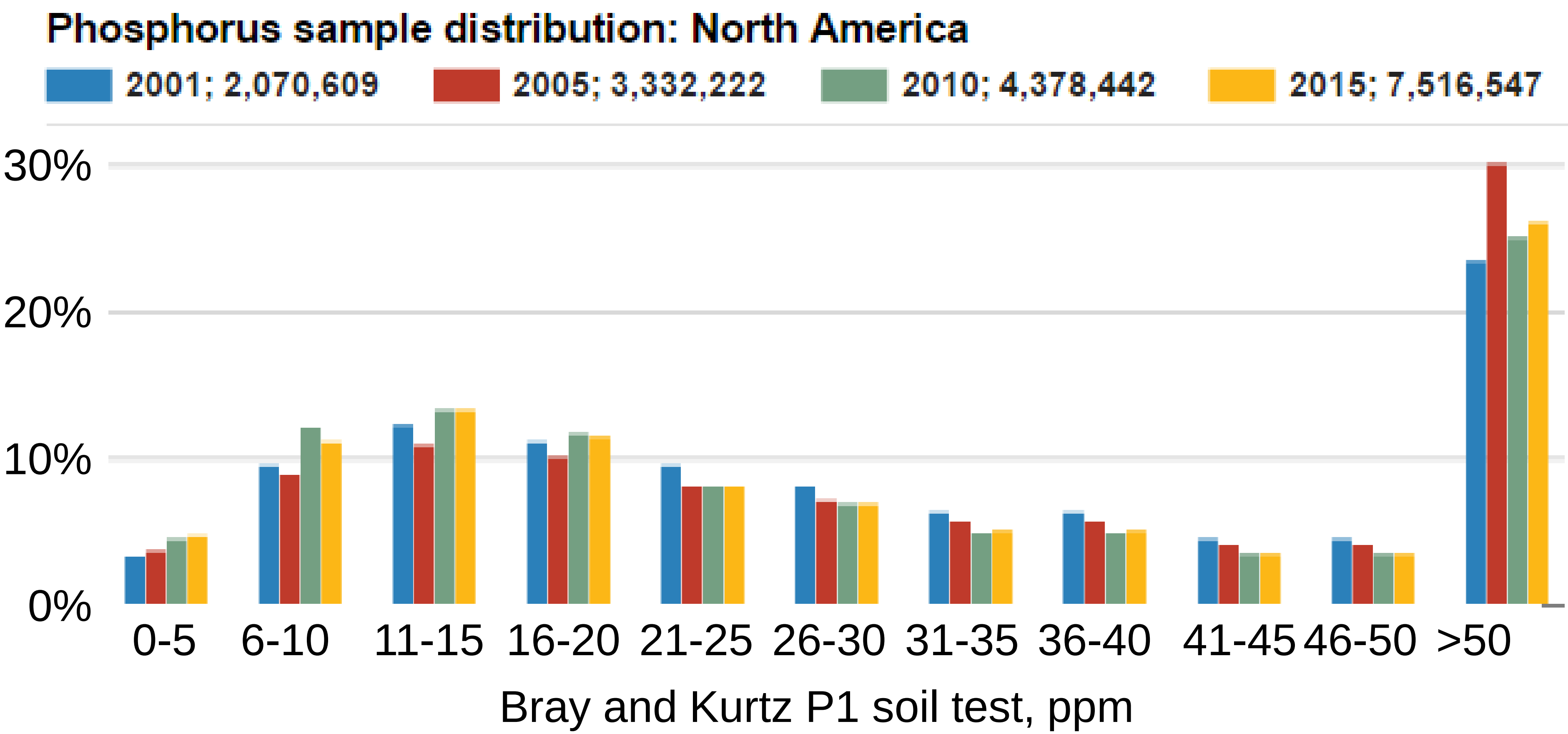
Short term crop response to P is much smaller

- 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





Soil tests below critical decreased from about 60% in the 1960s to a low of 40% in 2005 but increased to 44% over the past ten years.

http://soiltest.ipni.net

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- Home
- Background
- BFDC Interrogator
- Included data
- Calibrations
- Publications
- Contact us
- Acknowledgements
- Disclaimer

