Proceedings of the 11th Nutrient Management Conference

Phosphorus Management Challenges Confronting the U.S.

Heidi Peterson
Phosphorus Program Director
Stillwater, Minnesota

Minnesota Nutrient Management Conference
St. Cloud, Minnesota
February 19, 2019

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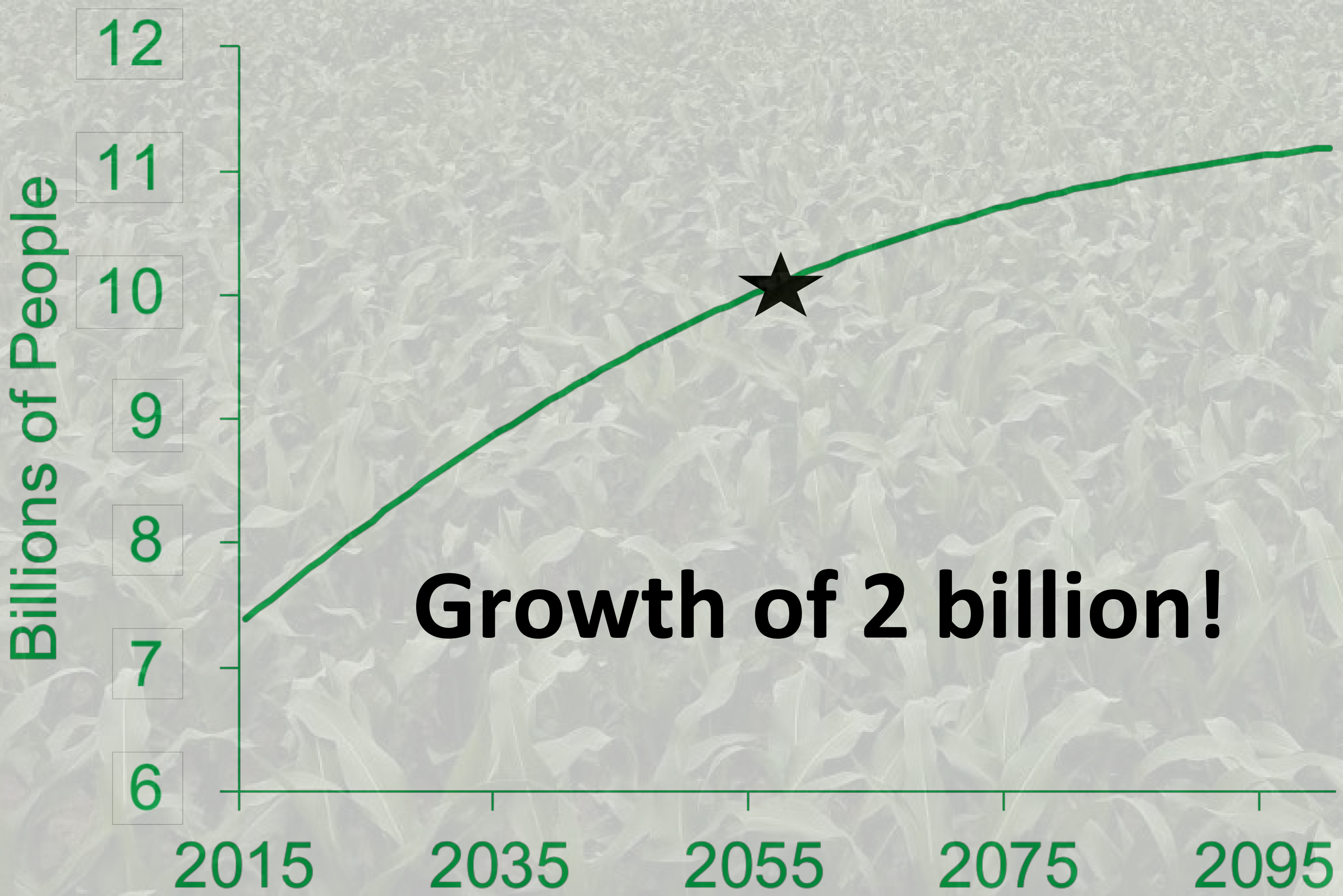
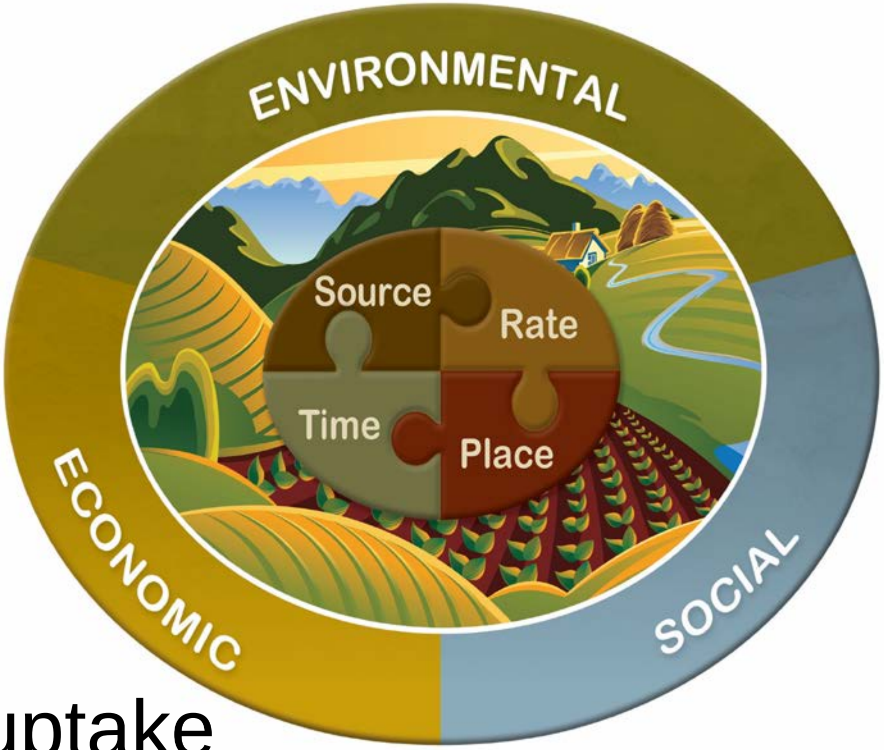
Global population >9 billion by 2050



Data Source: UN, 2017

4R Nutrient Stewardship:



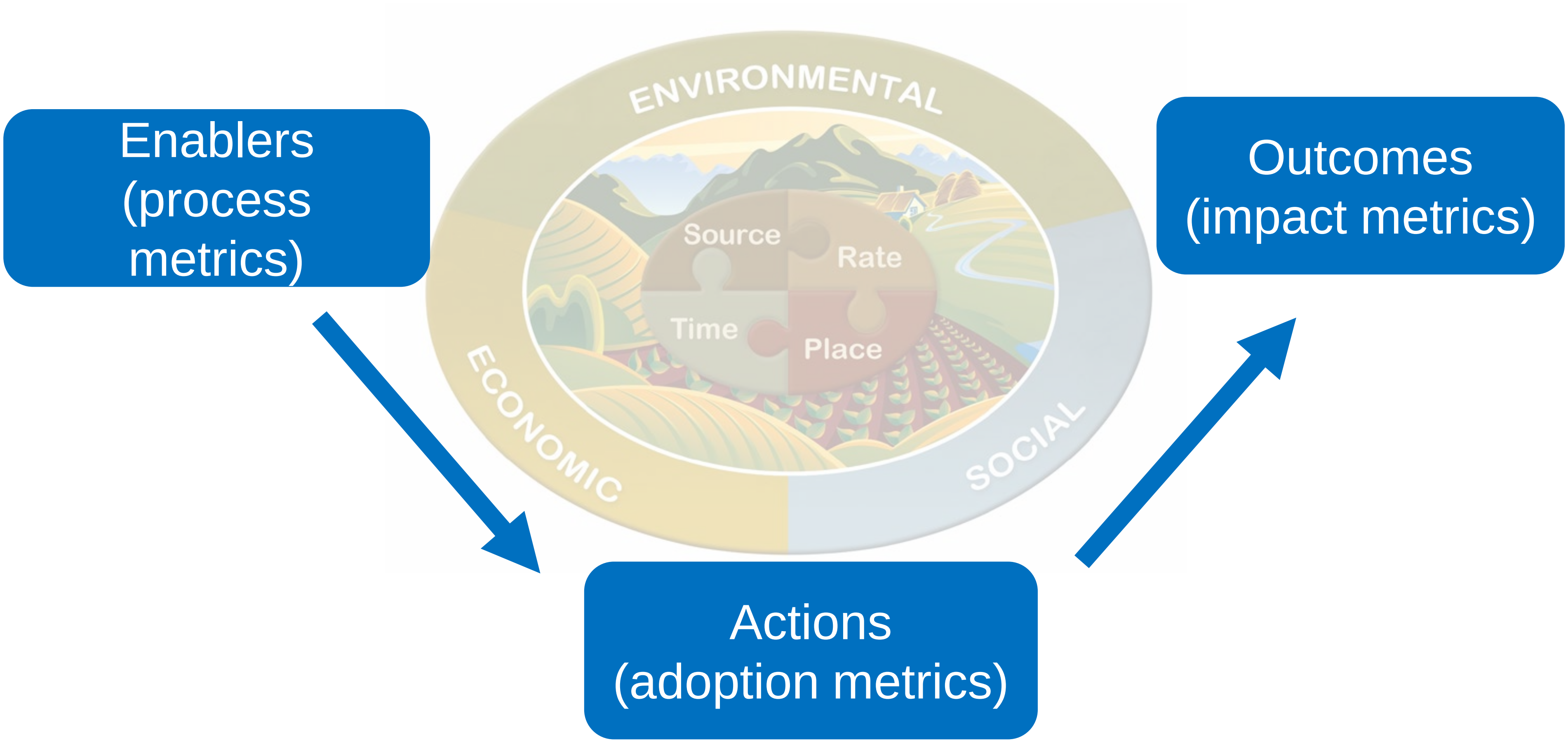
Right **Source** of fertilizer

Right **Rate** for crop needs

Right **Time** to match crop uptake

Right **Place** so crops can utilize

Nutrient Stewardship Metrics for Sustainable Crop Nutrition



Enablers: Process Metrics

Extension & ag professionals
Infrastructure
Stakeholder engagement
Research & innovation

Actions: Adoption Metrics

Cropland area under 4R

Requires regional definitions of 4R practices

Outcomes: Impact Metrics

- Farmland productivity
- Soil health
- Nutrient use efficiency
- Water quality
- Air quality
- Greenhouse gases
- Food & nutrition security
- Biodiversity
- Economic value

P is an Essential Fertilizer Ingredient

- Involved in photosynthesis, energy transfer, cell division and enlargement
- Important in root formation and growth
- Improves the quality of fruit and vegetable crops
- Is vital to seed formation
- Improves water use
- Helps hasten maturity

P Fertilizer and the Soil

15
P
Phosphorus
30.974

- P taken up by crops primarily as orthophosphate ($H_2PO_4^-$ and HPO_4^{2-})
- Common commercial P fertilizers are highly (≥90%) water soluble
- Once dissolved in soils, orthophosphate is available for plant uptake
- P chemistry in soils is complex – P may become sparingly available to plants in some soils due to formation of less soluble products

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Why Focus on P?

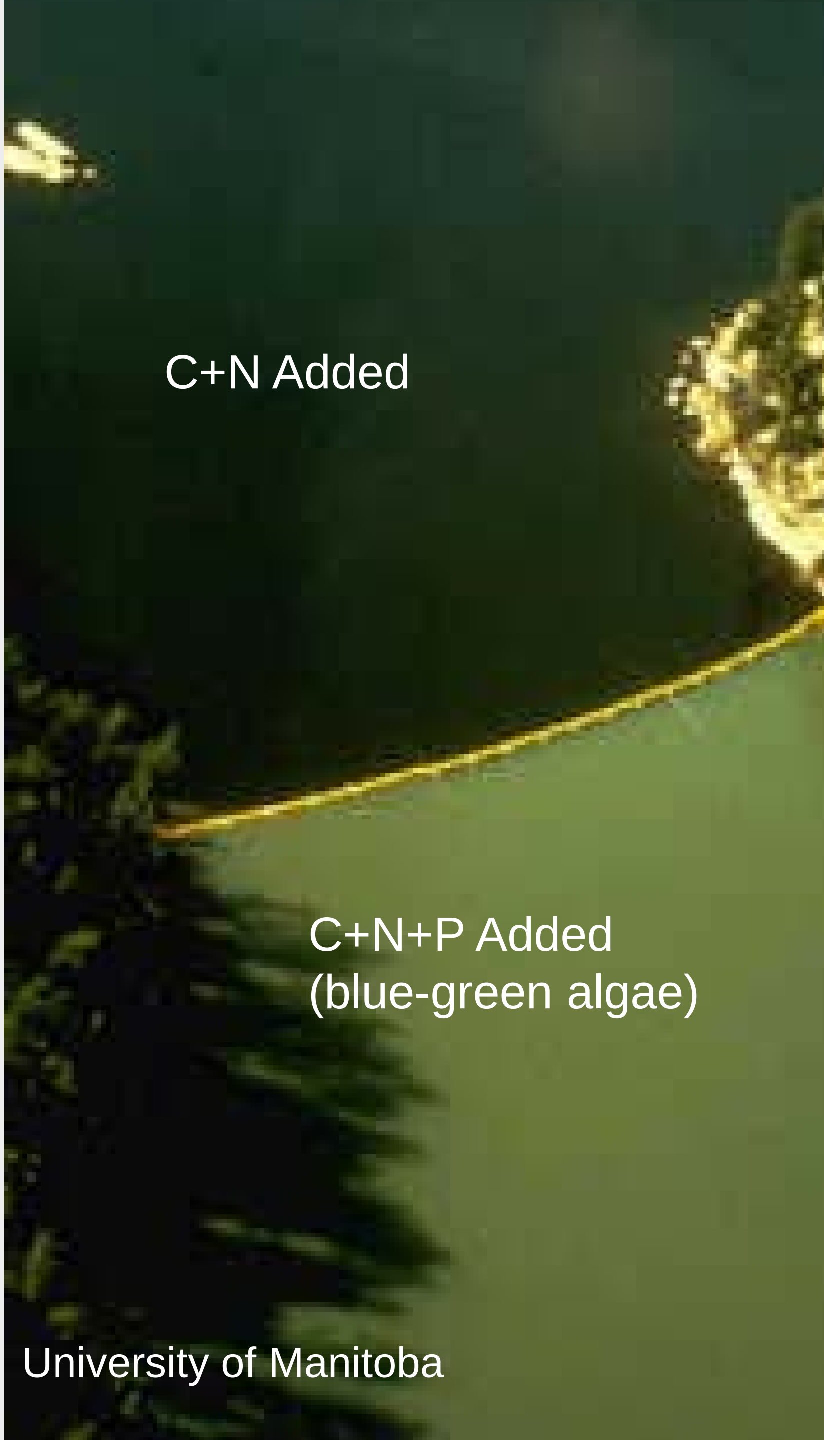
Eutrophication – the natural aging of lakes or streams by nutrient enrichment

Nutrient additions can accelerate the process

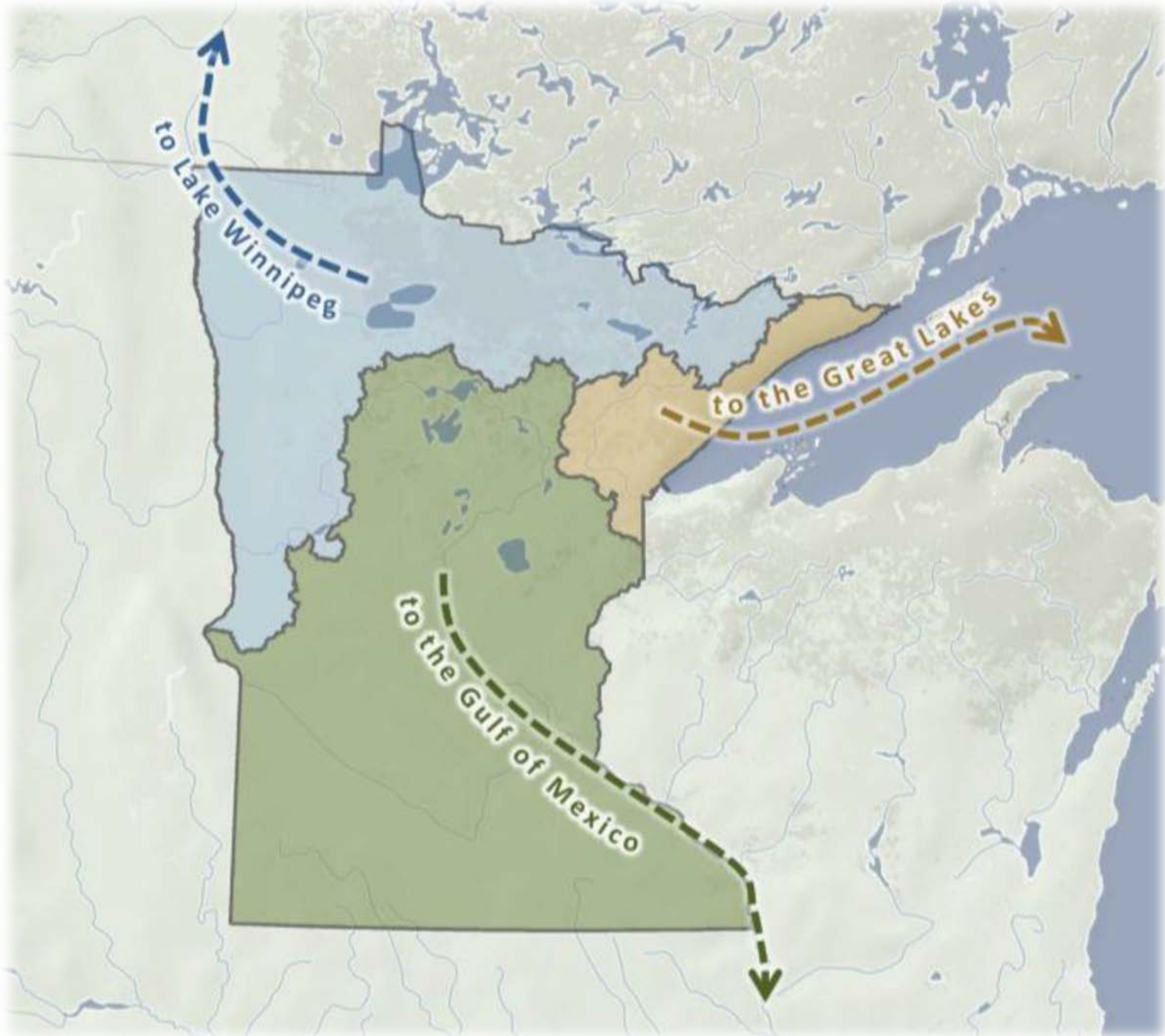
P is often the limiting element

Dissolved oxygen is depleted by excessive plant growth

Best management practices (BMPs) can help minimize P runoff from fields




Do I have you convinced?
year fight removes less than 1% of phosphorus
innipeg basin
geted action needed against nutrient causing toxic algae blooms, scientists and advocates say
ameron MacLean, CBC News Posted: Sep 17, 2017 4:00 AM CT | Last Updated: Sep 17, 2017 11:02 AM CT
Stay Conn
Half of lakes and streams in southern Minnesota found too polluted for safe swimming, fis
Pollution tied to farms will take decades to fix, state st finds.
By Tony Kennedy
APRIL 30, 2015 — 5:33AM
DNR plan to save algae-plagued lake sparks optimism, opposition
Environment
Kirsti Marohn · Rice, Minn. · Jun 28, 2018