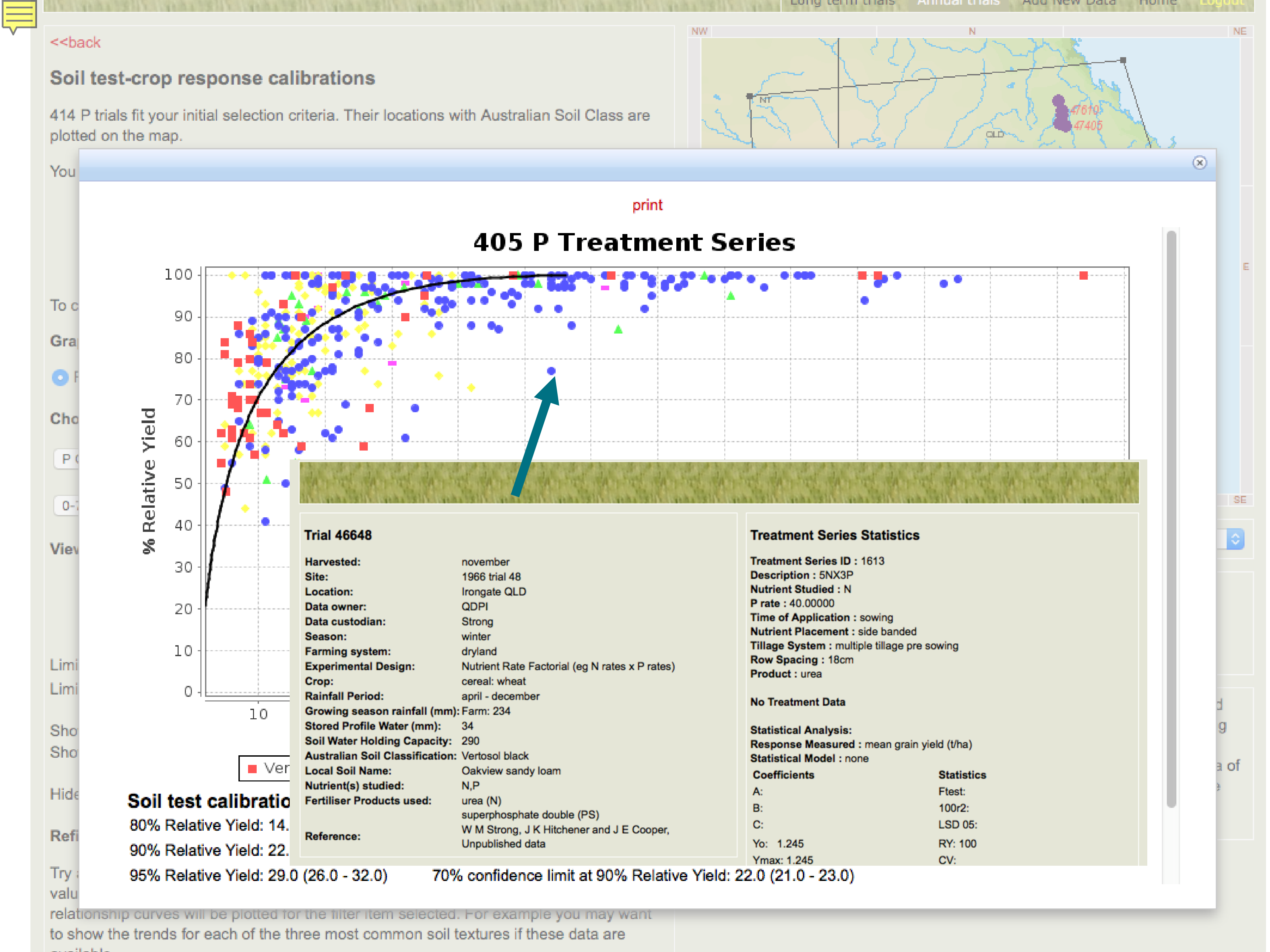
MAKING BETTER FERTILISER DECISIONS FOR CROPPING SYSTEMS IN AUSTRALIA

NSW Department of Primary Industries

GRDC Grains Research & Development Corporation
Your GRDC working with you

F I F A

http://www.bfdc.com.au


Long term trials
Annual trials
Add New Data
Home
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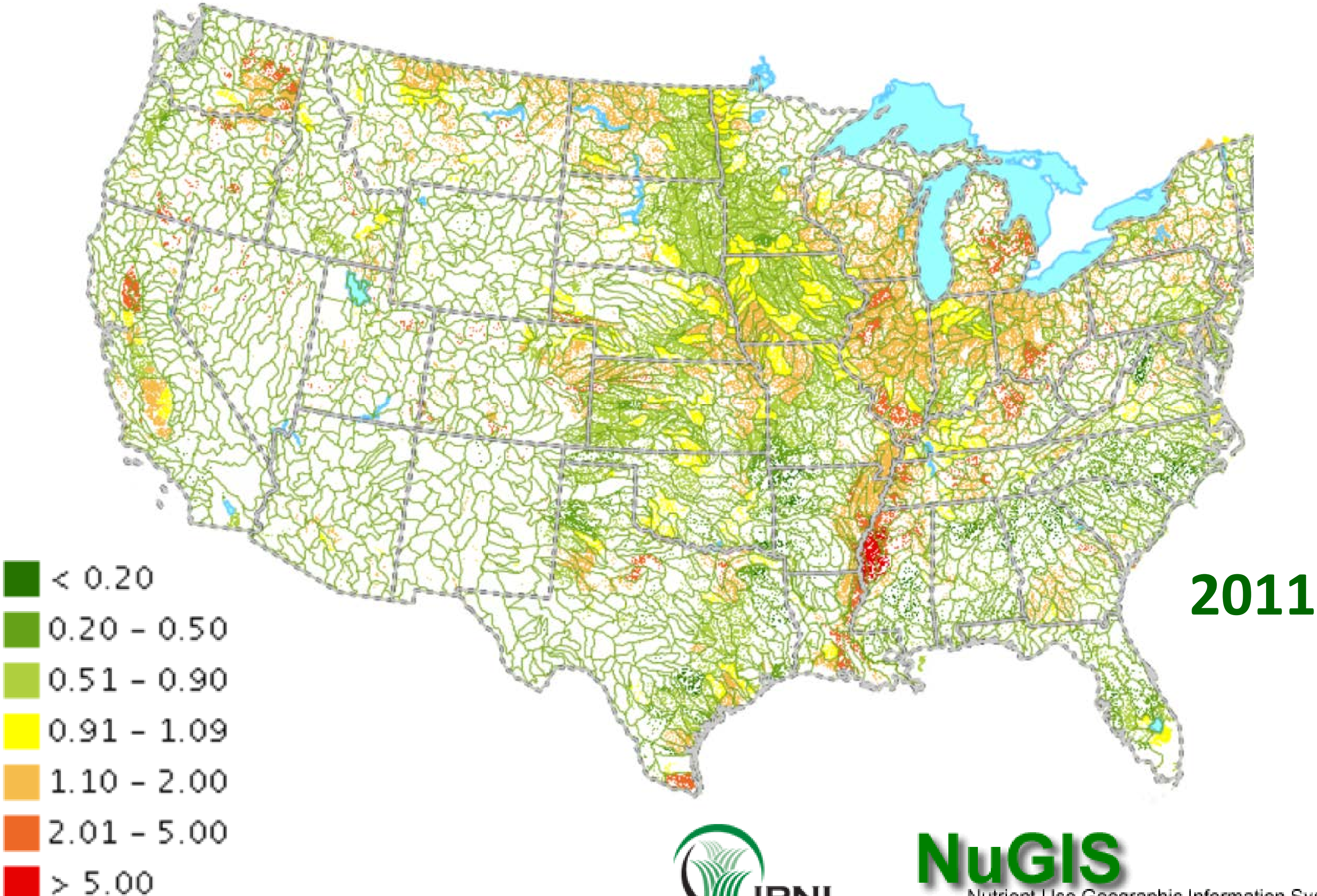
Soil test-crop response calibrations
414 P trials fit your initial selection criteria. Their locations with Australian Soil Class are plotted on the map.
NW
N
NE
NT
QLD
47610
47405
E
SE
print
405 P Treatment Series
% Relative Yield
100
90
80
70
60
50
40
30
20
10
0
10
Trial 46648
Harvested: november
Site: 1966 trial 48
Location: Irongate QLD
Data owner: QDPI
Data custodian: Strong
Season: winter
Farming system: dryland
Experimental Design: Nutrient Rate Factorial (eg N rates x P rates)
Crop: cereal: wheat
Rainfall Period: april - december
Growing season rainfall (mm): Farm: 234
Stored Profile Water (mm): 34
Soil Water Holding Capacity: 290
Australian Soil Classification: Vertosol black
Local Soil Name: Oakview sandy loam
Nutrient(s) studied: N,P
Fertiliser Products used: urea (N) superphosphate double (PS)
Reference: W M Strong, J K Hitchener and J E Cooper, Unpublished data
Treatment Series Statistics
Treatment Series ID : 1613
Description : 5NX3P
Nutrient Studied : N
P rate : 40.00000
Time of Application : sowing
Nutrient Placement : side banded
Tillage System : multiple tillage pre sowing
Row Spacing : 18cm
Product : urea
No Treatment Data
Statistical Analysis:
Response Measured : mean grain yield (t/ha)
Statistical Model : none
Coefficients
Statistics
A:
Ftest:
B:
100r2:
C:
LSD 05:
Yo: 1.245
RY: 100
Ymax: 1.245
CV:
Soil test calibratio
80% Relative Yield: 14.
90% Relative Yield: 22.
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

PUE: Ratio of removal to use varies across US cropland



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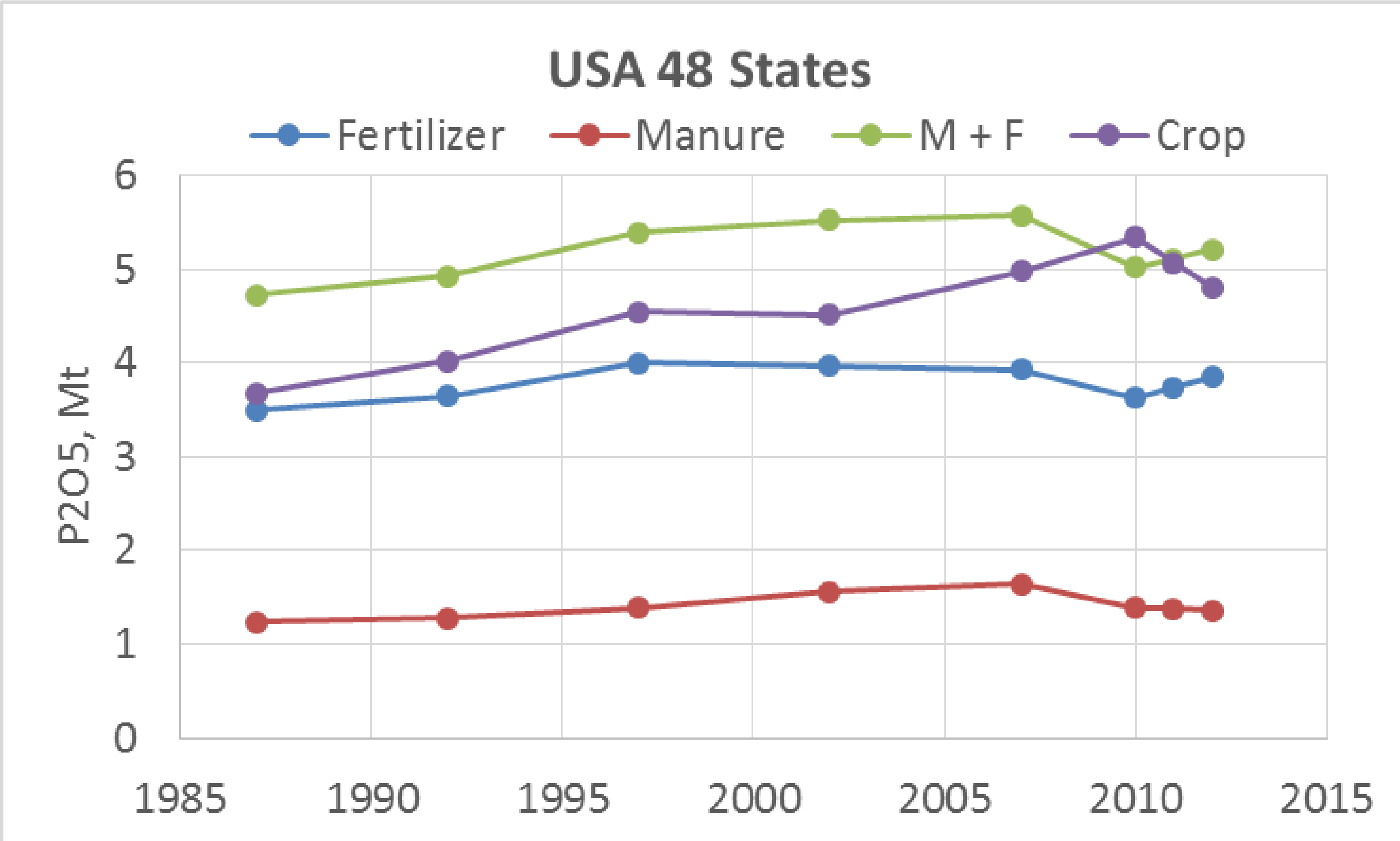
NuGIS
Nutrient Use Geographic Information System

Phosphorus Balance, USA – on average, seldom in deficit



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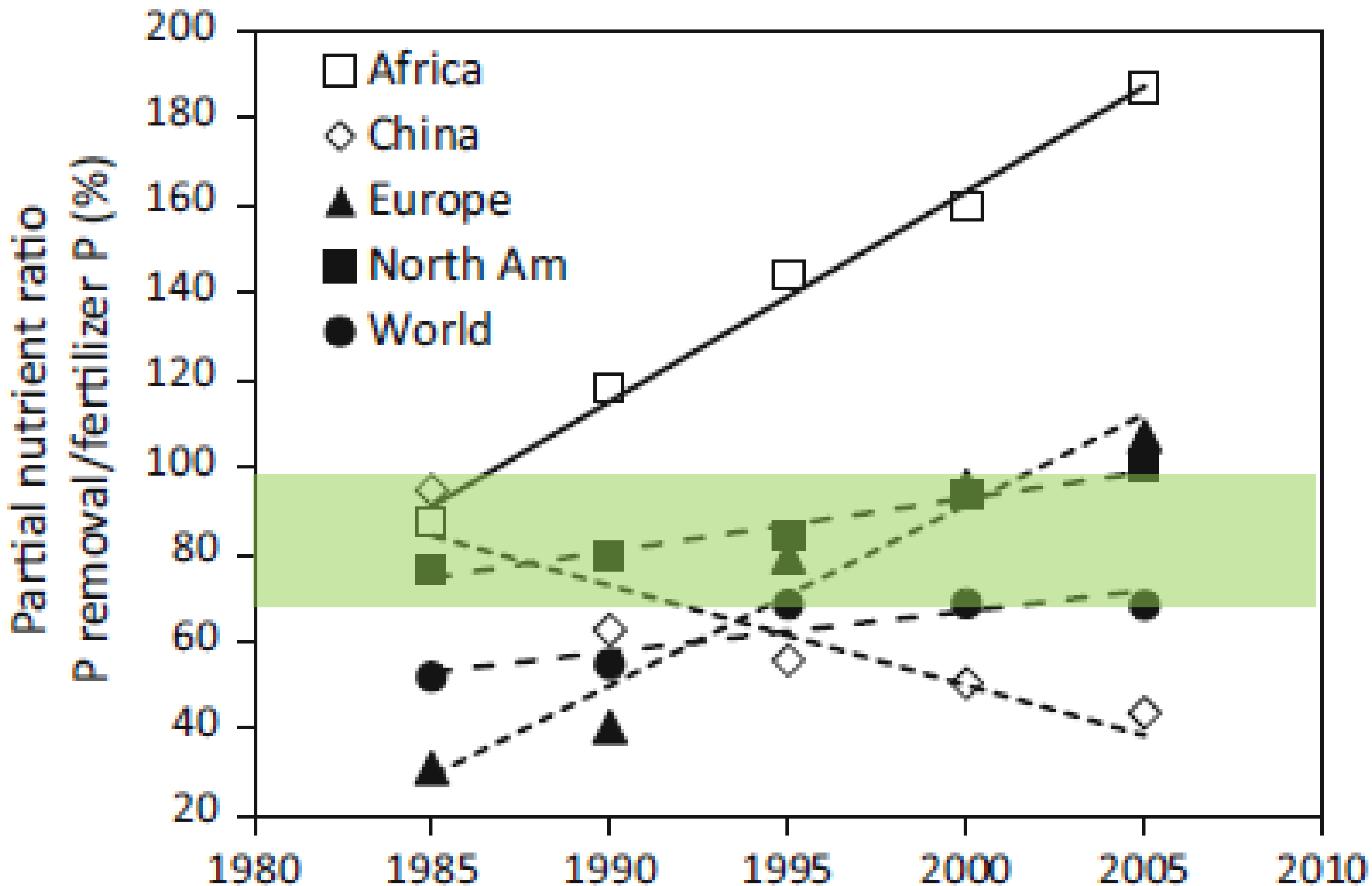
NuGIS
Nutrient Use Geographic Information System

Global cropland PUE of ~70% is the average of too much and too little



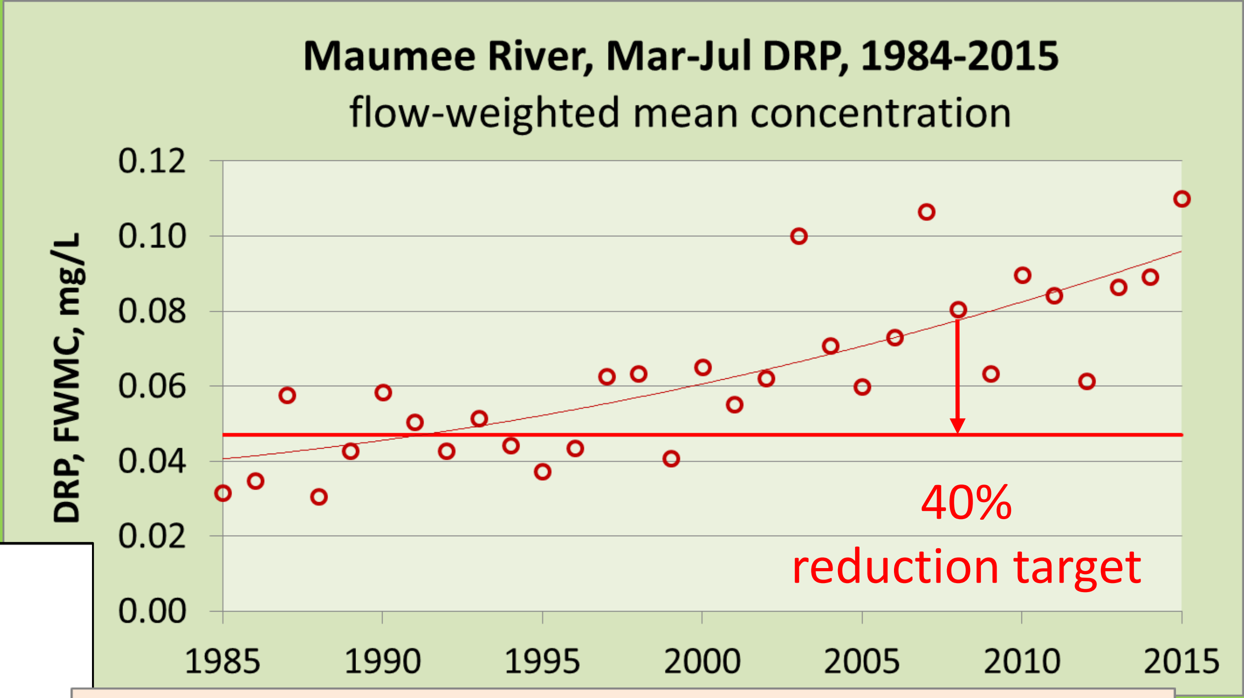
Fixen et al., 2015, cited in Nziguheba, Zingore, et al., 2016. Nutr Cycl Agroecosyst (2016) 104:321–340