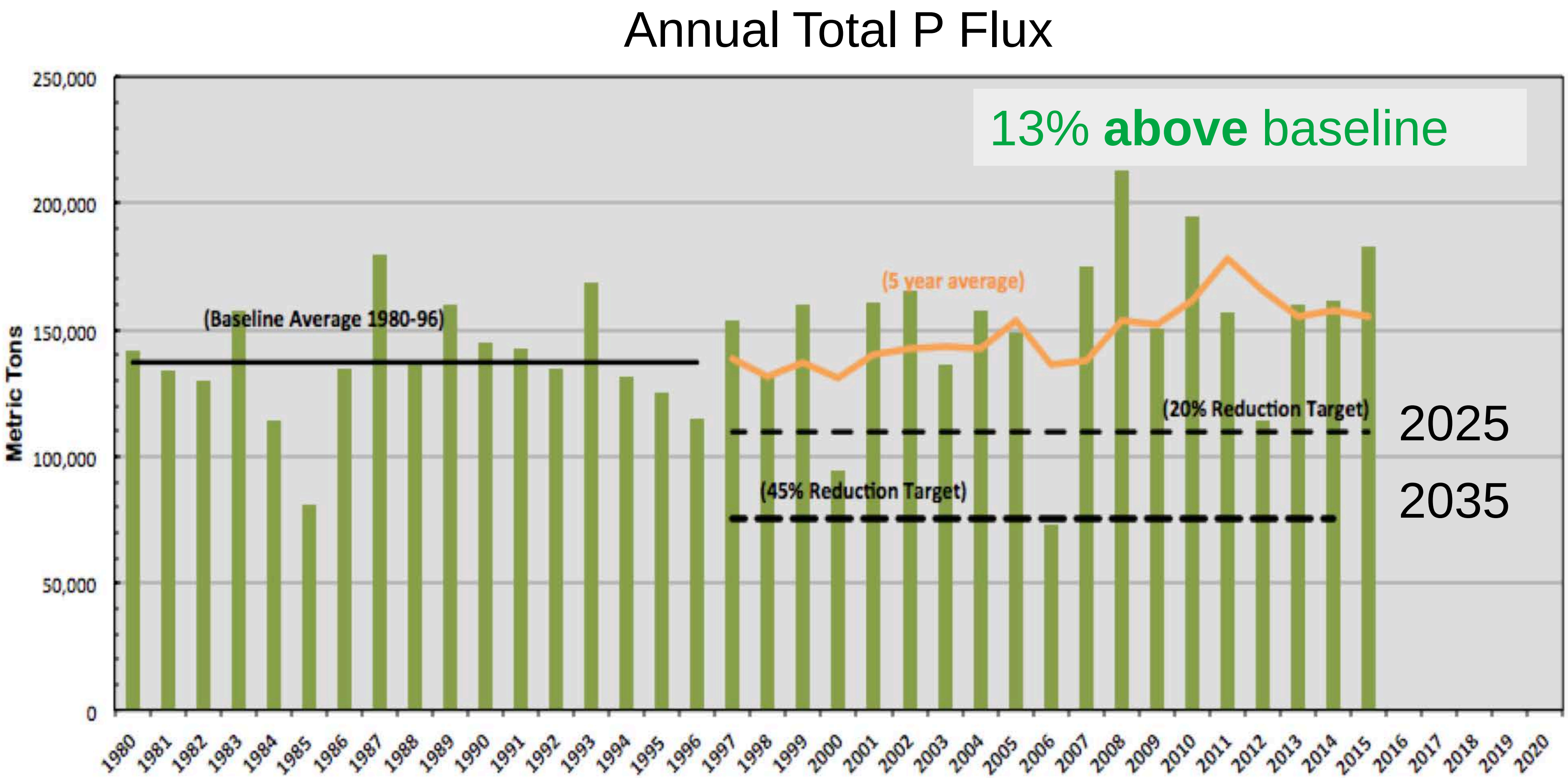


*MPCA, 2014. Minnesota Nutrient Reduction Strategy

Mississippi River Basin

Produces 40% of the world’s corn!

Total P Load to Gulf of Mexico



Graph from the HTF 2017 Report to Congress

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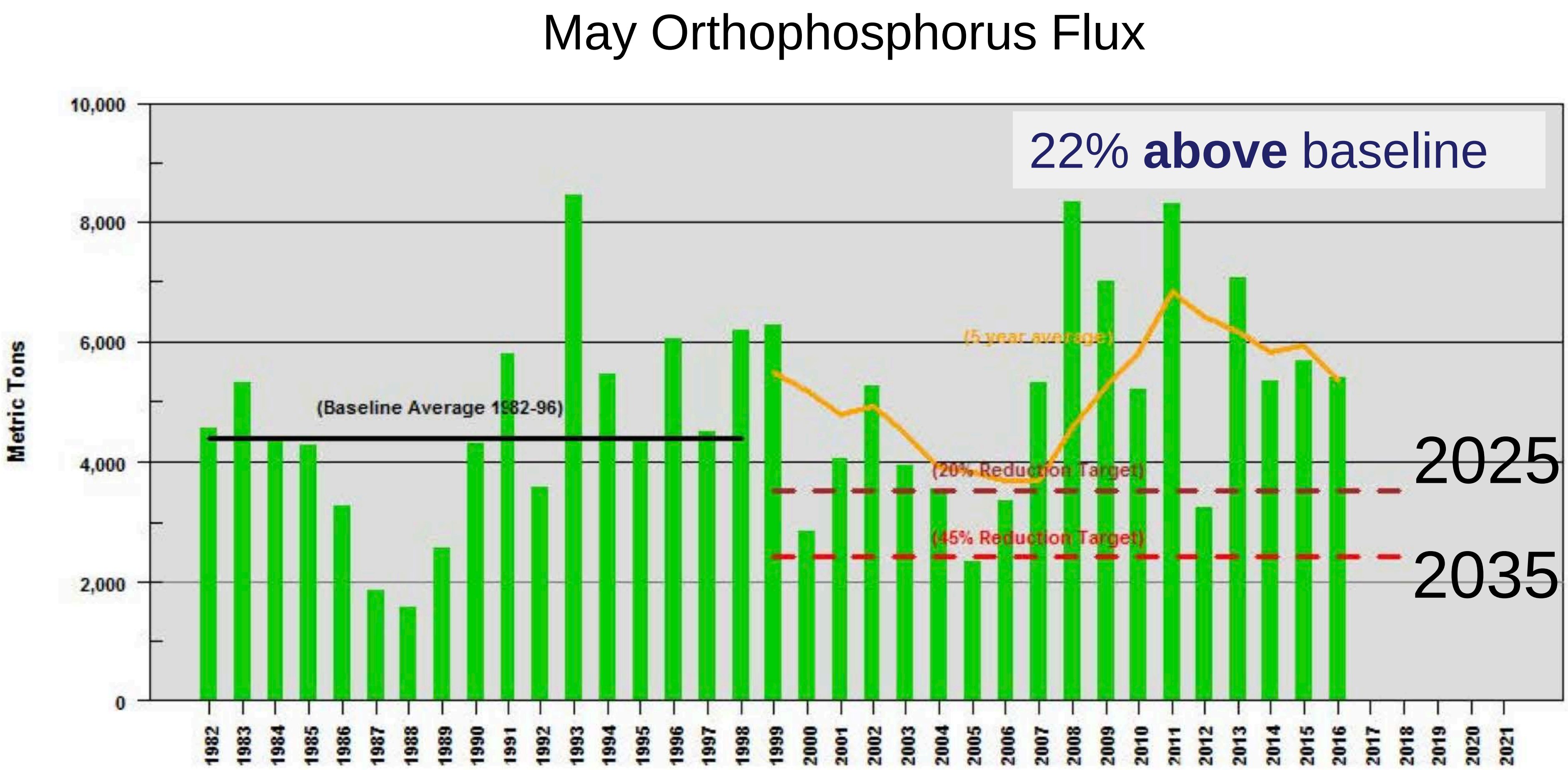
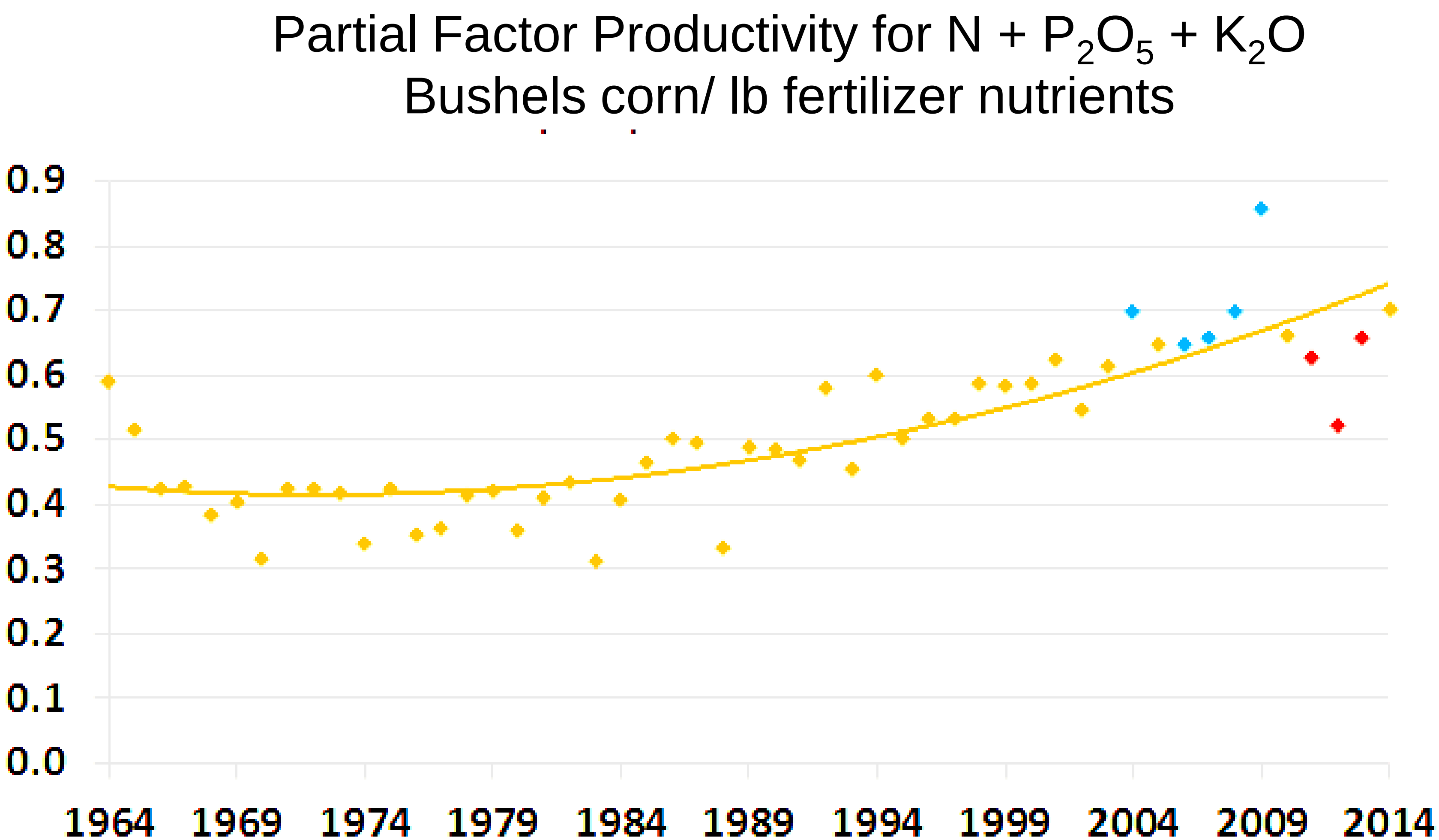
Ortho P Flux to Gulf of Mexico



Graph from the HTF 2017 Report to Congress

US Fertilizer Use Efficiency in Corn Doubled between 1980 and 2014



Critical value is the soil test level where recommended nutrient rates generally drop to zero in sufficiency approaches or to a crop removal level in build maintenance approaches.

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31 Mar 2016

Soil Test Levels in North America

2015 Summary Update

The 2015 Summary Update provides interpretive analysis of the results of the most recent survey of soil test levels for North America. This summary is a supplemental resource for the survey's new web-based data access system found at http://soiltest.ipni.net. This website provides new opportunities to view, compare, and contrast soil fertility data over the four most recent surveys (2001, 2005, 2010 and 2015). The site also provides full access to a range of charts, maps, and tabular data sets.

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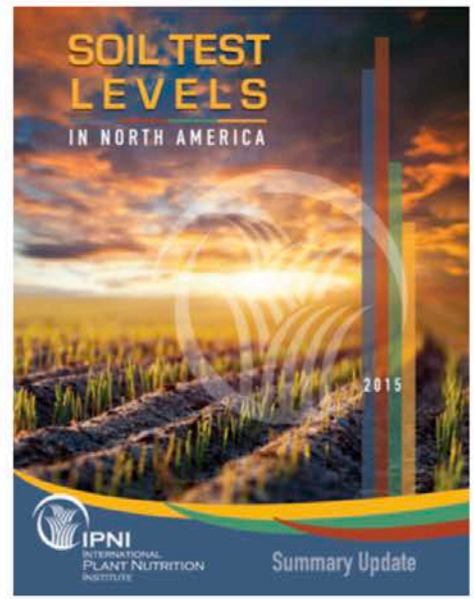

Related Content

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Soil Test Levels in North America: 2015 Summary Update

From the Soil Test Summary Archive

Better Fertilizer Recommendations
More on this topic.

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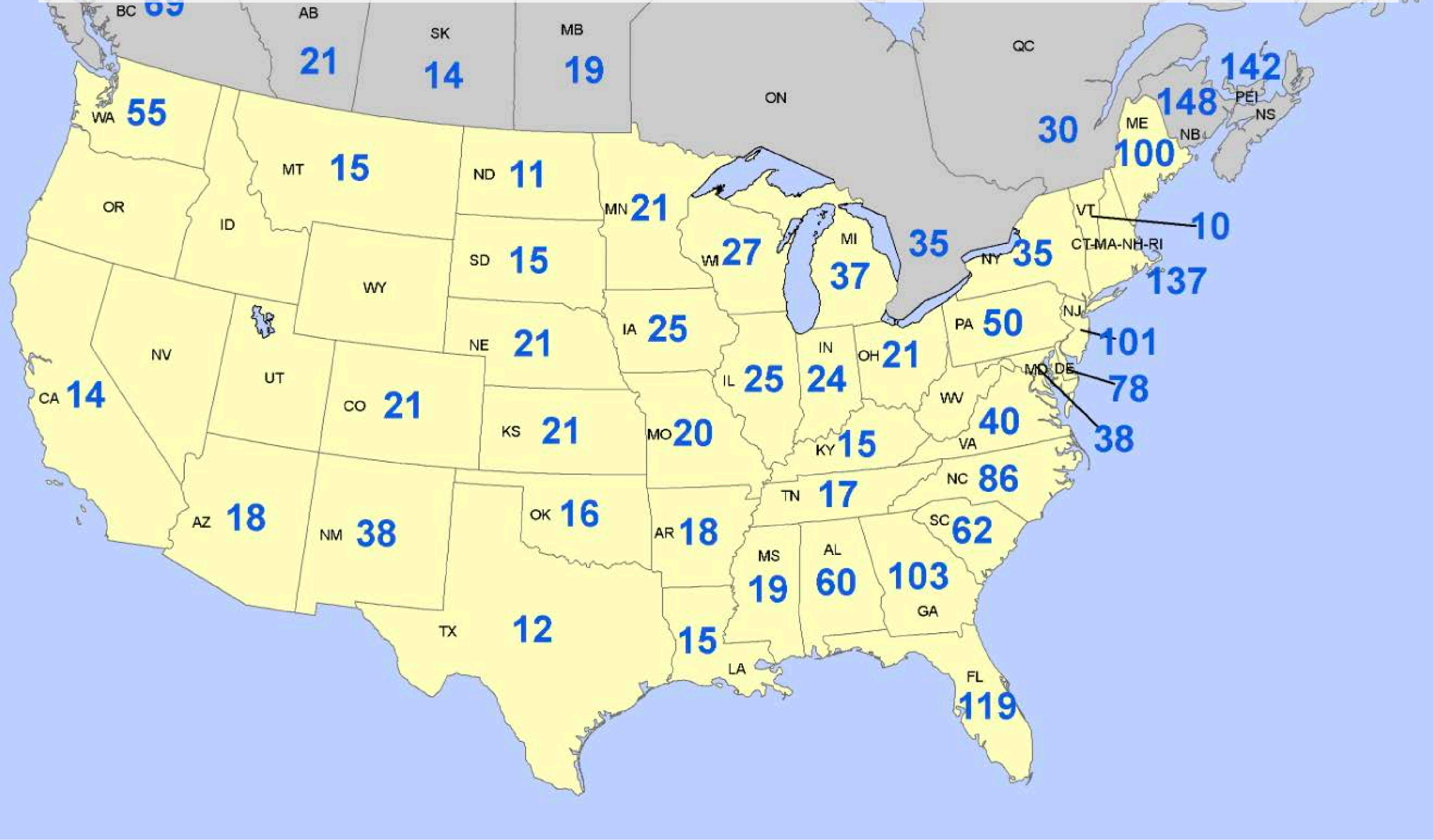
Median Bray & Kurtz P1 Equivalent Soil Test Level, ppm (2015)