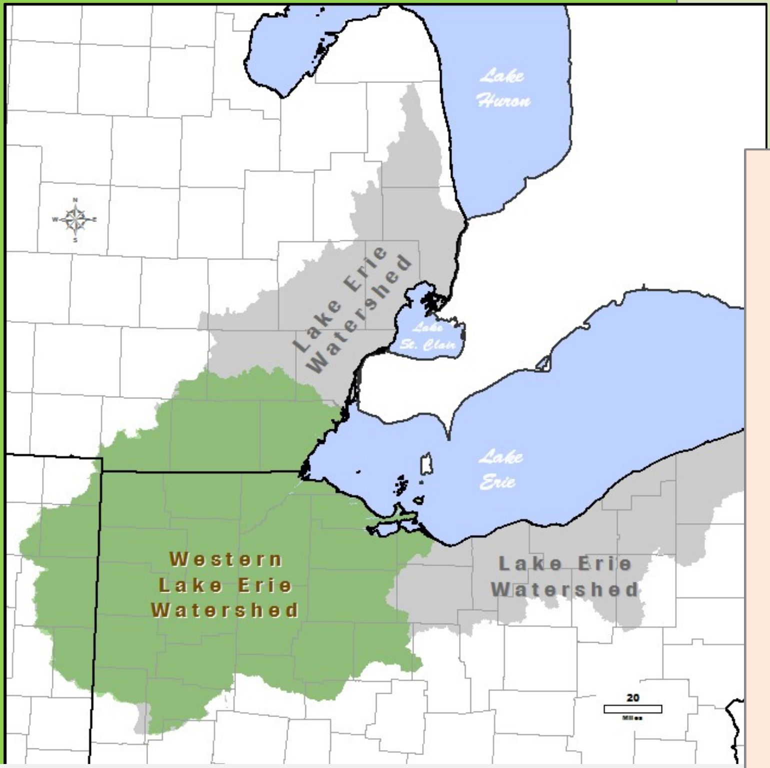
Phosphorus – legacy and use efficiency

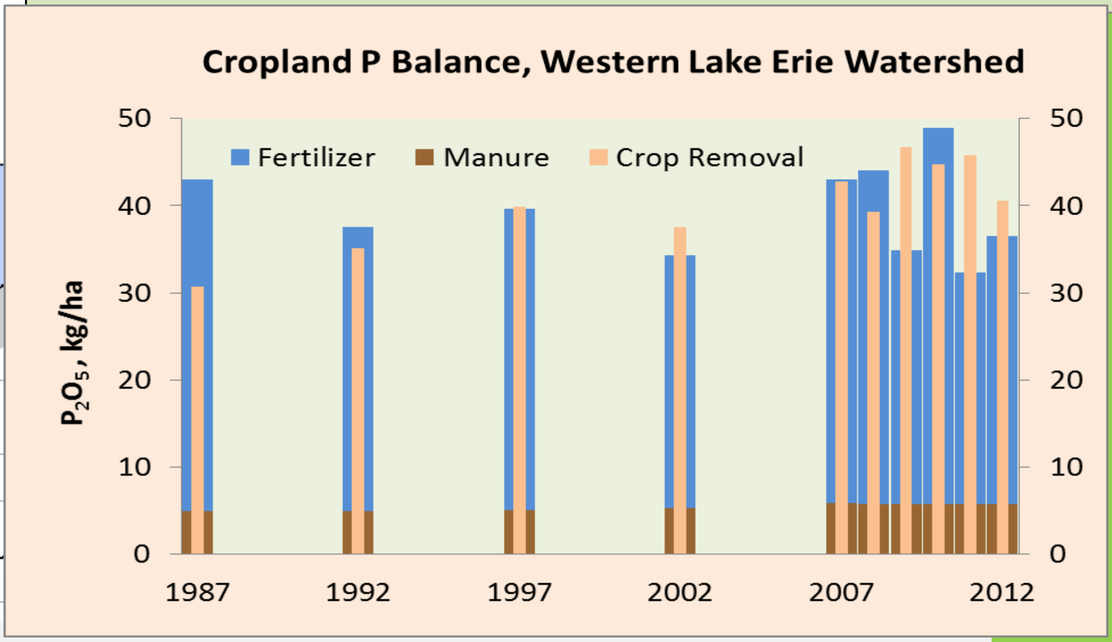
- Legacy
  - Feeds the world
  - Global food security
  - Increased soil fertility
  - In cropland soils, two levels: beneficial and risk to water quality
  - Storage in sediments in stream, river, and lake
- Use efficiency
  - Minimizes surplus available for loss
  - Increases reserve life of finite resources
  - Recovery does not = balance
  - Requires optimum soil test level

4R practices may impact water quality more than use efficiency

Western Lake Erie watershed: cropland P in balance, but dissolved P losses increasing.







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

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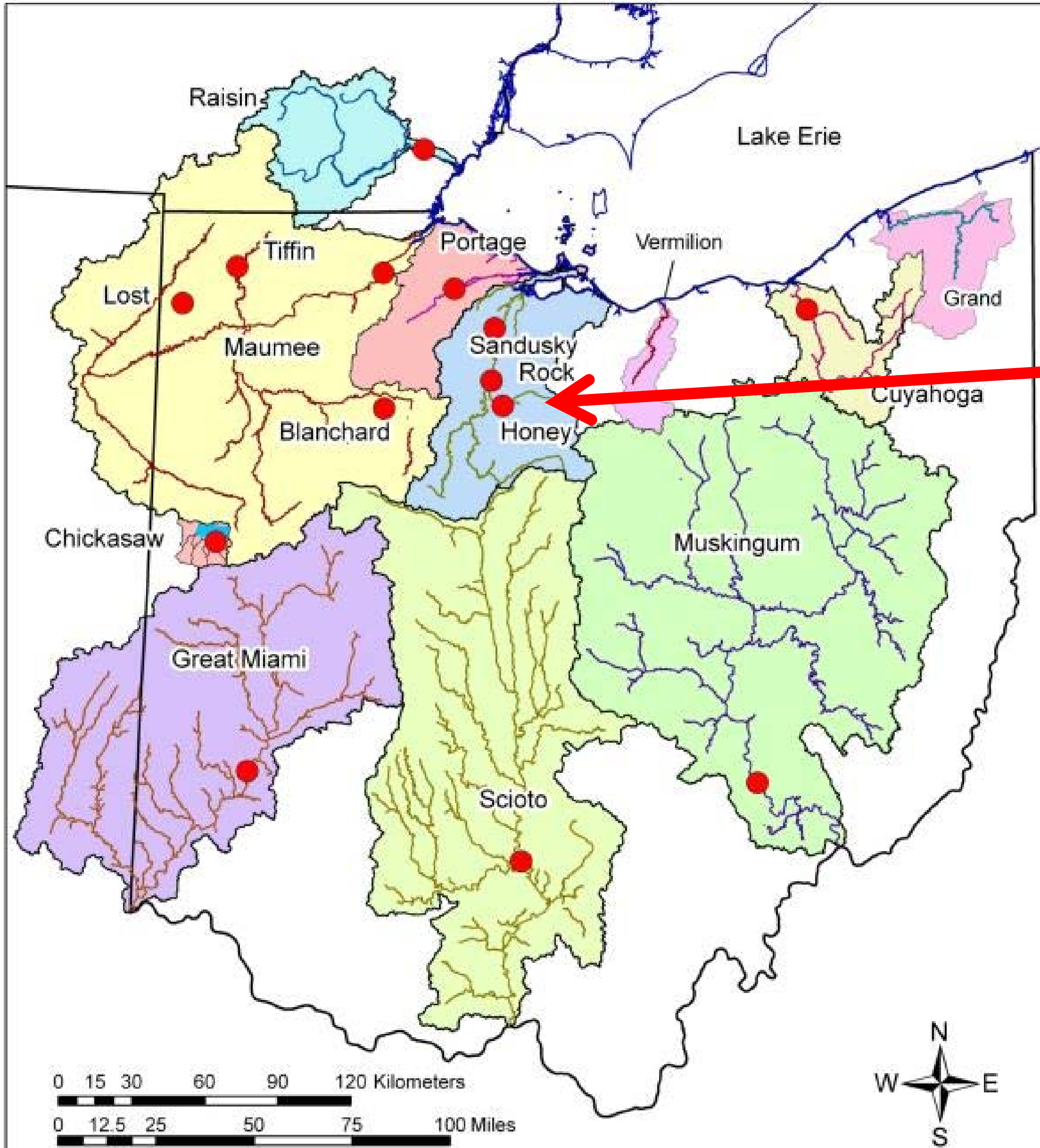
P loss monitored at a watershed scale



The Heidelberg University Tributary Loading Program

Honey Creek Watershed:

- **~38,000 hectares**
- **~80% row crops**
- **drains into the Sandusky River**

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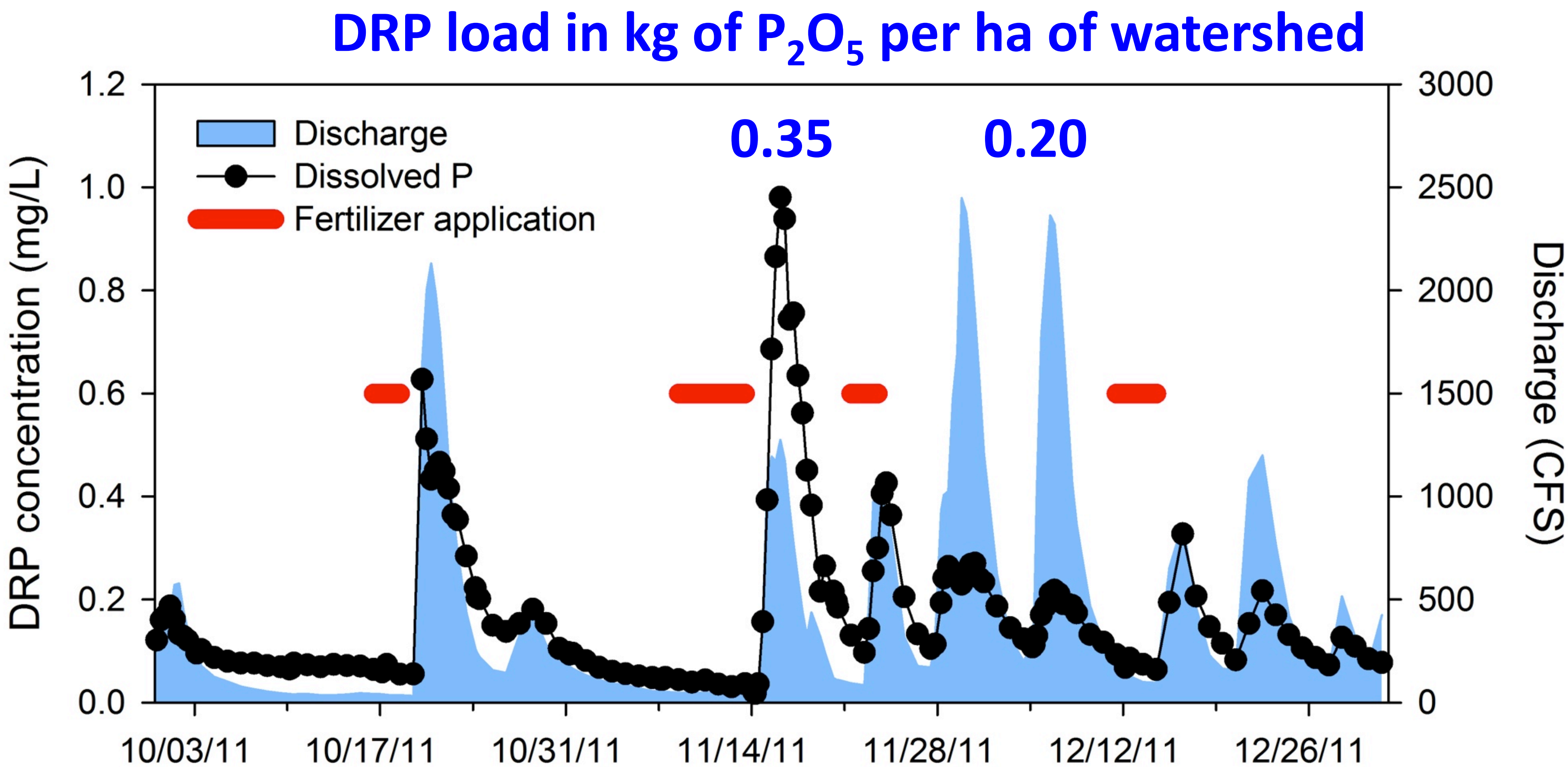
Right Time



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.

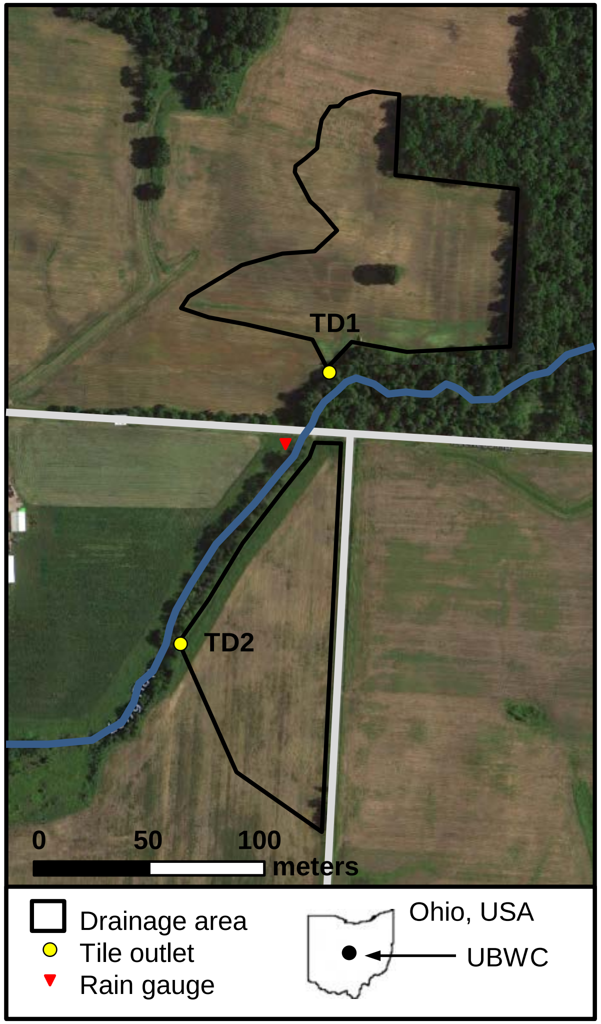
David Baker and Laura Johnson, Heidelberg University

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

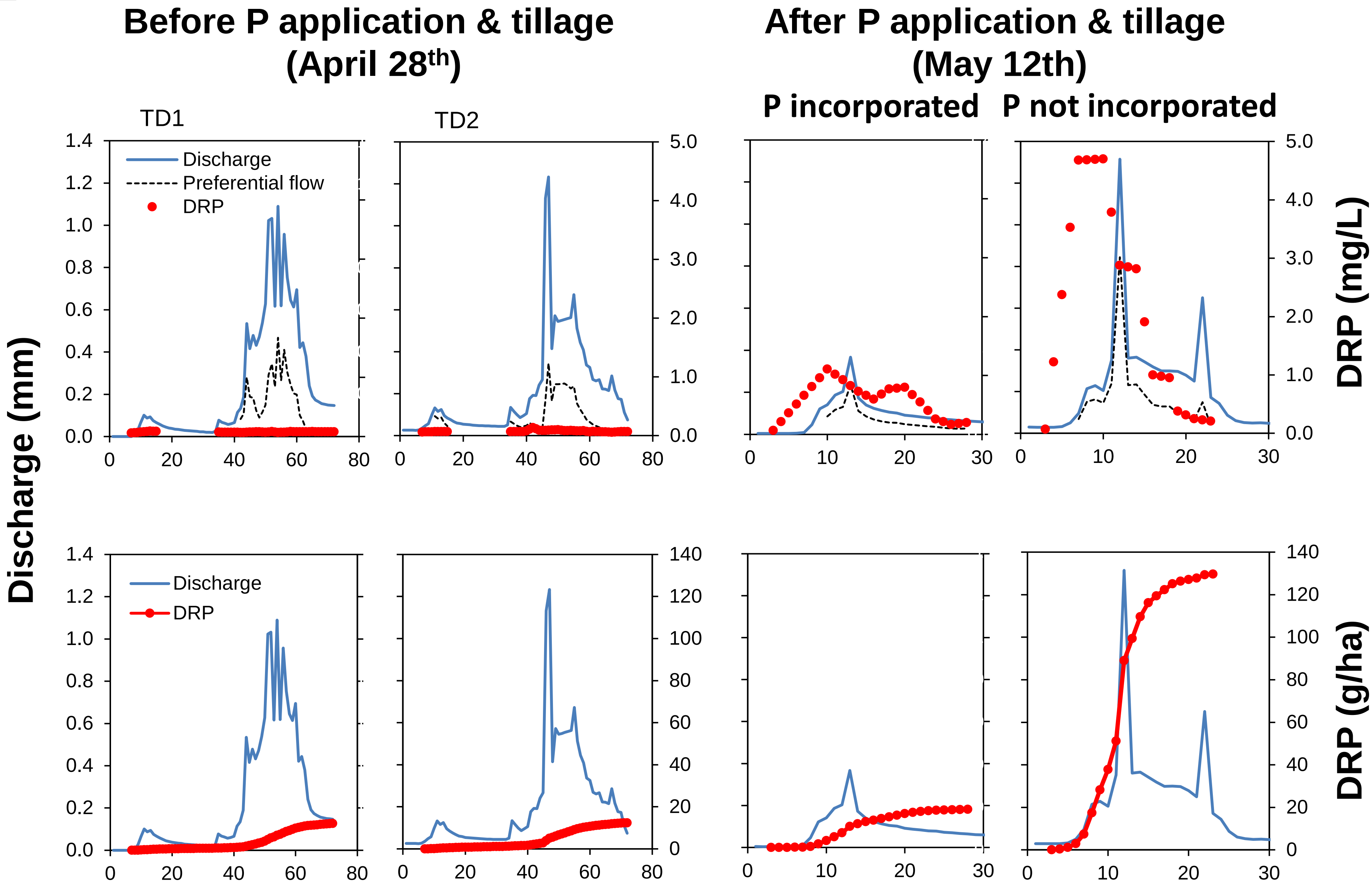
Soil type: Silt loam
Tile depth: 75 cm
Soil test P: 30 ppm Mehlich-3P
Tillage: No-till