http://soiltest.ipni.net/

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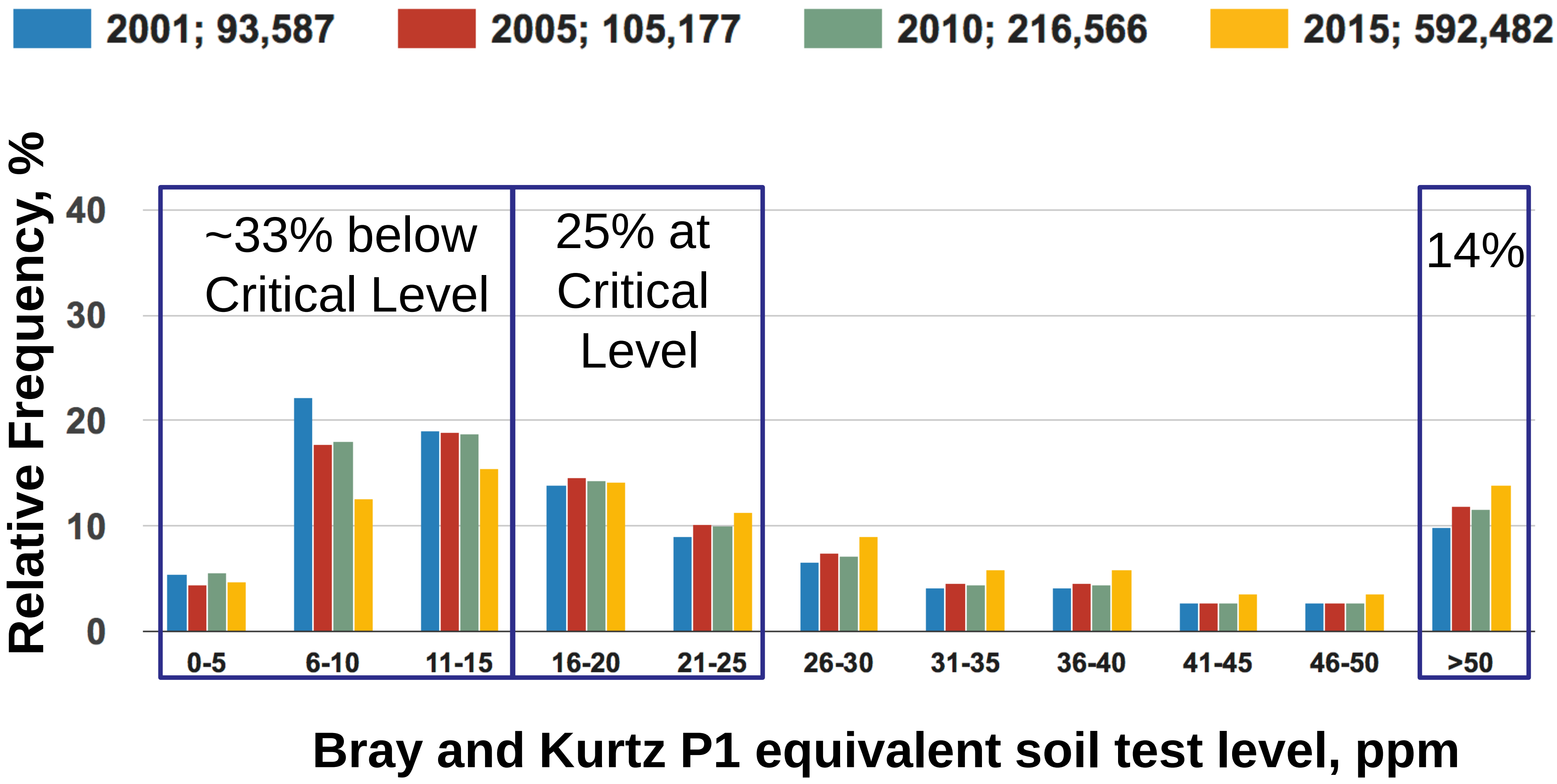
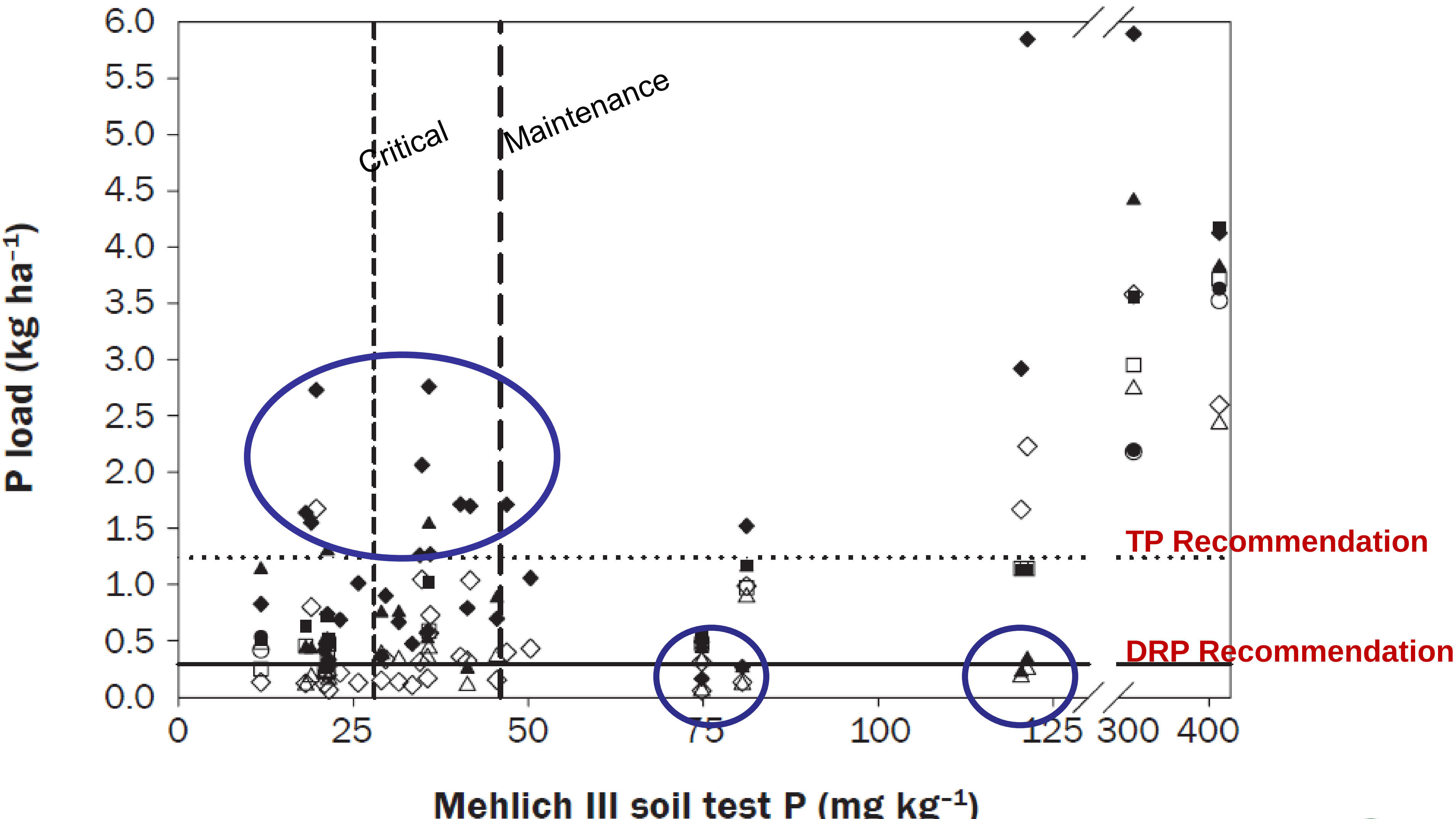
STP Distribution in Minnesota



http://soiltest.ipni.net/charts/distribution

STP **below** recommended rates does not always equal no risk



Duncan et al., 2017; King et al., 2018

Phosphorus Use Efficiency

Partial Nutrient Balance

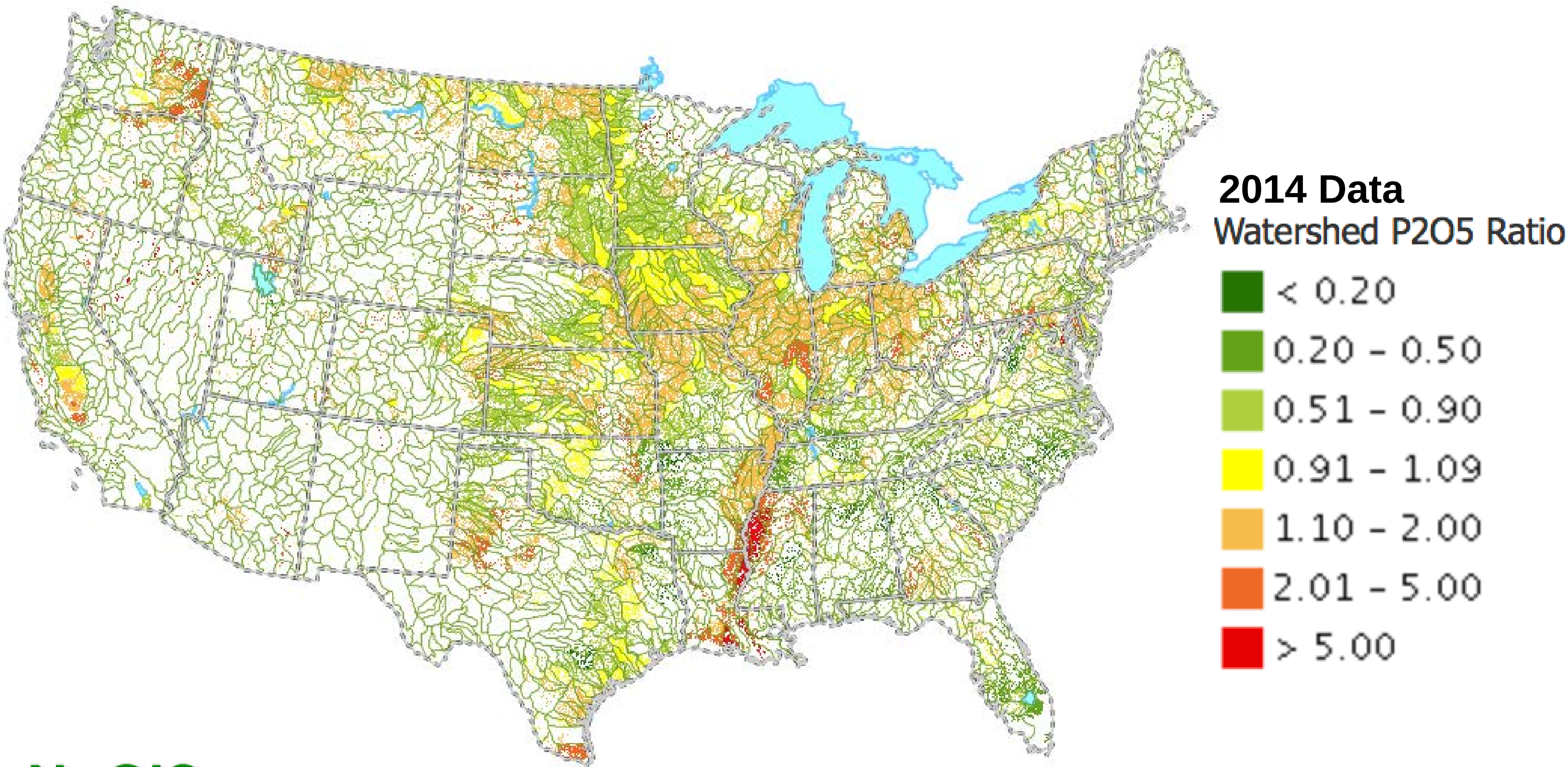
$$\text{Crop PUE} = \frac{\text{crop P removal}}{\text{fertilizer P + manure P applied}}$$

PUE > 1: Soil P decreases = **Crop mining P from soil**

PUE < 1: Soil P increases = **P Storage**

IPNI’s NuGIS Database

http://nugis.ipni.net/map/



NuGIS
Nutrient Use Geographic Information System

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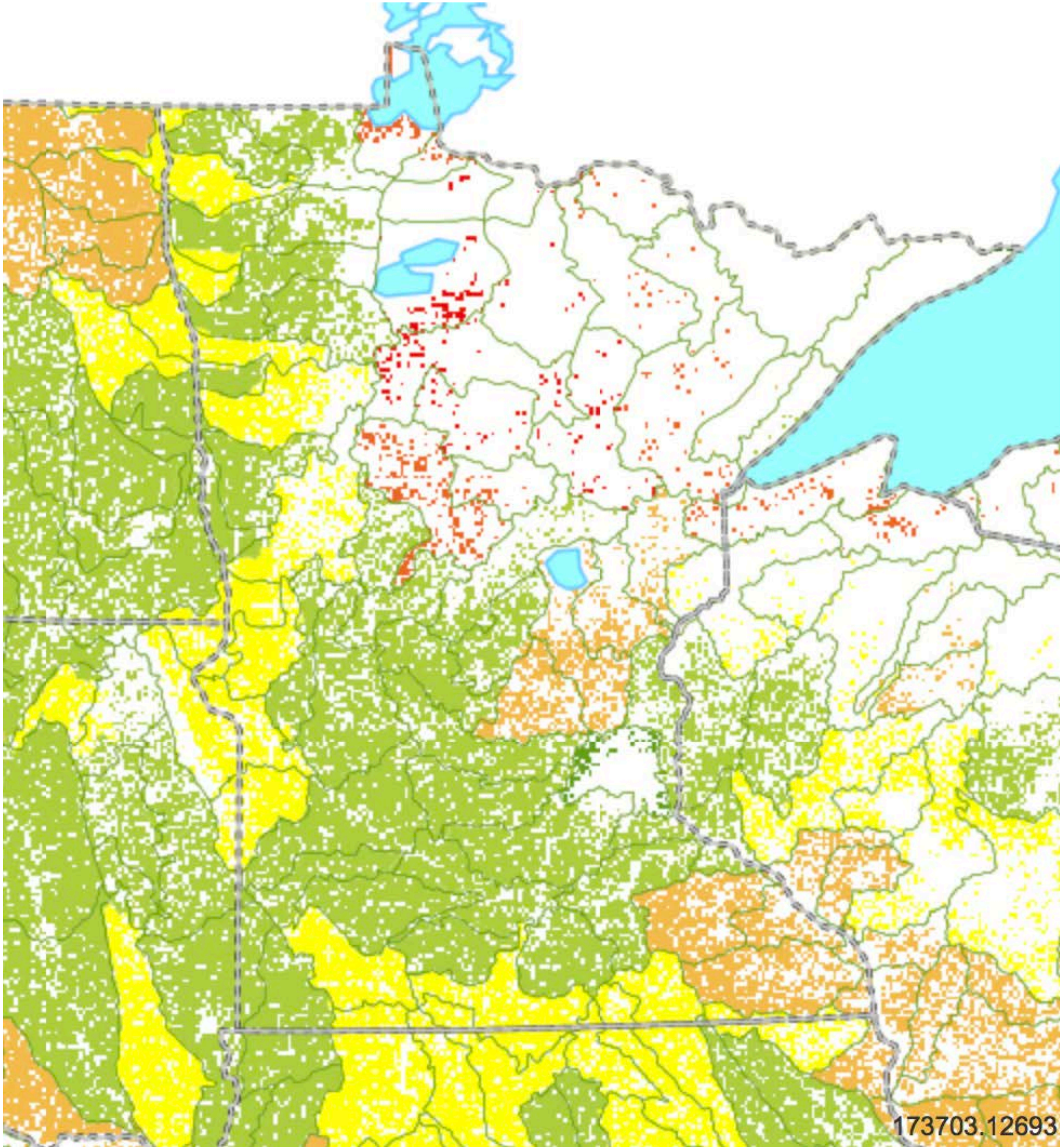

2014 Data

Watershed P_2O_5 Ratio

- < 0.20
- 0.20 – 0.50
- 0.51 – 0.90
- 0.91 – 1.09
- 1.10 – 2.00
- 2.01 – 5.00
- > 5.00

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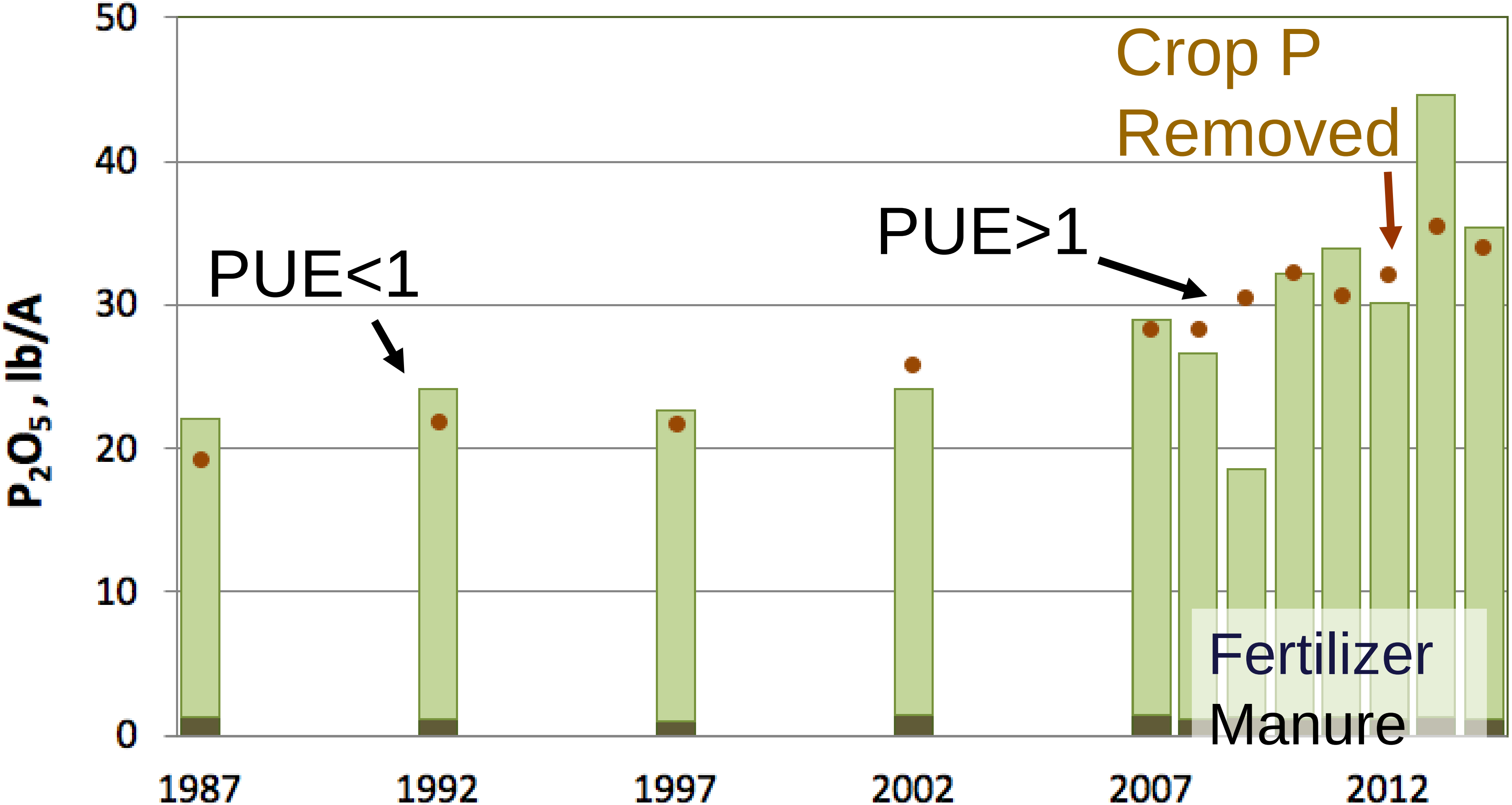
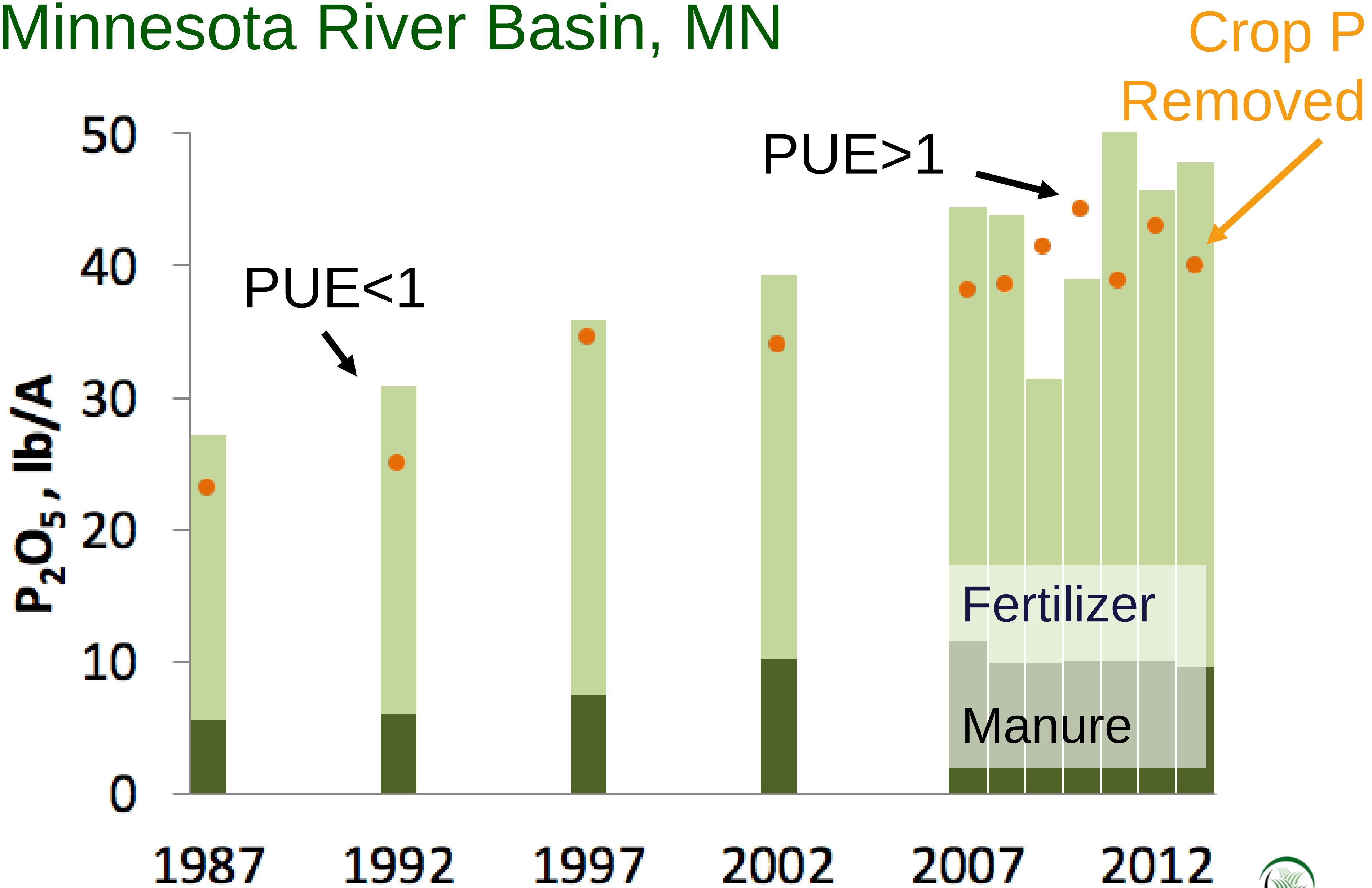
P Inputs > Crop Removal,

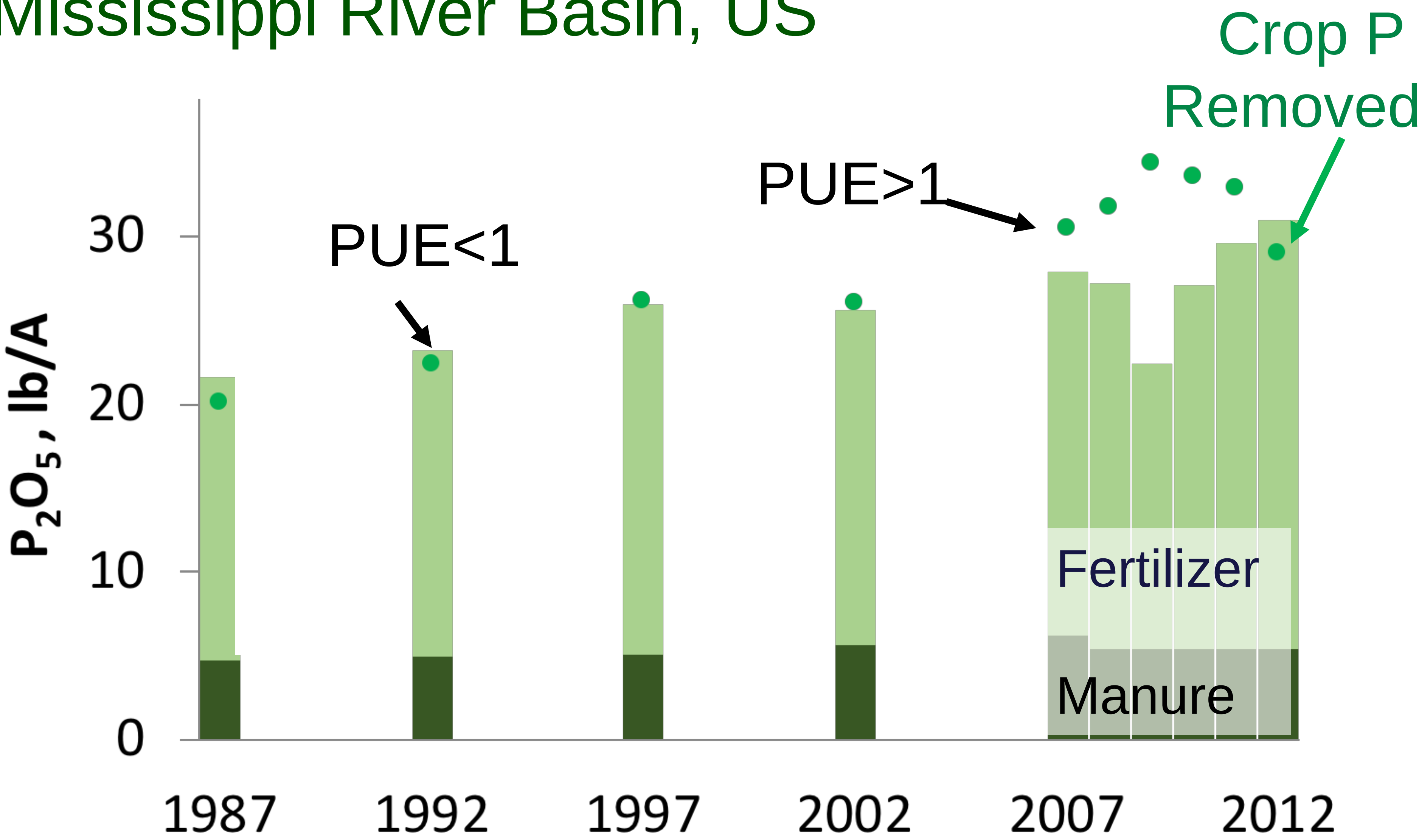
Souris-Red-Rainy Basin, ND/MN



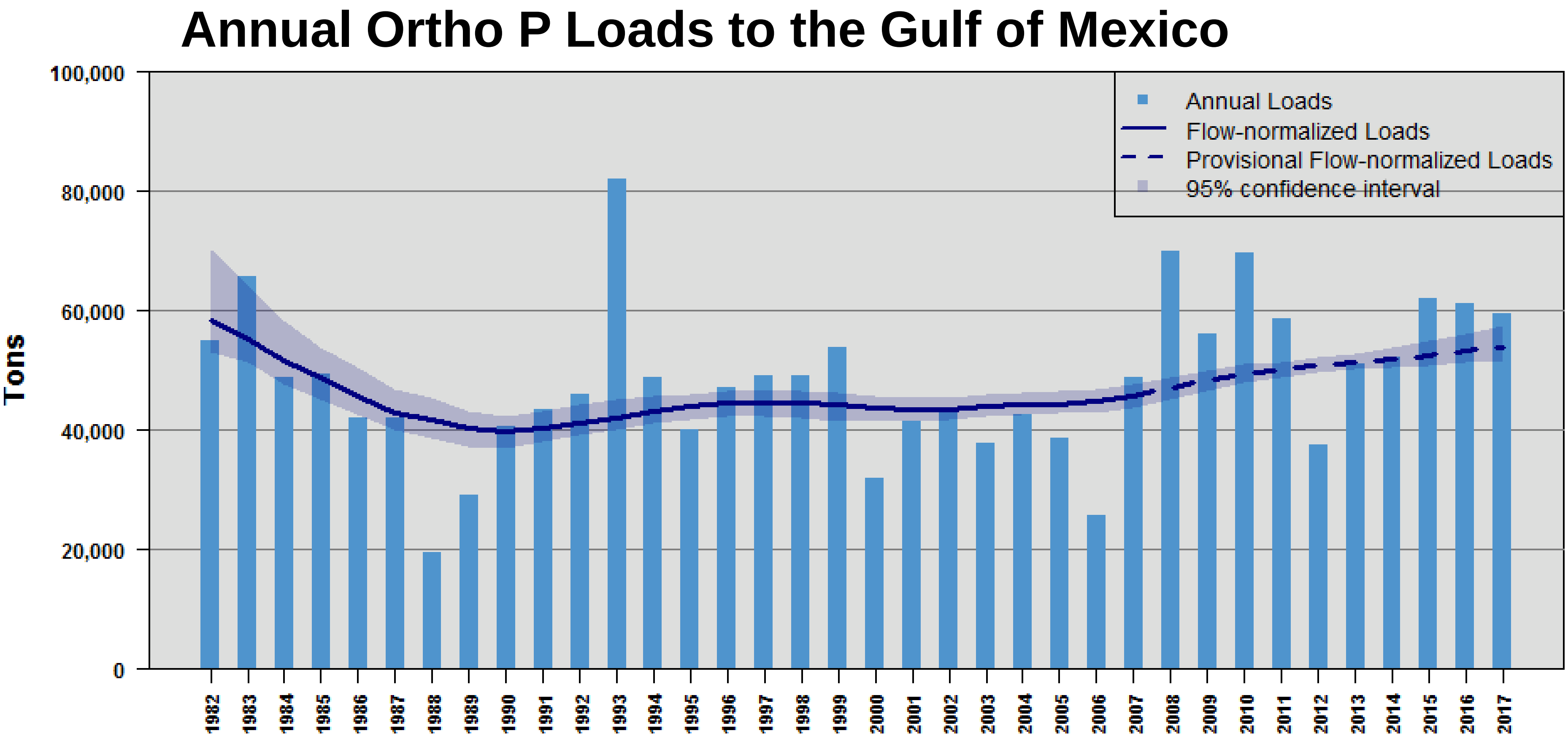
P Inputs > Crop Removal,
Minnesota River Basin, MN



P Inputs < Crop Removal,
Mississippi River Basin, US



Increased Ortho P Load Exceeds Natural Variability



https://nrtwq.usgs.gov/mississippi_loads/#/GULF

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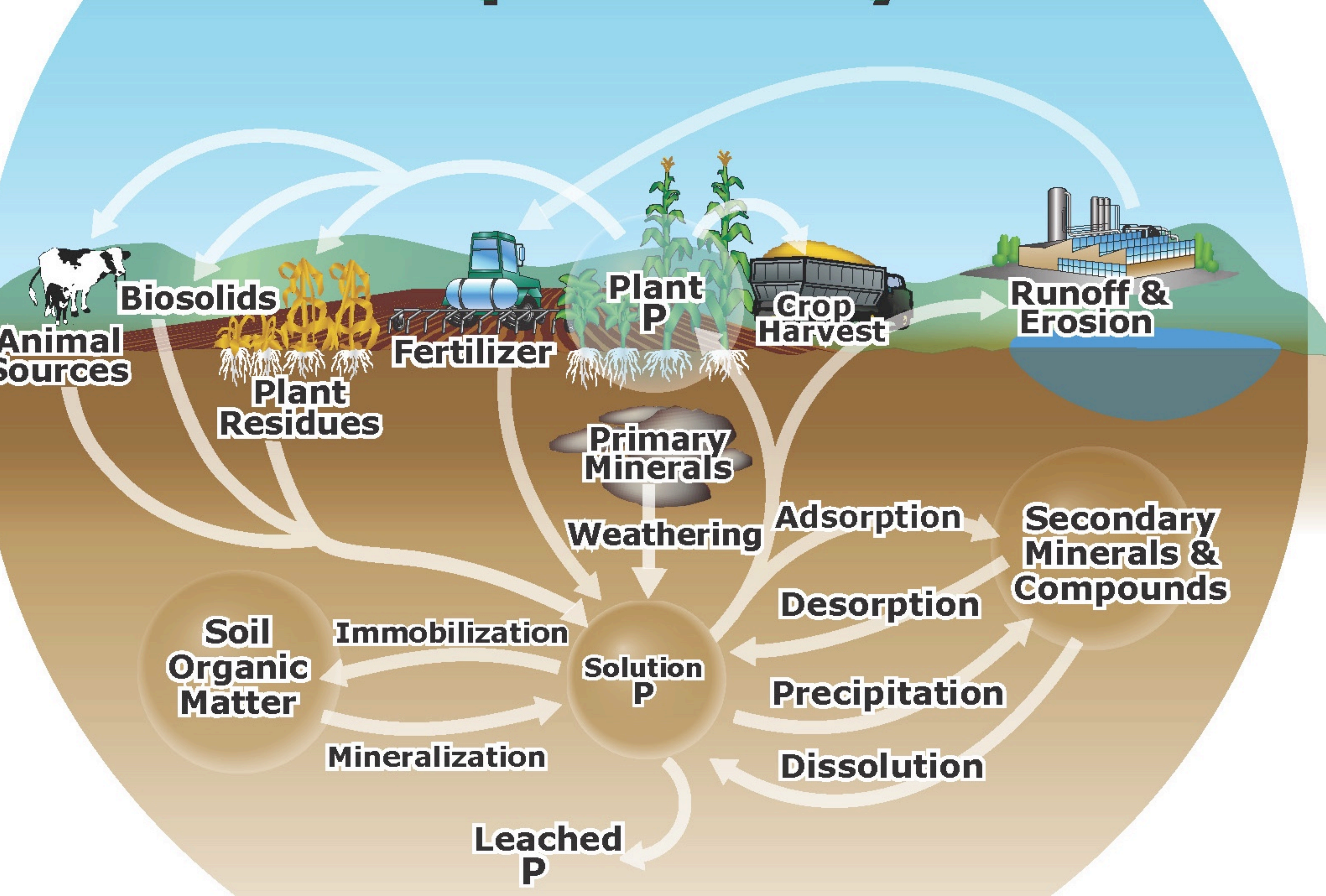
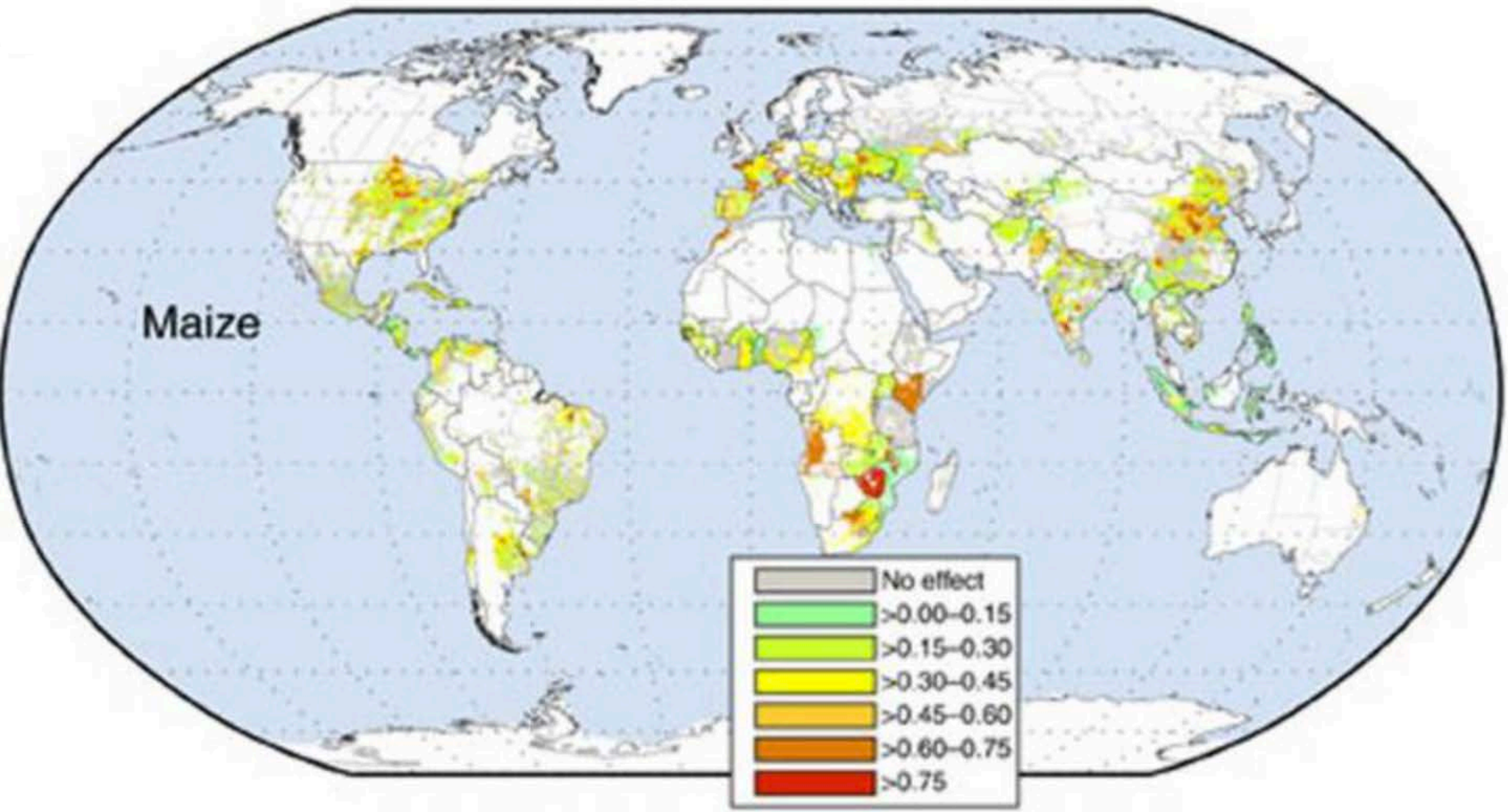
Phosphorus Cycle