<u>2014 management</u>
May 6th – Applied MAP @ 200 kg/ha
May 8th – Tilled field TD1 (disc)
(TD2 remained no-till)

<u>Study Objective</u>
Compare P transport before and after tillage and between tilled and no-till fields



Williams and King, USDA-ARS, Columbus, Ohio



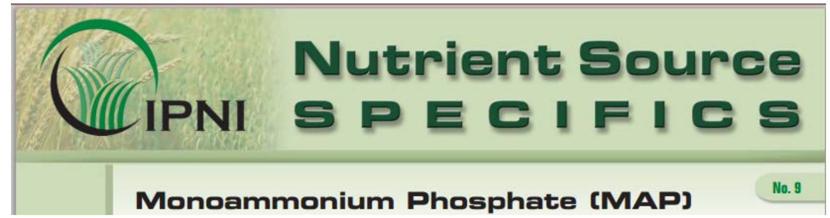
Incorporating P reduced DRP loss by 70% over 5 rain events (from 0.9 kg P_2O_5/ha)

Williams and King, USDA-ARS, Columbus, Ohio

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



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

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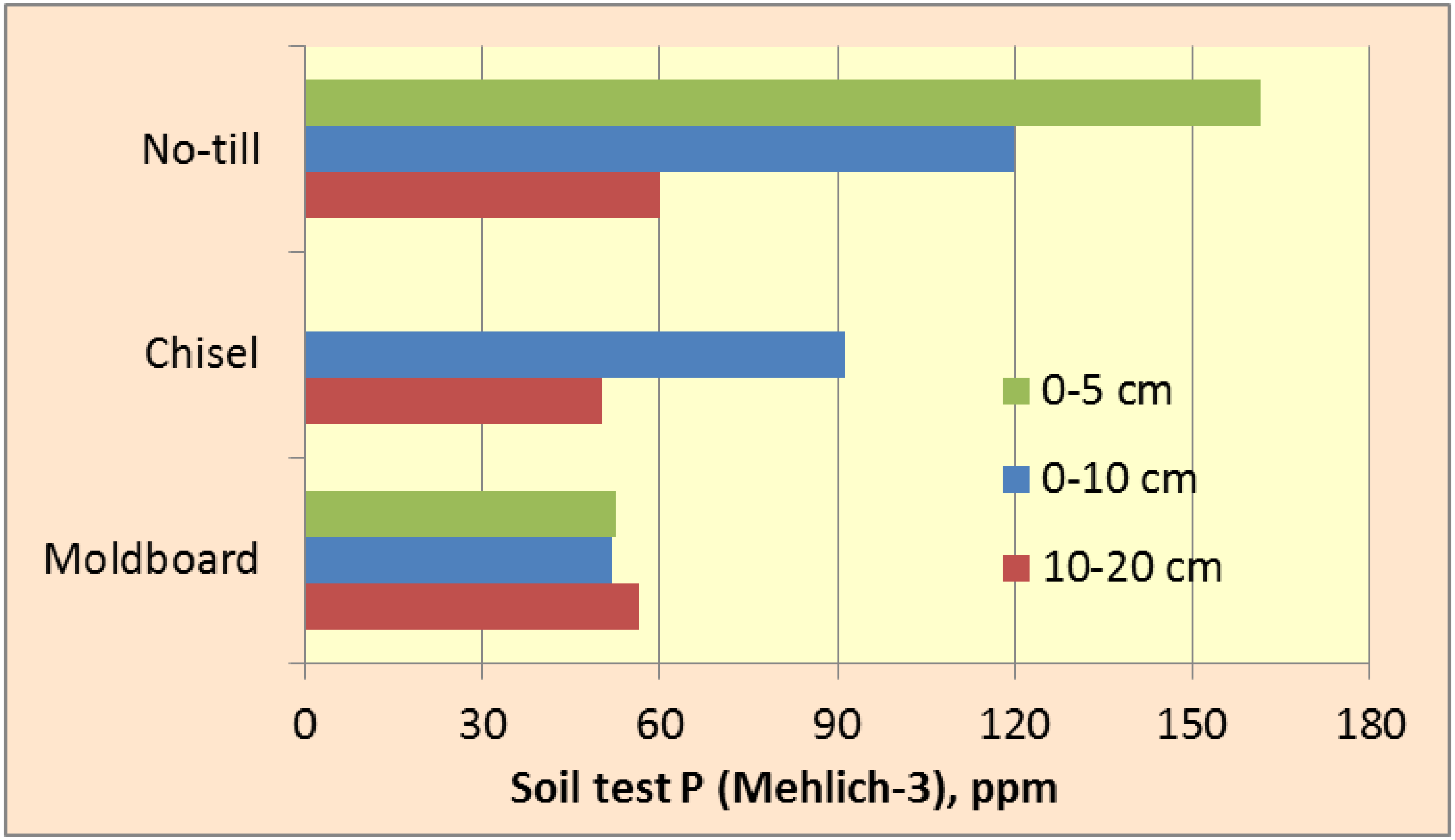
Soil test P stratifies when moldboard plowing stops



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.

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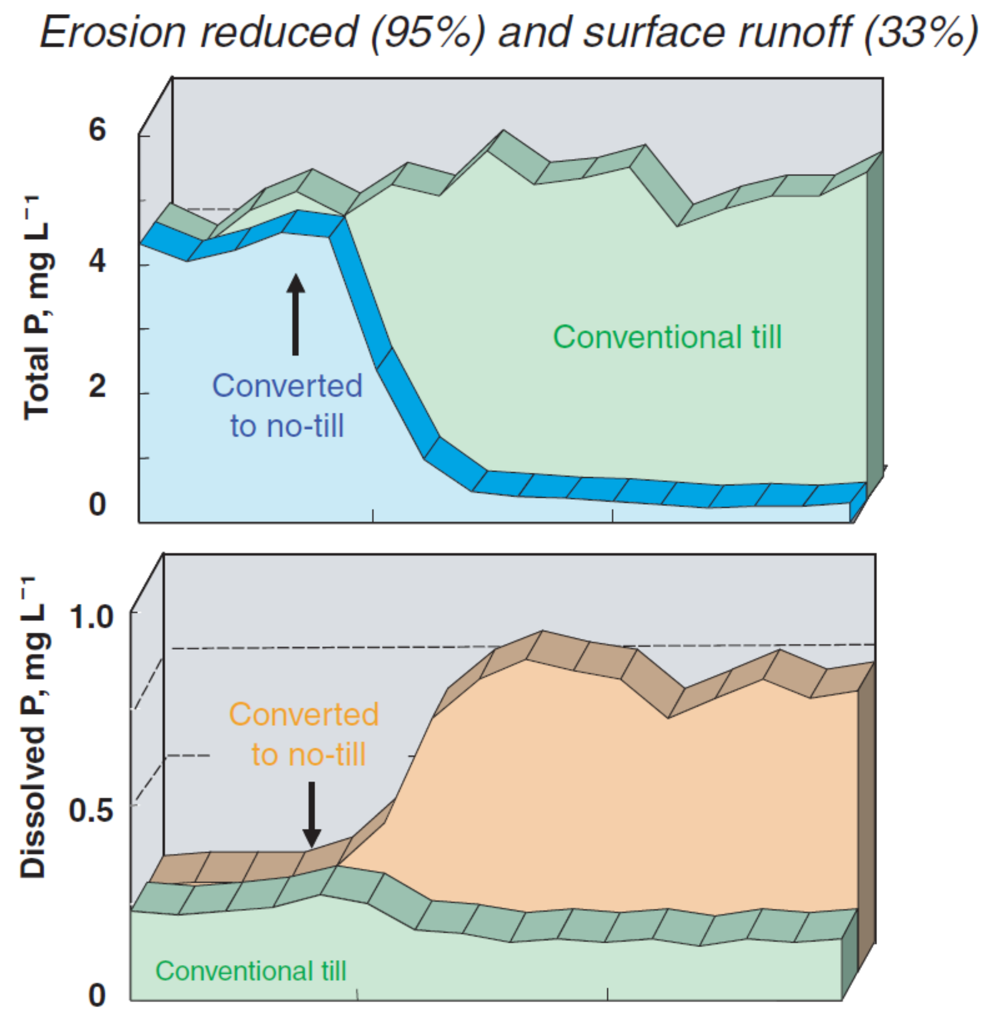
Tillage increases erosion, but can increase dissolved P