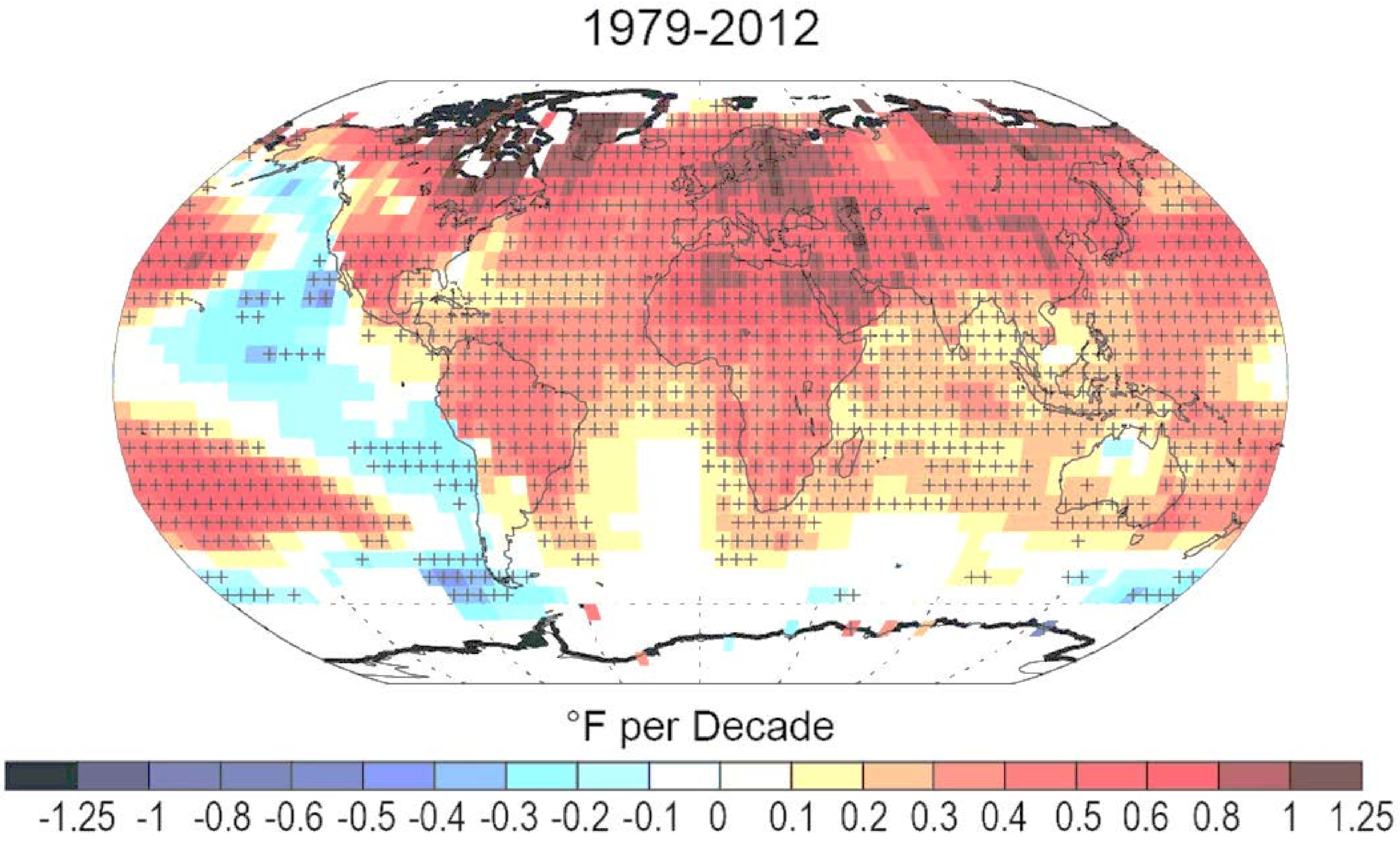
Globally, 39% of Annual Corn Yield Variability Climate Related



(Figure source: Ray et al 2015)


"Last year we did not get enough rain…"
What happens to all the unused plant available P?

Global Temperatures are Increasing, Faster



(Figure source: Melillo et al., 2014, updated from Vose et al., 2012)

P Response to Increasing Temperature…..

No Easy Answer!

<u>May</u> increase SOM decomposition?

Increased mineralization or immobilization?

Accumulation of available P or increased fixation?

Soil testing will be key!

(Conant et al., 2011;)

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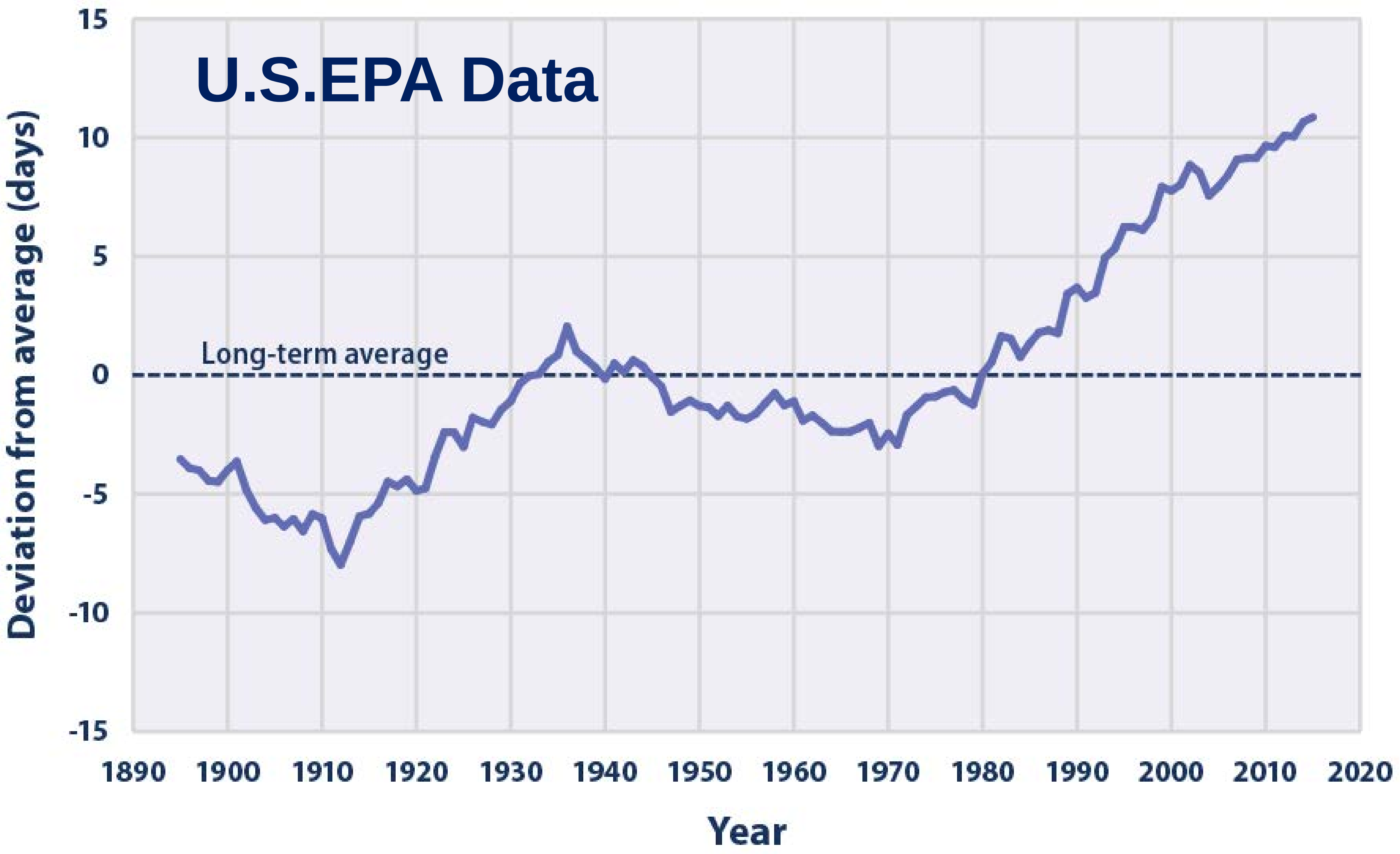
Long-term experiments are valuable for detecting slow changes!

Geissler and Scow. 2014. Soil Bio & Biochem

Growing Seasons are Getting Longer



(Figure source: Kunkel, 2016)

Response to Longer Growing Seasons…..

Cropping systems *in areas receiving adequate rainfall* may produce greater yields and longer-maturing crops.

Increased adoption of double cropping.

More inputs to respond to greater output?

(Mueller et al., 2015)

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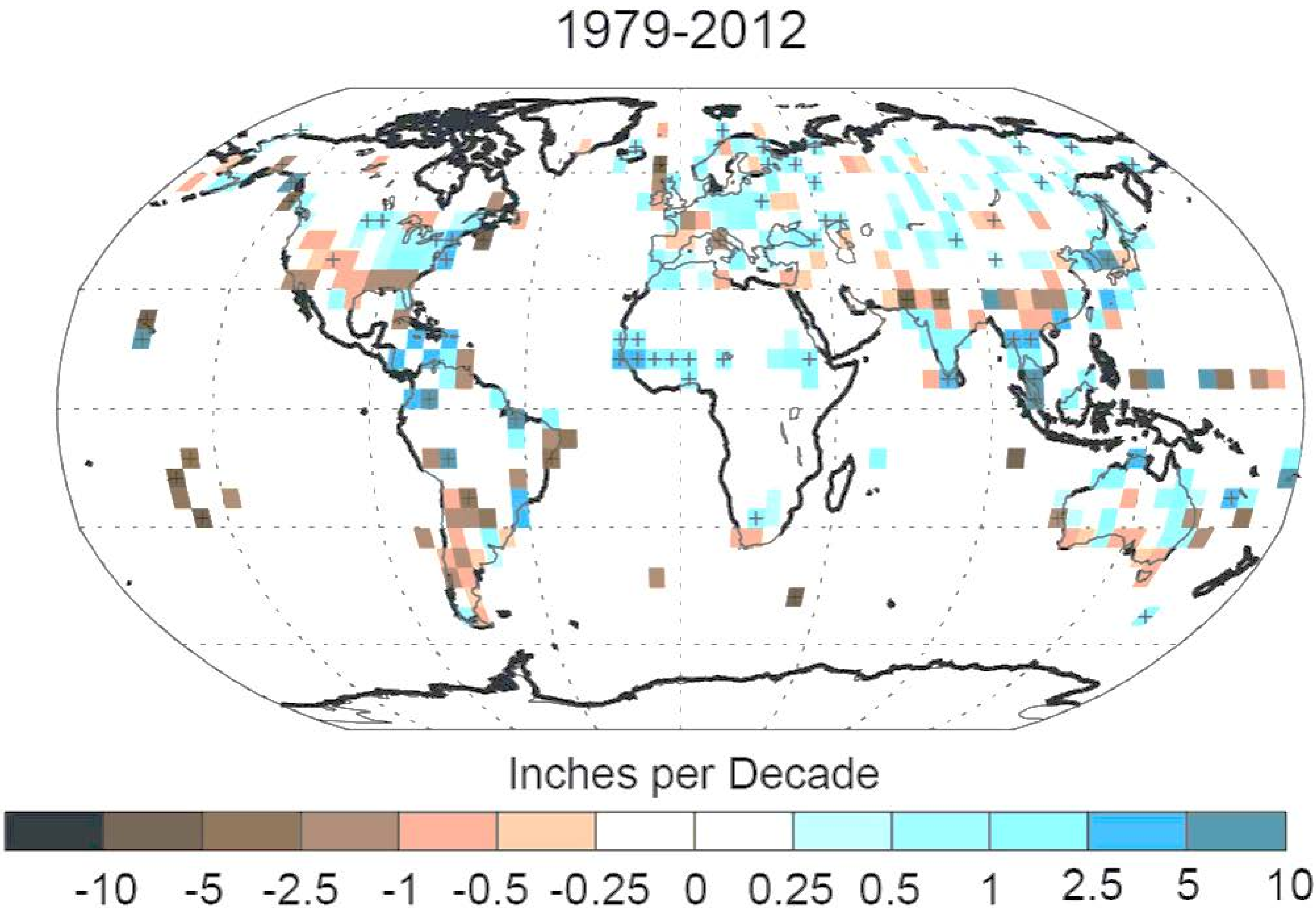
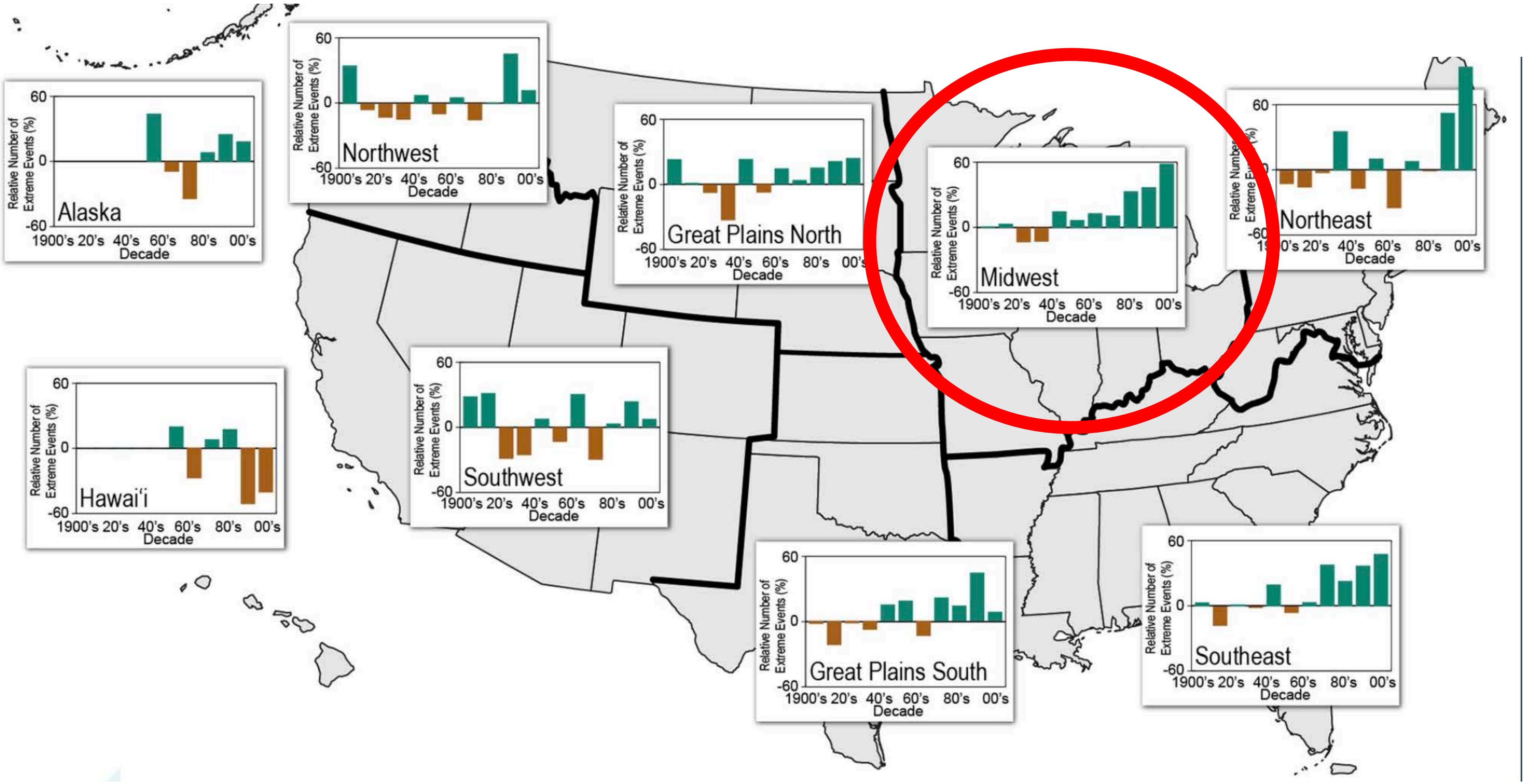
Wet Areas are Wetter; Dry Areas Drier



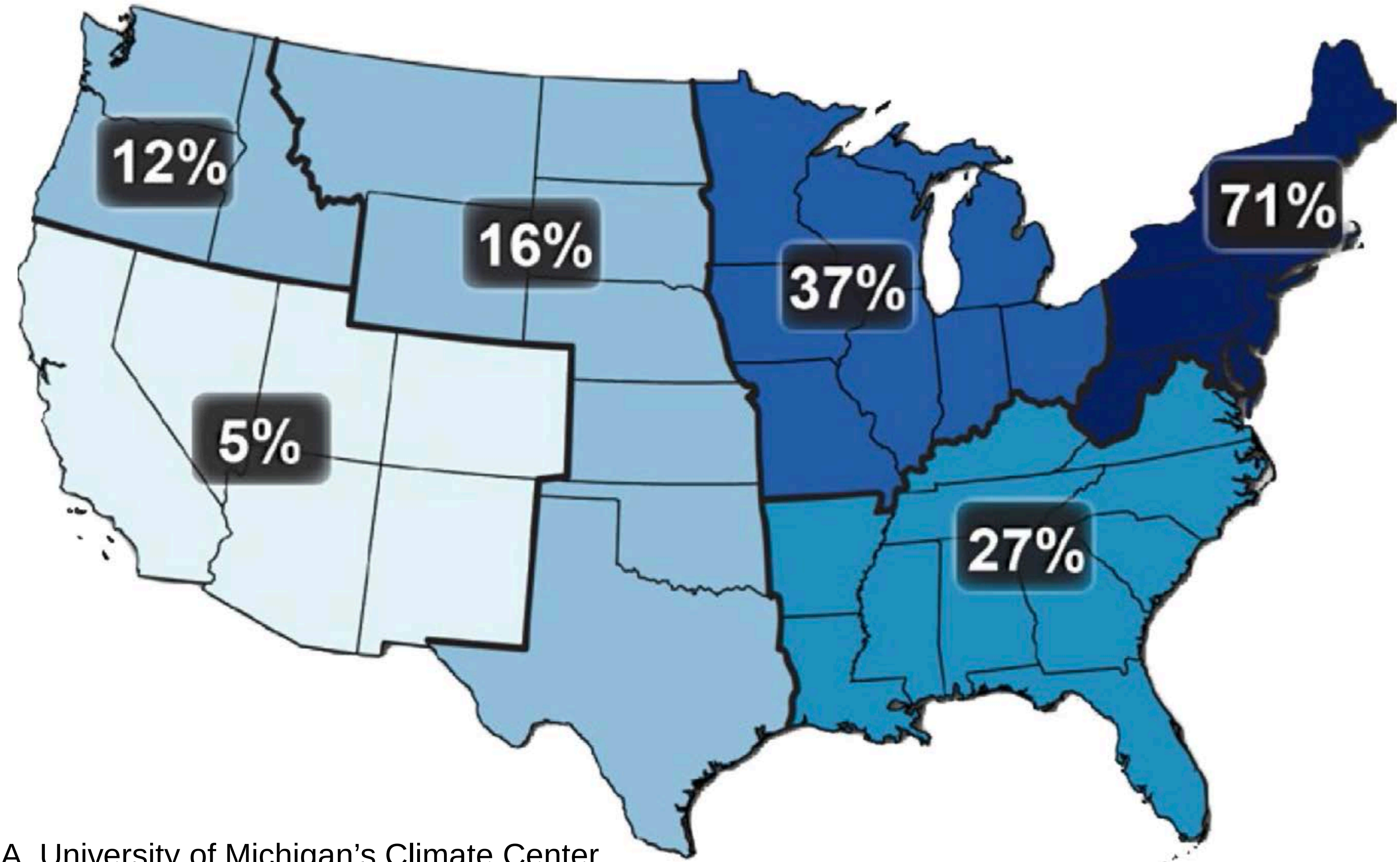
(Figure source: NOAA NCDC/CICS-NC

Increase in Extreme Precipitation Events



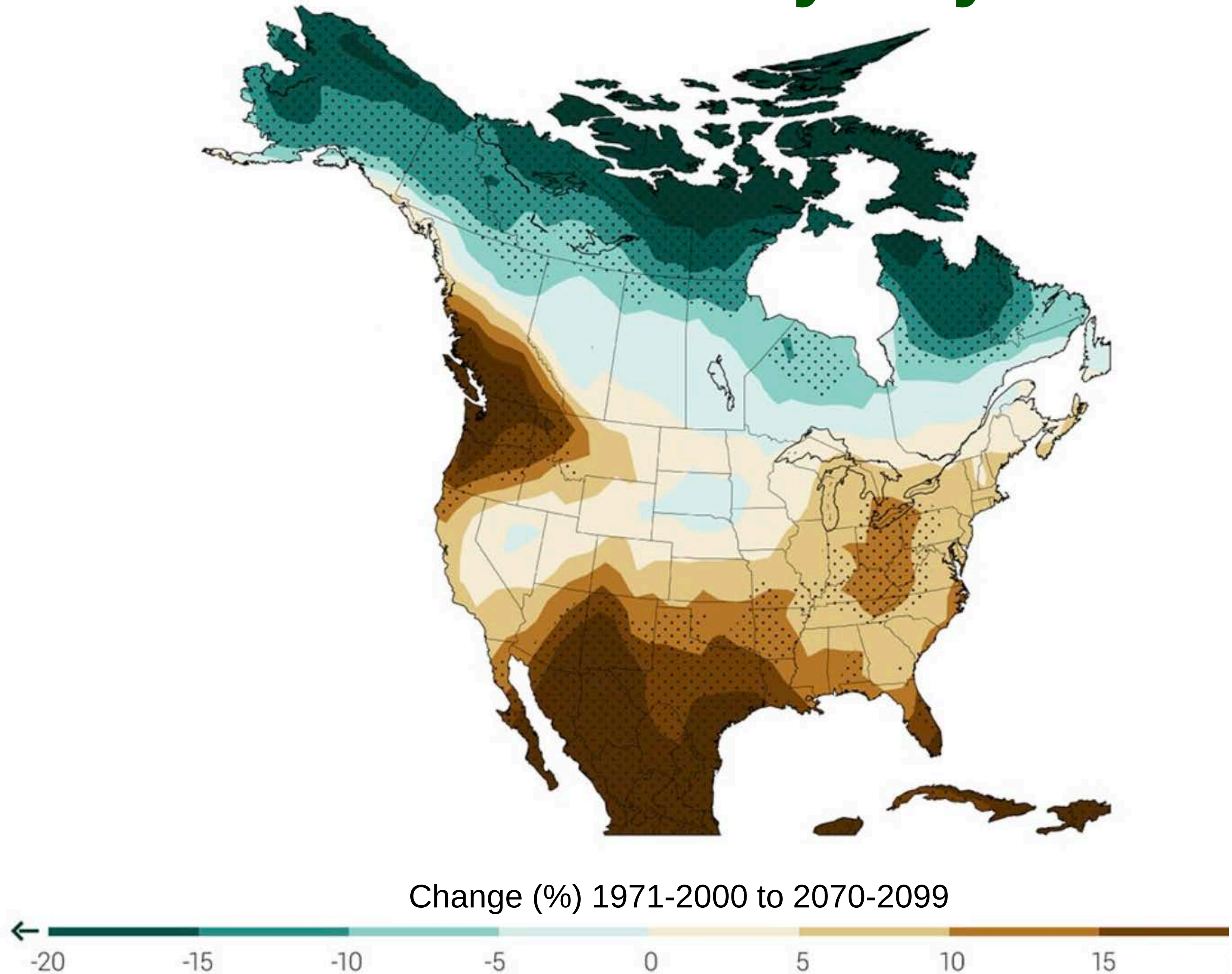
(Figure source: Melillo et al., 2014, updated from Kunkel et al., 2013)

Precipitation falling during the top 1% of severe storms has increased 37% in the Midwest from 1958 to 2012.



GLISA, University of Michigan's Climate Center

Maximum Number of Dry Days Increasing



(Figure source: NOAA NCDC/CICS-NC)


(He and Dkjkstra, 2014)

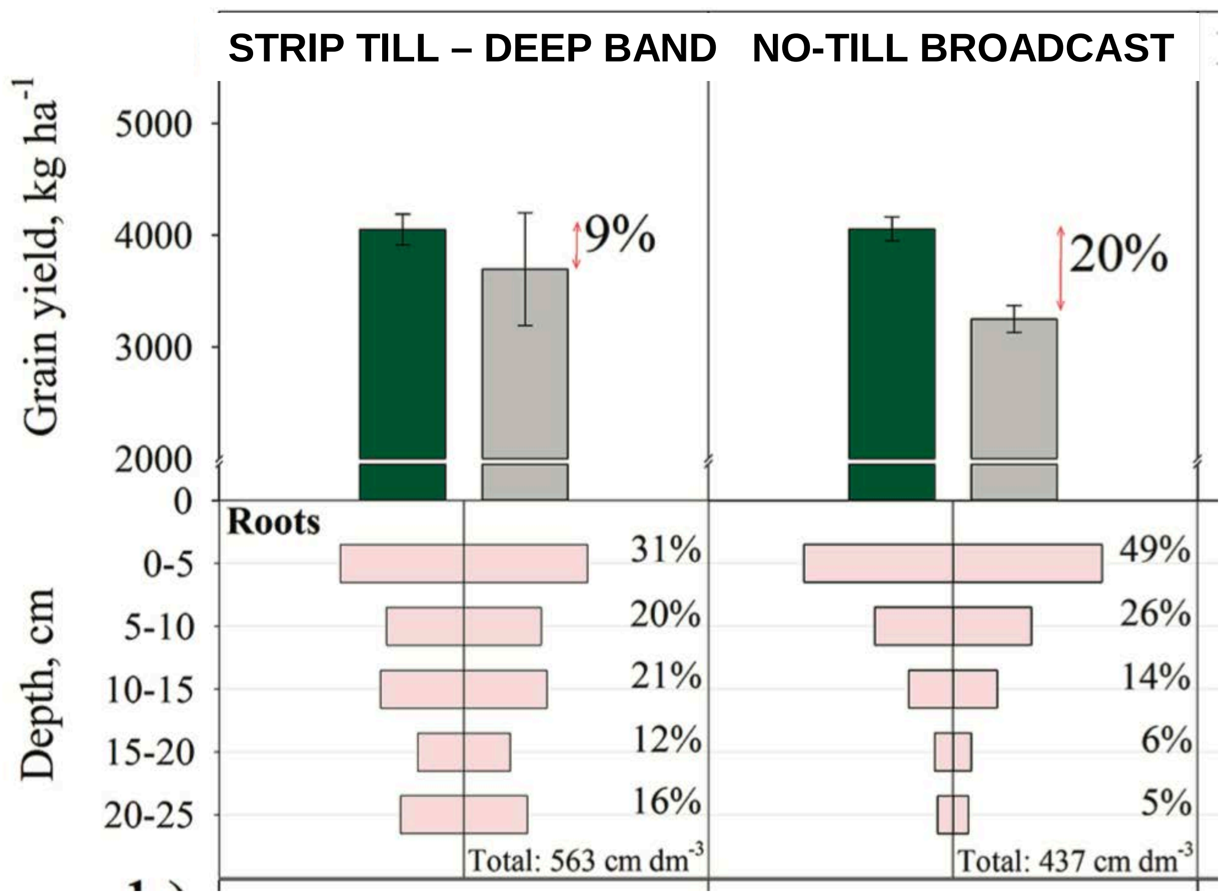
Drought stress could result in less plant available P.

- ↓ soil moisture,
- ↓ mineralization,
- ↑ P fixation,
- ↓ plant uptake.

P Placement can affect Root Growth During Droughts

Strip-till + deep band P enhance deeper soybean root growth.

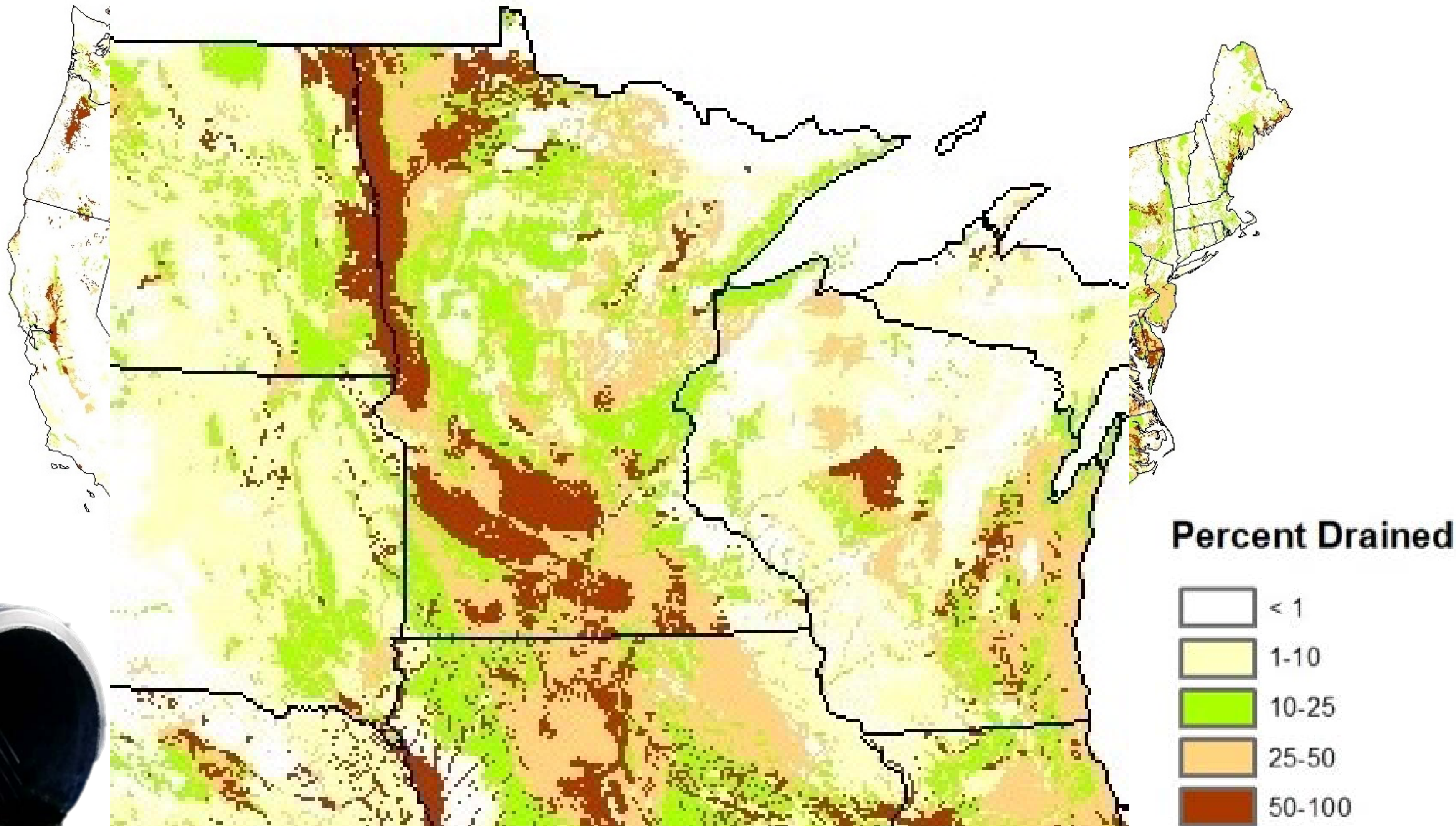
Soybean root growth at deeper soil layers improve resilience to induced drought.



Rio Grande do Sul, S. Brazil

(Figure source: Hansel et al., 2017)

Anthropogenic Landscape Change



Source: Jaynes and James 2007

Can nutrient placement reduce dissolved losses?

Trade-offs:

Surface application:

↑ runoff or leaching losses

↓ soil disturbance

4R Research Fund

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Research

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Evaluating the 4R Nutrient Stewardship Concept and Certification Program in the Western Lake Erie Basin

IPNI-2014-USA-4RN09

Overview | Related

Since the mid-1990s, the frequency and extent of algal blooms and loadings of dissolved phosphorus (P) in the Western Lake Erie Basin (WLEB) have been on increasing trends. Agricultural crop management has been identified as a primary source of P to the Lake. Over the past 2-3 years, educational programs directed at growers and nutrient service providers (e. g. Read more

Year of initiation:	Year of completion:	Map:
2014	?	