The conversion of conventional moldboard plow wheat to no-till wheat decreased total P transport in surface runoff but increased dissolved P in runoff … 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

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/

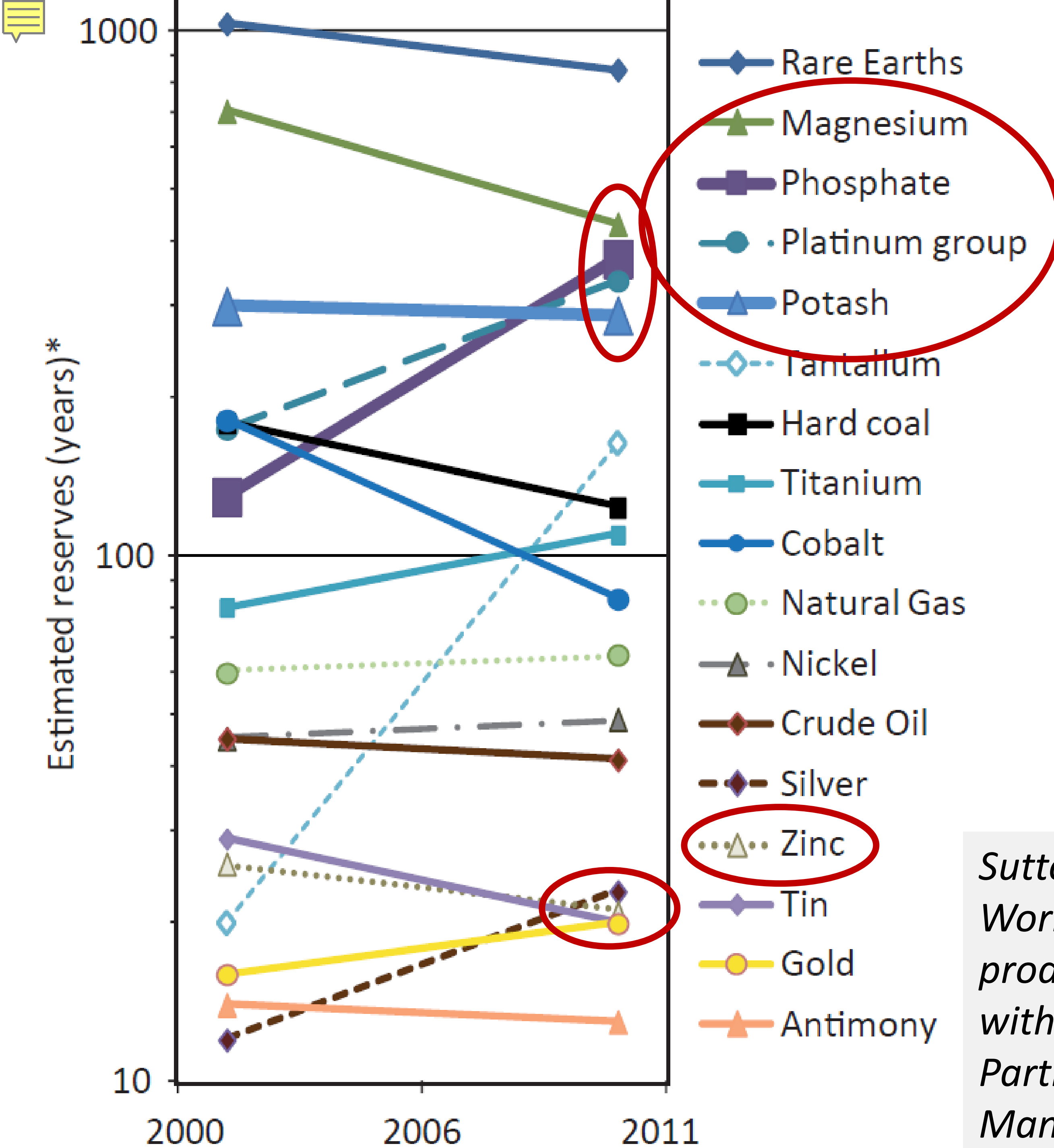
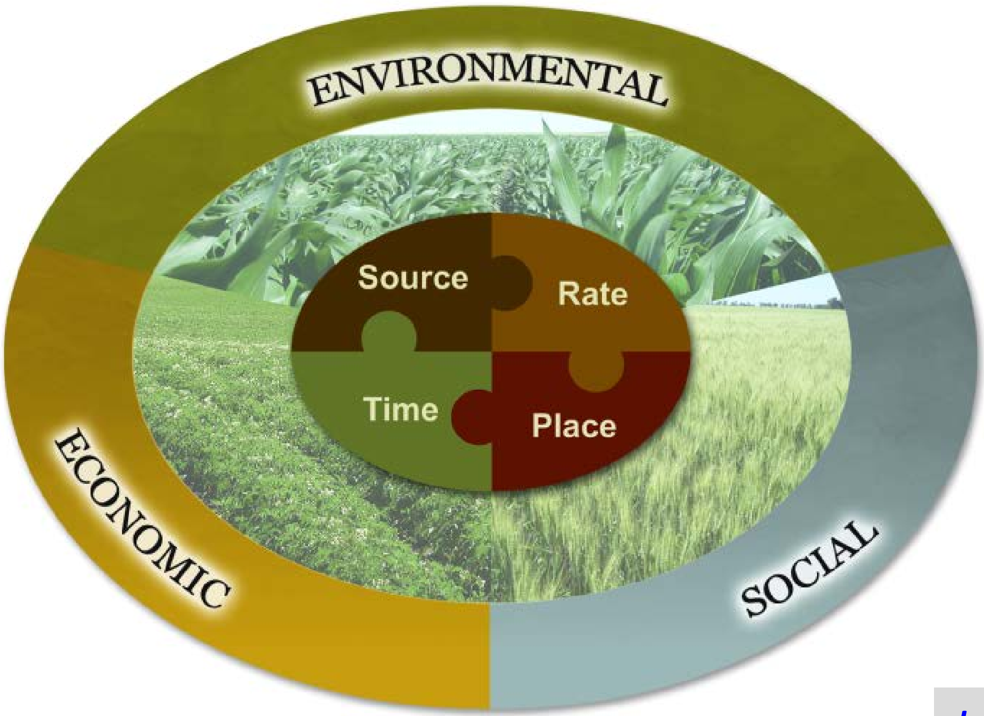


Figure 2.9 Putting phosphorus and potassium (potash) reserves into context.

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.