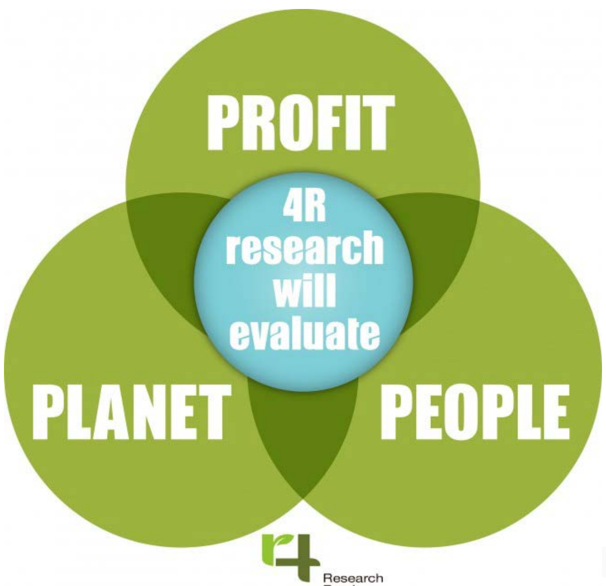
more photos

Interpretive Summary

2016 — The increase in harmful algal blooms in Lake Erie since the mid 1990s is correlated with an increasing trend in dissolved phosphate loading. A considerable proportion of this dissolved phosphate comes from cropland. This multi-disciplinary research project, initiated in July 2014, aims to quantify the water quality benefits of 4R initiatives in the Western Lake Erie Basin.

Project Leader

Kevin King, USDA-ARS



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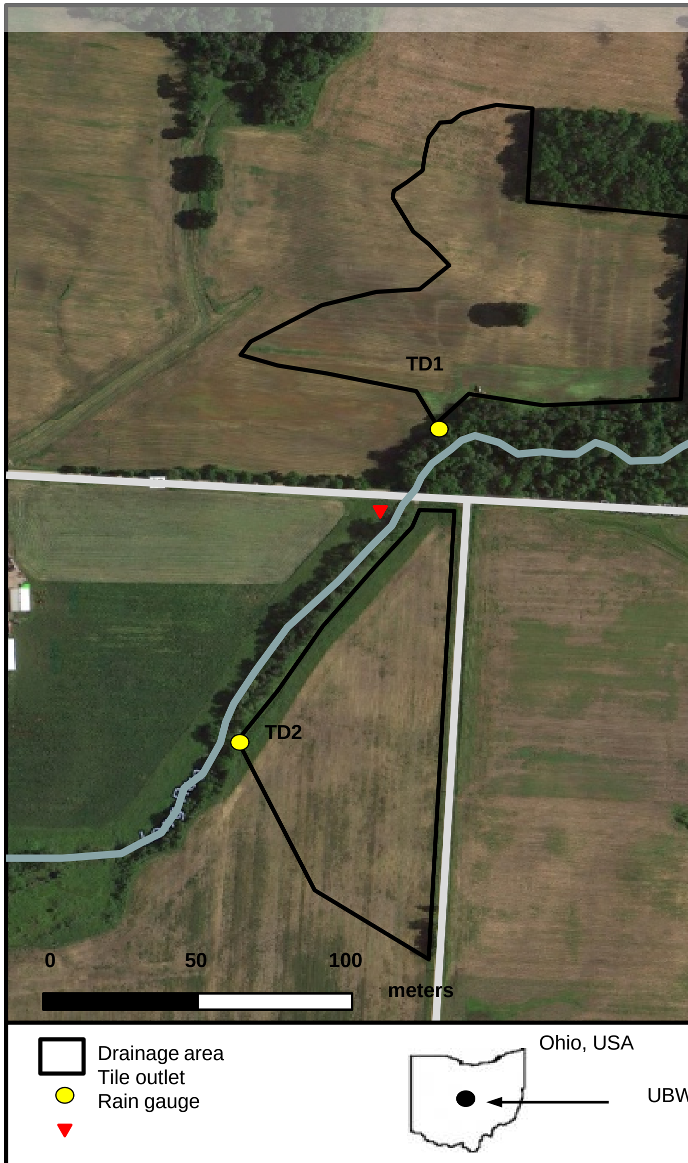
Right Place: Tile Drains & Fertilizer Placement

Soil type: Silt loam
Tile depth: 3 ft
Soil test P: 30 ppm Mehlich-3P

<u>2014 management</u>
May 6th – Applied MAP @ 40 lb P/acre
May 8th – Tilled field TD1 (disc),
TD2 no-till

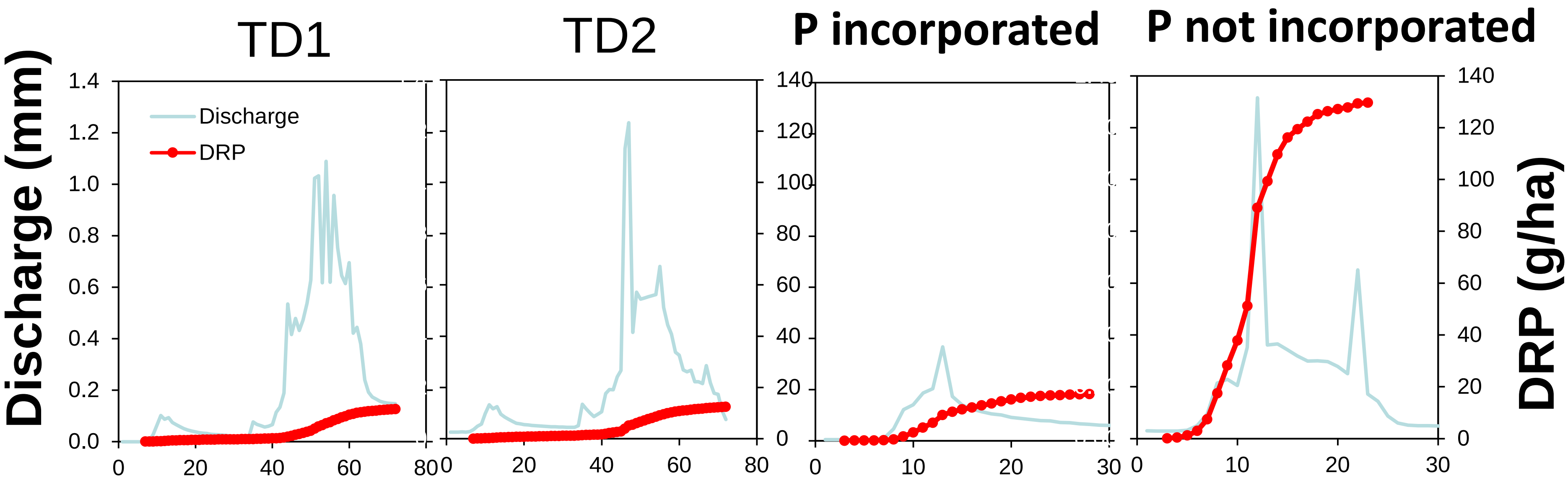
Compared tile drain P transport:
Broadcast P incorporated
Broadcast P not incorporated



Williams and King, USDA-ARS, Columbus, Ohio

Before P application & tillage (April 28th)

After P application & tillage (May 12th)



Incorporating P significantly reduced tile DRP concentration

Williams and King, USDA-ARS, Columbus, Ohio

Tillage, Tile and Fertilizer Placement

Incorporation ("right place") of broadcast fertilizer reduced P loss in tile drains by 45%.

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

Examine the effect of fertilizer placement and tillage on P leachate.

Soil & Tillage Research 178 (2018) 130–138

Contents lists available at ScienceDirect

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Fertilizer placement and tillage effects on phosphorus concentration in leachate from fine-textured soils

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ARTICLE INFO

Keywords:
Tile drainage
Preferential flow
Lysimeter

ABSTRACT

Adoption of no-tillage in agricultural watersheds has resulted in substantial reductions in sediment and particulate phosphorus (P) transport in surface runoff. No-tillage, however, may result in increased losses of dissolved P in tile-drained landscapes due to the accumulation of P in surface soil layers and prevalence of preferential flow pathways. The objective of this study was to examine the effect of fertilizer placement and tillage on P leaching in fine-textured soils following fertilizer application. Rainfall simulations (90 min; 3.8 cm rainfall depth) immediately following application of monoammonium phosphate fertilizer (75 kg P ha^{-1}) were conducted on 9 m^2 plots with pan lysimeters (0.6 m depth) in four agricultural fields located in northwestern Ohio, USA. Three fertilizer placement treatments that covered a range of soil disturbance and soil-fertilizer mixing (broadcasted, injected, and tilled) were replicated on each field. Stable water isotopes were used to separate leachate into preferential and matrix flow components. Results showed that leachate dissolved P concentration was significantly greater when fertilizer was surface broadcast on no-tilled plots (43.7 mg L^{-1}) compared to when the fertilizer was either injected (14.9 mg L^{-1}) or tilled (11.0 mg L^{-1}) into the soil. Event water comprised between 6 and 46% (mean = 22%) of lysimeter leachate and did not vary among treatments. Similar event water contributions among treatments suggest that the disruption of the macropore network was not likely the main mechanism responsible for decreased P concentration in leachate, but rather increased soil-fertilizer contact and decreased interaction between the highly soluble fertilizer and ponded surface water were likely responsible for decreased P concentrations observed for the injected and tilled treatments compared to the broadcasted treatment. Findings indicate that subsurface injection of fertilizer has the potential to limit dissolved P leaching compared to surface broadcast applications and also minimize soil disturbance relative to tillage; thus, it should be considered a promising conservation practice to help meet water quality goals in tile-drained landscapes.

1. Introduction

Excess phosphorus (P) delivery from tile-drained agricultural watersheds has been linked to increases in the magnitude and severity of hypoxic zones and harmful algal blooms in receiving surface waters (Rabalais et al., 2010; Stumpf et al., 2012; Michalak et al., 2013; Kane et al., 2014). In humid regions of the world with poorly drained soils, P transport in subsurface tile drainage is of increasing environmental concern, as tile drains may export P at rates greater than those associated with overland flow (Jamieson et al., 2003; King et al., 2015a; Williams et al., 2016a). Recent studies in the Great Lakes region of North America have shown that tile drains can contribute nearly 50% of watershed discharge and dissolved P fluxes (Macrae et al., 2007; King et al., 2015b). Edge-of-field monitoring in artificially drained landscapes has also indicated that tile drains can account for 47–66% of annual dissolved P losses, but in some instances they may account for up to 95% (Eastman et al., 2010; Van Esbroeck et al., 2016; Williams et al., 2016c). Understanding the dominant processes controlling subsurface P transport and identifying management practices that decrease P loss is therefore critical for attaining water quality goals in these landscapes.

In fine-textured soils, preferential flow through soil macropores (e.g., root channels, earthworm burrows, and desiccation cracks) has been hypothesized to be an important process controlling subsurface P transport (Sims et al., 1998; King et al., 2015a). Preferential flow pathways can provide a direct connection between the soil surface and tile drains (Akay and Fox, 2007), which has been evidenced by the rapid response of drainflow to tracer applications at the soil surface

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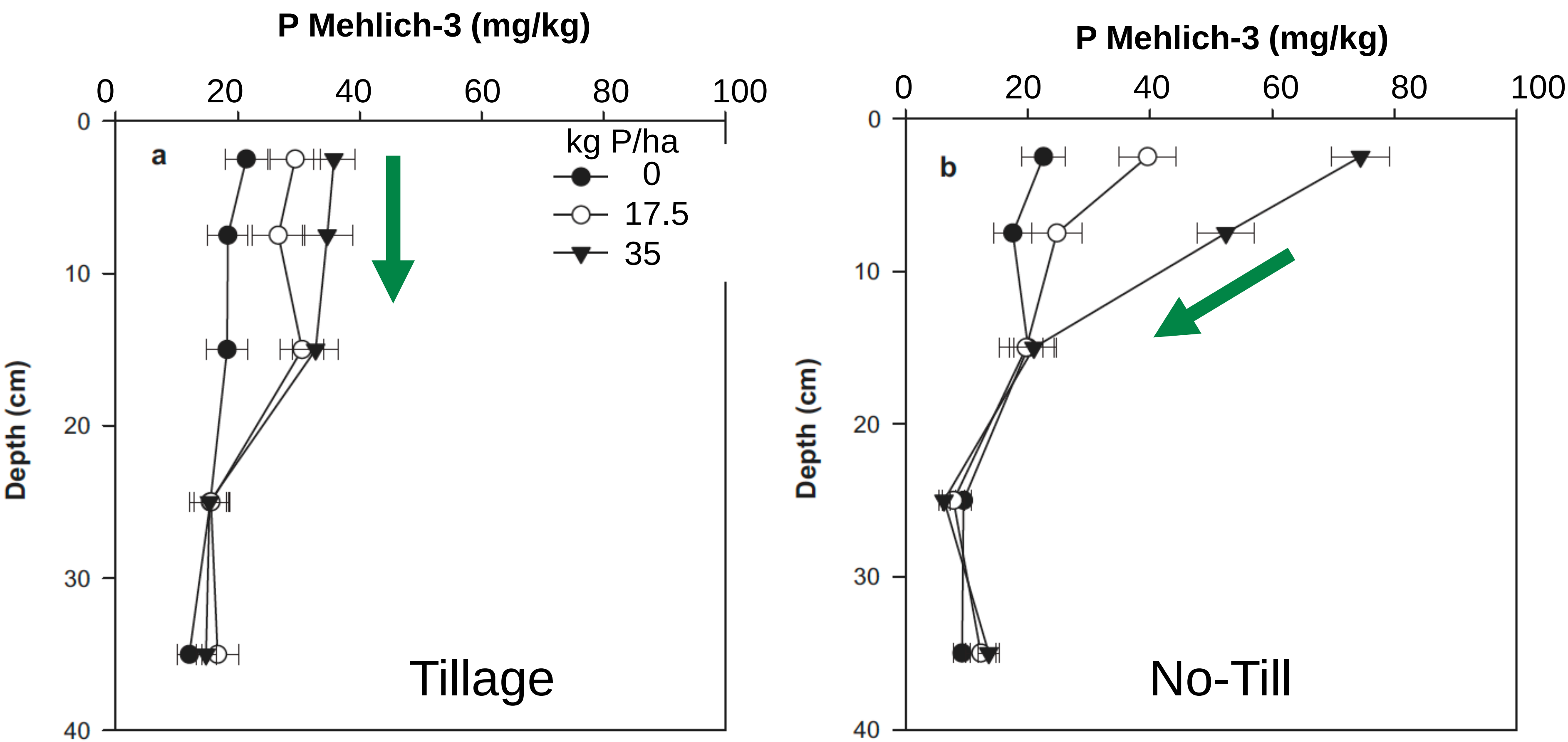
https://doi.org/10.1016/j.still.2017.12.010

Rooting zone P dynamics change with no-till.



Messiga et al., 2012. Field Crops Research

Site Description:

Maumee River Watershed

Flat, Poorly Drained

SL/SiCL Soils

Rotations:

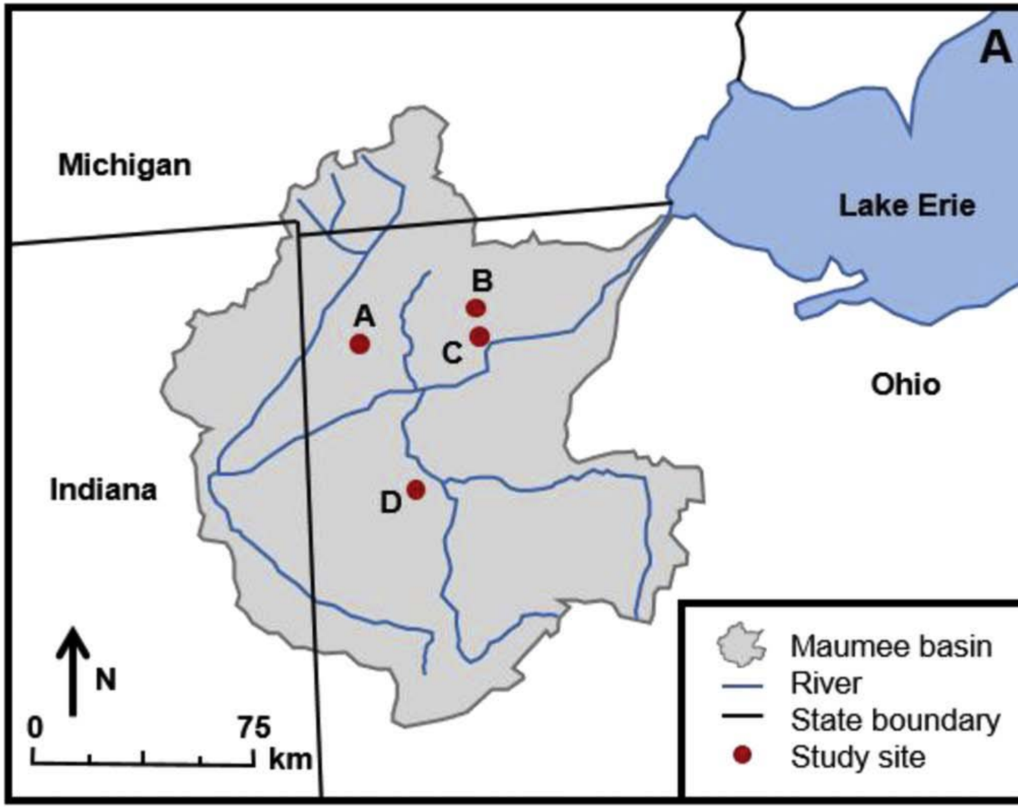
Corn/Soybean/Wheat

STP: 21-32 PPM Mehlich-3

Tile Description:

2.5 - 3.0 ft depth

35 - 45 ft spacing



Fertilizer Placement

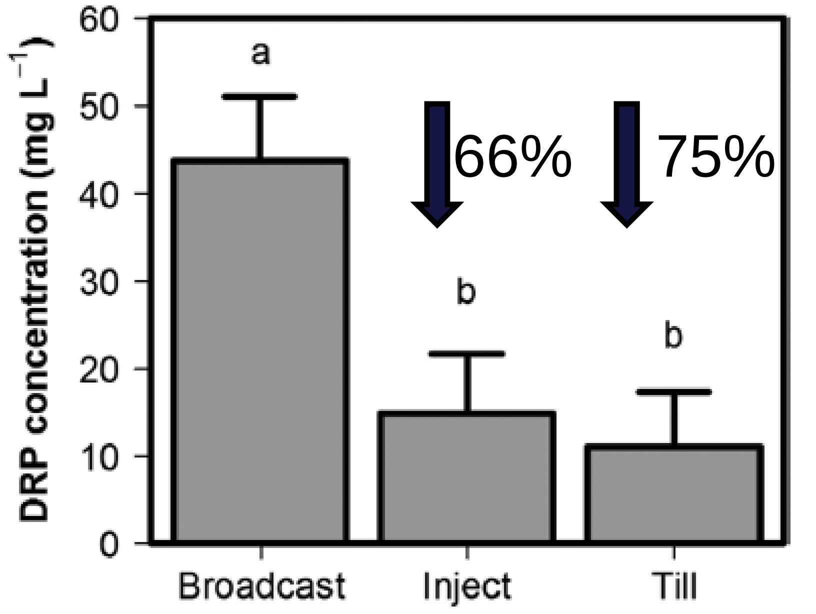
Monoammonium Phosphate (MAP; 11-52-0) @ 67 lb P/acre

Applied after harvest in October 2016

Placement:

- Broadcasted (no-tillage)
- Incorporation via Tillage (3-4 in)
- Incorporation via Injection (4 in)

Leachate P Loss Greatest with Broadcasting



Mean Dissolved Reactive P (DRP) leachate concentration was significantly greater for broadcast treatment.