4R: "right" means sustainable



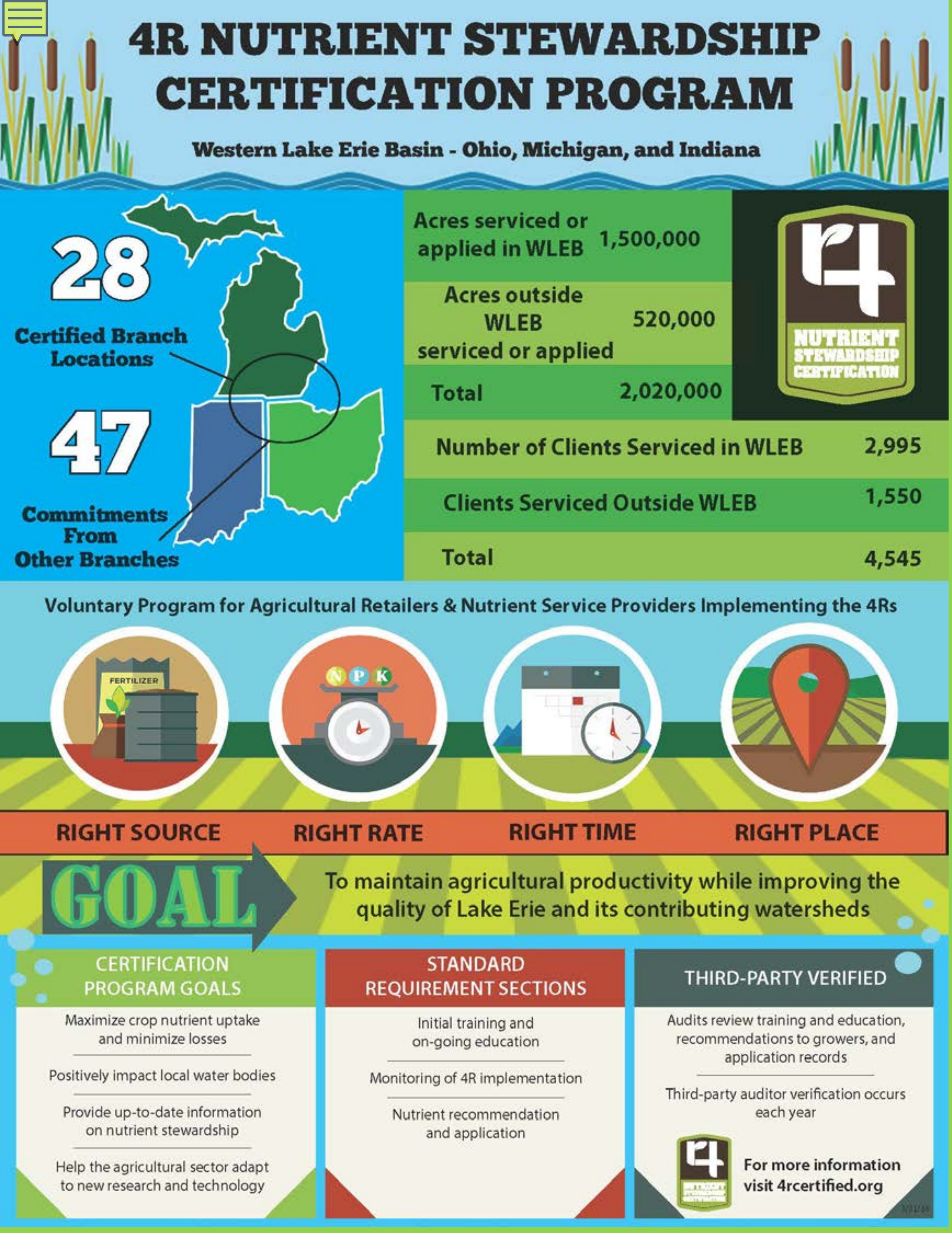
Field to Market®

The Alliance for Sustainable Agriculture

http://www.ipni.net/4r-decisionguides

4R nutrient stewardship

DECISION-MAKING GUIDE PHOSPHORUS



- Regional implementation of 4R
- Western Lake Erie Basin – OH, MI, IN
- Focus on phosphorus
- Current reach over 2 million acres (800,000 ha)

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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

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 benefits and costs in terms of all key outcome metrics: yield, soil health, NUE, and water quality.

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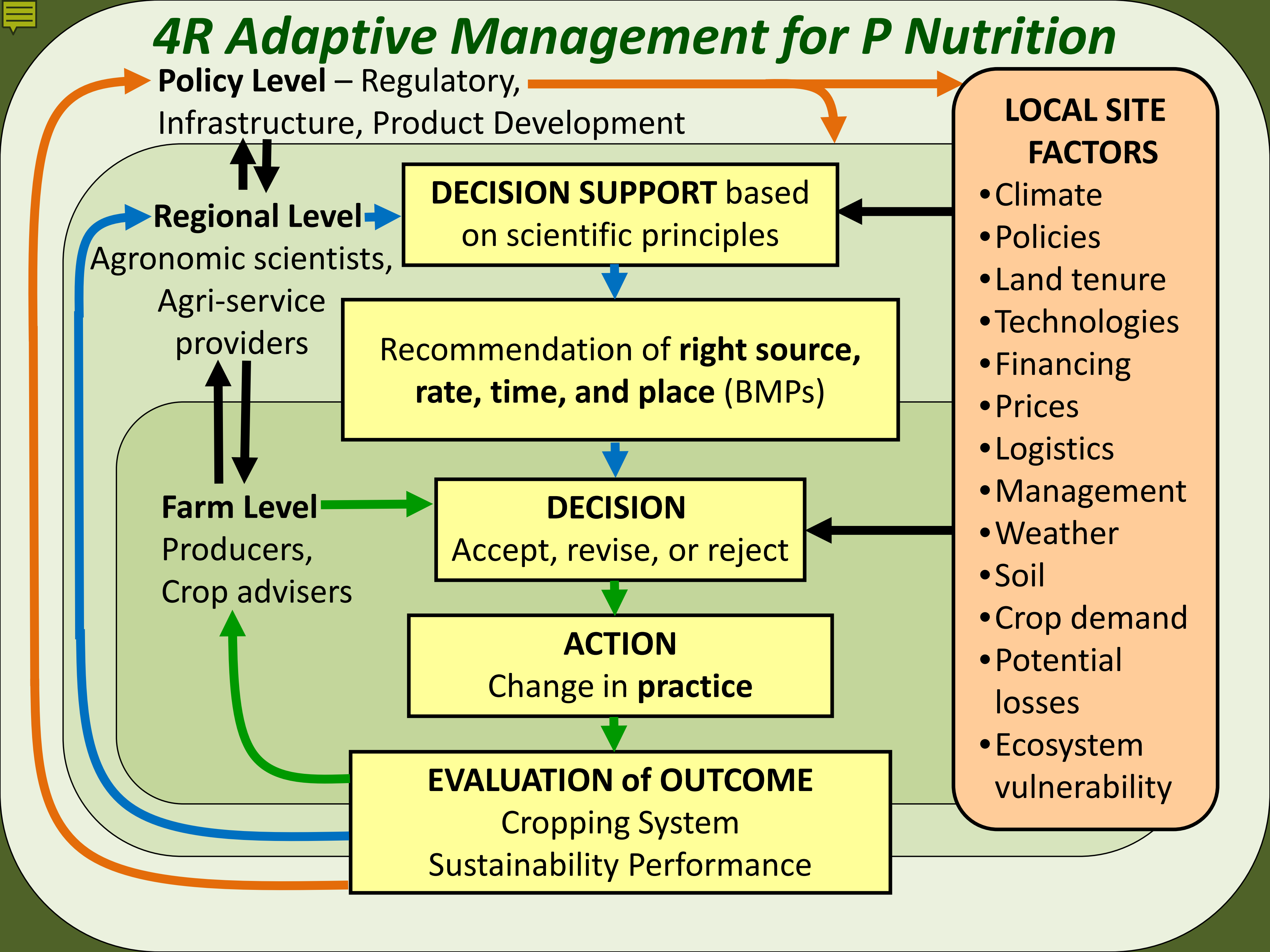
Some growers fertilize all their crops in bands near the seed.


4R Adaptive Management for P Nutrition
Policy Level – Regulatory, Infrastructure, Product Development
Regional Level
Agronomic scientists, Agri-service providers
Farm Level
Producers, Crop advisers
DECISION SUPPORT based on scientific principles
Recommendation of right source, rate, time, and place (BMPs)
DECISION
Accept, revise, or reject
ACTION
Change in practice
EVALUATION of OUTCOME
Cropping System Sustainability Performance
LOCAL SITE FACTORS
• Climate
• Policies
• Land tenure
• Technologies
• Financing
• Prices
• Logistics
• Management
• Weather
• Soil
• Crop demand
• Potential losses
• Ecosystem vulnerability

Certified Crop Adviser Specialties

- 4R Nutrient Management Specialist
  - Performance objectives effective May 2015
  - Currently 100 certified 4R Nutrient Management Specialists
  - 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
  - References 4R Nutrient Stewardship

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Summary – Phosphorus Sustainability

- Spheres of phosphorus sustainability and agricultural sustainability intersect, and thus the scientists need to interact.
- 4R stewardship of phosphorus seeks to improve crop yields, maintain soil health, improve water quality, and conserve finite resources.
- Need continued adaptive management and research:
  - tillage and placement to reduce BOTH particulate and dissolved losses,
  - improved access to scientific data supporting 4R practices, and
  - increased recognition of 4R practices in sustainability reporting.

http://phosphorus.ipni.net

Tom.Bruulsema@ipni.net

4R nutrient stewardship

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