Mean Particulate P (PP) leachate concentration was significantly greater for broadcast treatment.

More Soil-Fertilizer-Water Contact ↓ P Leaching

Tillage did not significantly influence event water transport.

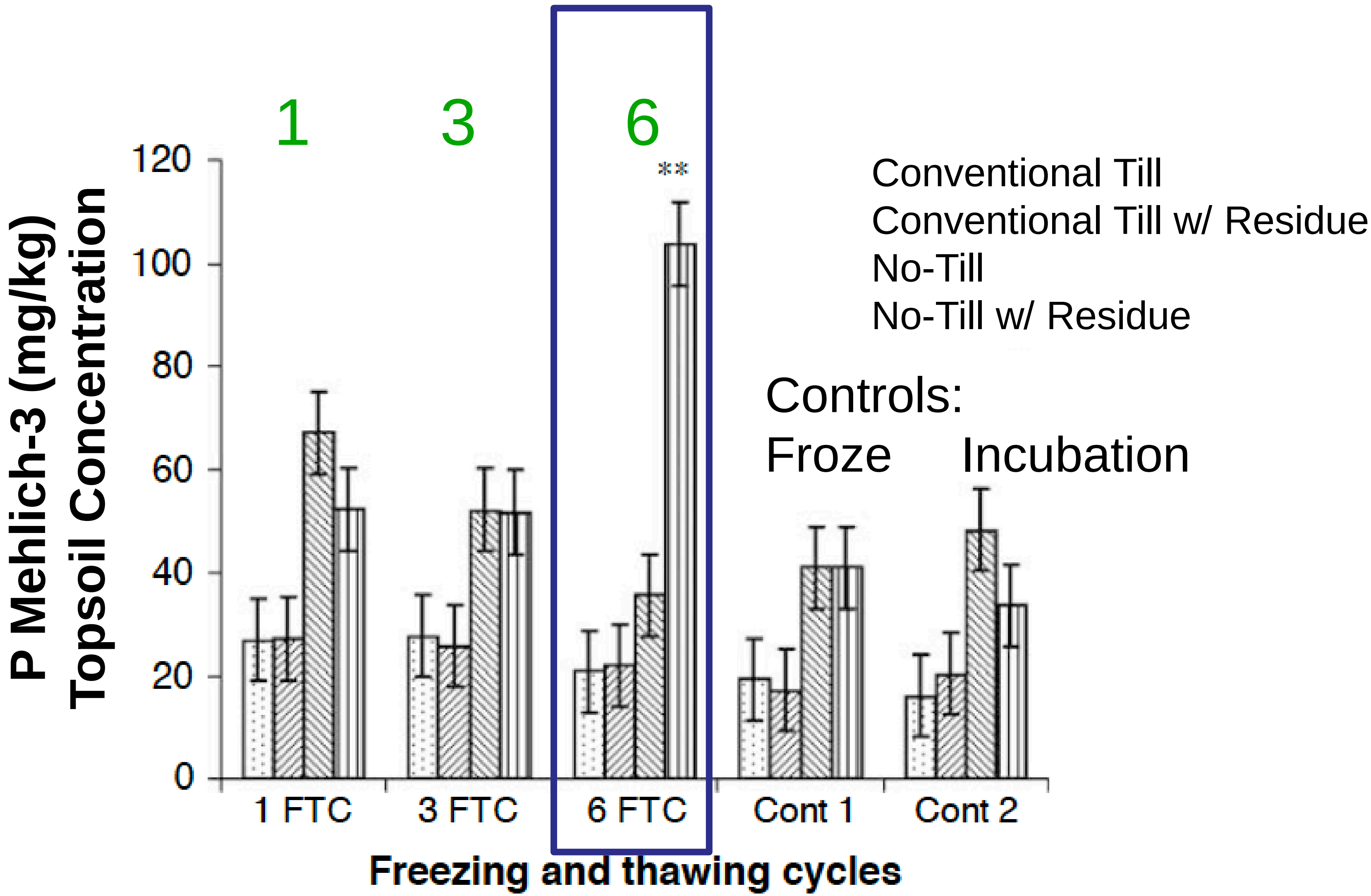
Disruption of macropore network not likely primary mechanism responsible for decreased leachate P concentrations.

Differences in soil-fertilizer-water contact, soil P sorption capacity, and proximal P availability were the primary factors resulting in P leaching reductions in injected and tilled soils.

Subsurface injection of fertilizer in fine-textured soils may limit dissolved P leaching and minimize surface disturbance.


How do soil health
practices influence soil P?

Freeze-thaw cycles in no-till increase available P.



Messiga et al., 2010. Can.J.Soil.Science

Can cover crops increase available P?

Longer-term research is still needed.

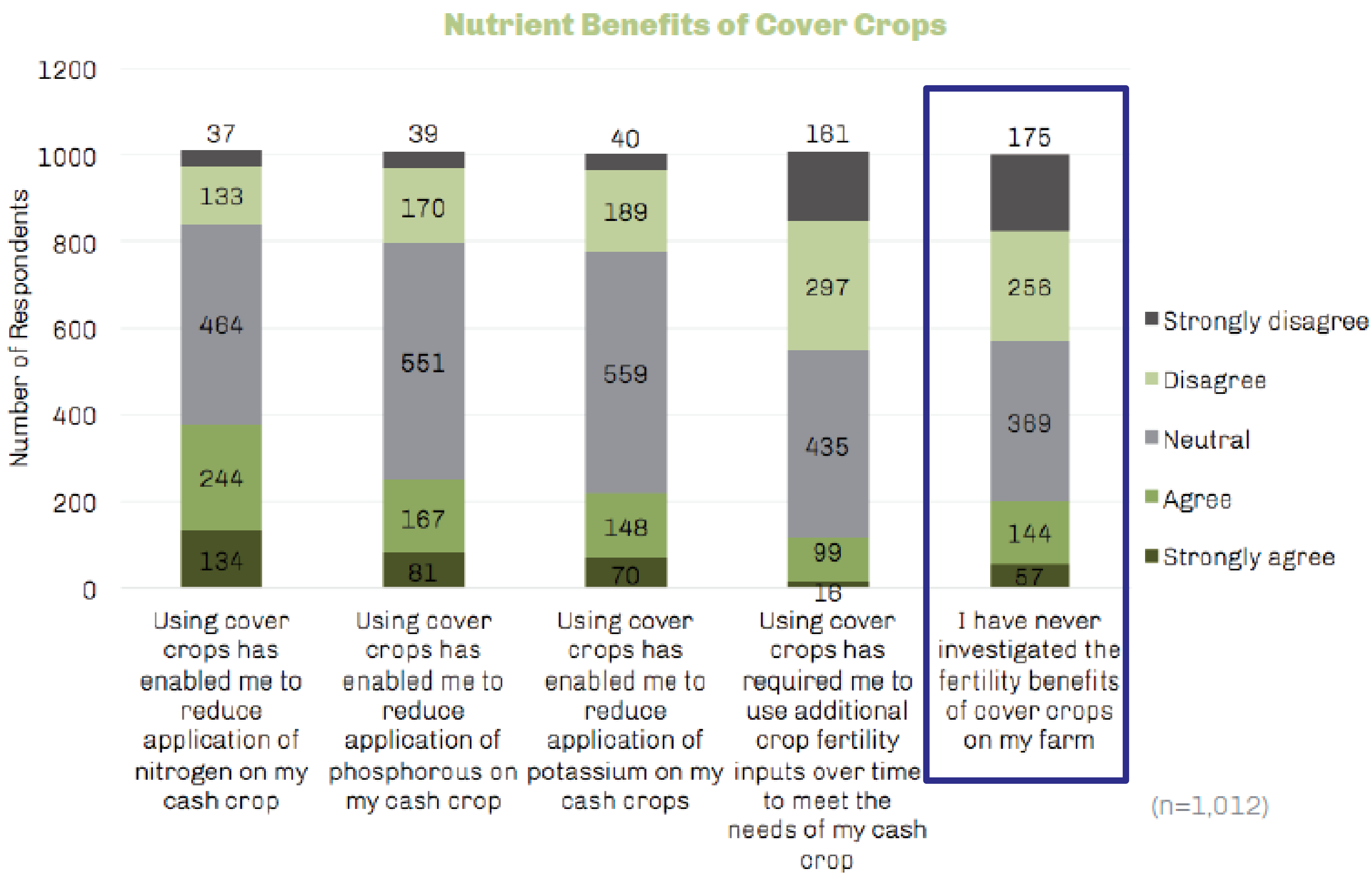
HOWEVER,

Ryegrass cover crop effect on total P leaching varied between an increase of 86% and decrease of 43%.

Climate conditions involving freezing-thawing during winter increased the risk of losses of dissolved P from cover crop biomass.

Aronsson et al., 2016. JSWC.

Cover Crops and Nutrient Use



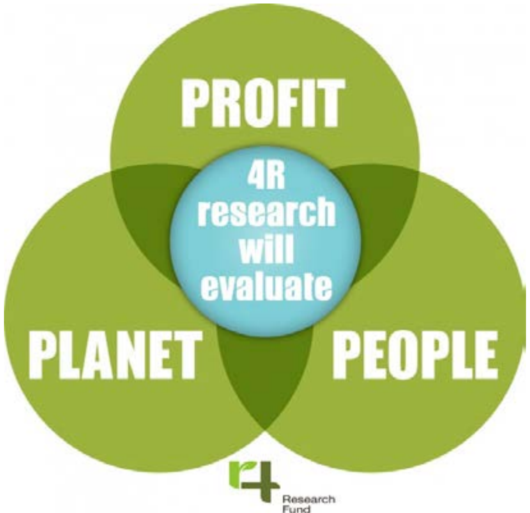
SARE Cover Crop Survey 2017

IPNI

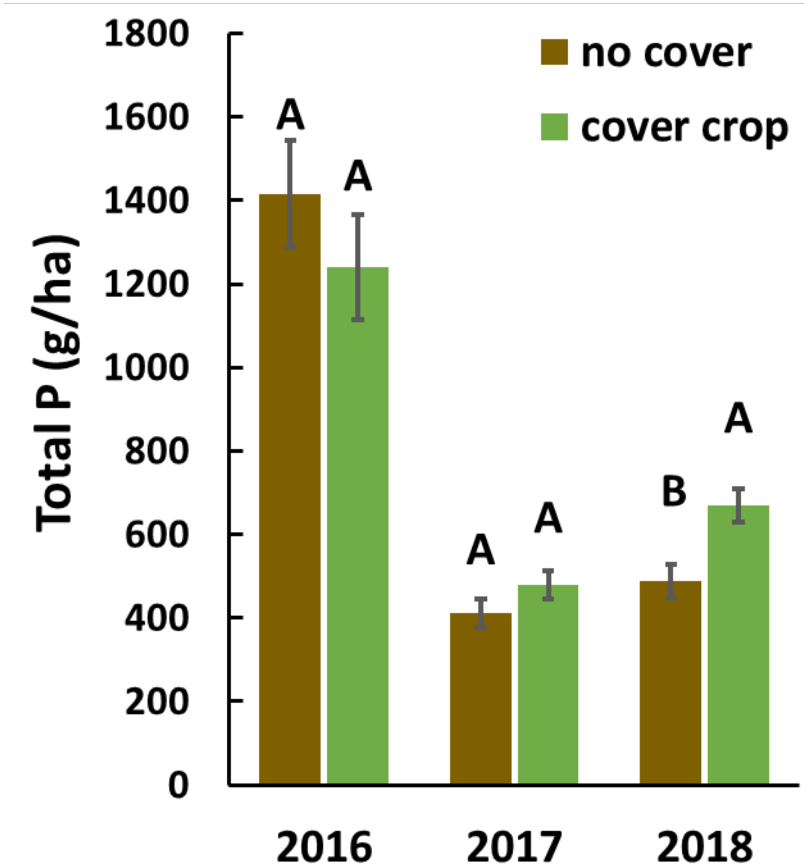
4R Research Fund

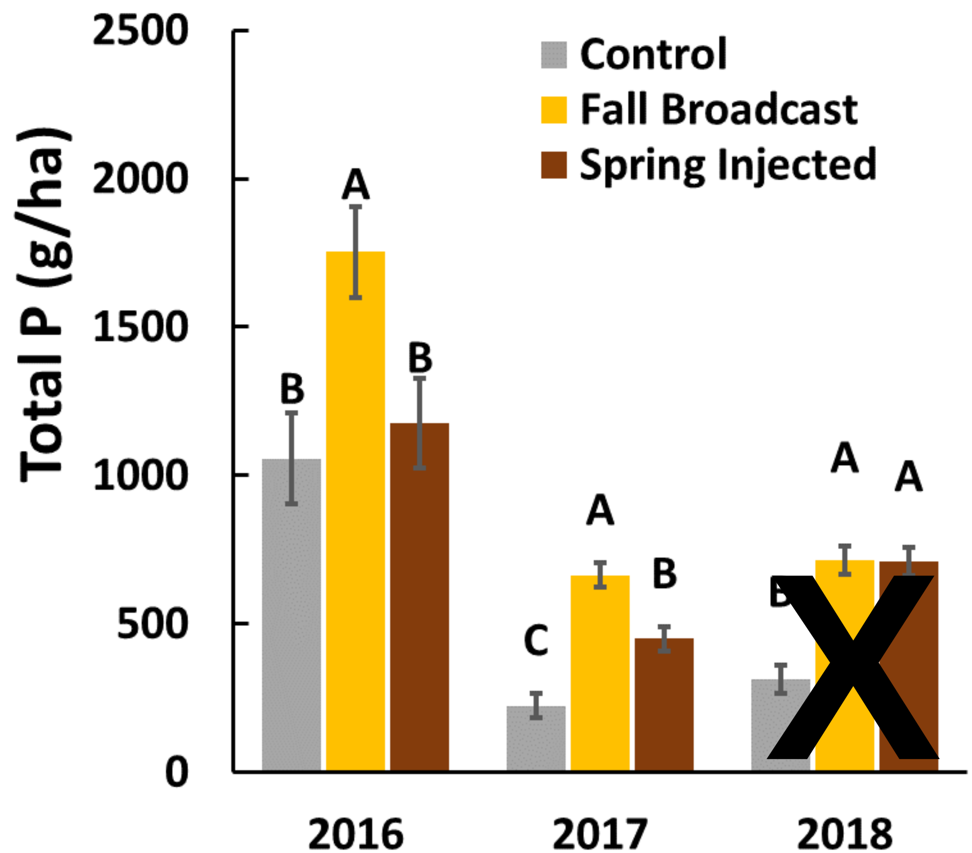
Minimizing P Loss with 4R Stewardship and Cover Crops

Dr. Nathan Nelson
Kansas State University



Cover crops can have varying effect on reducing total P

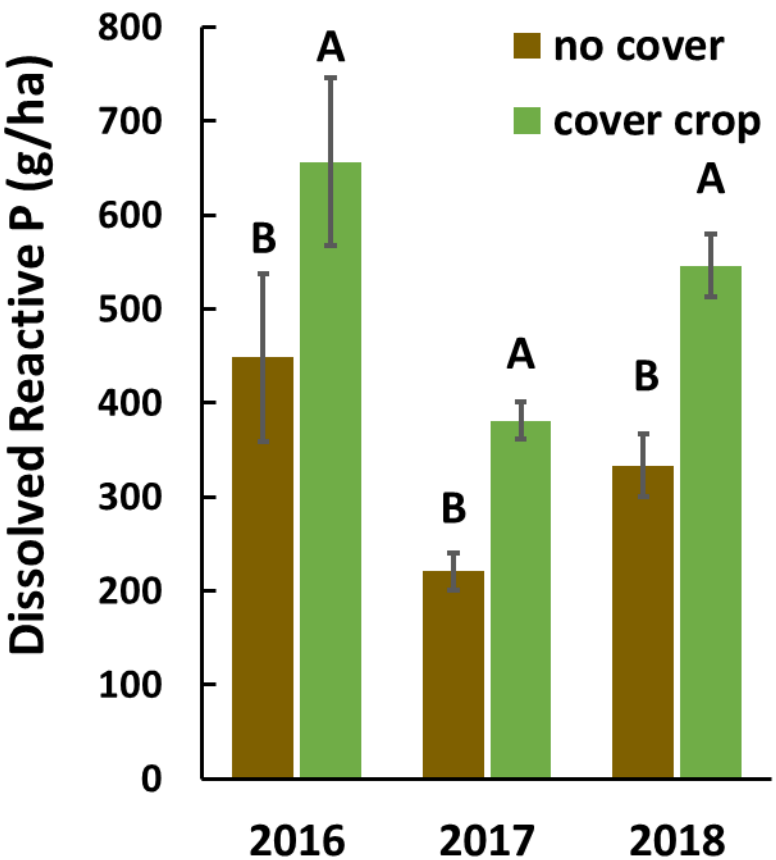


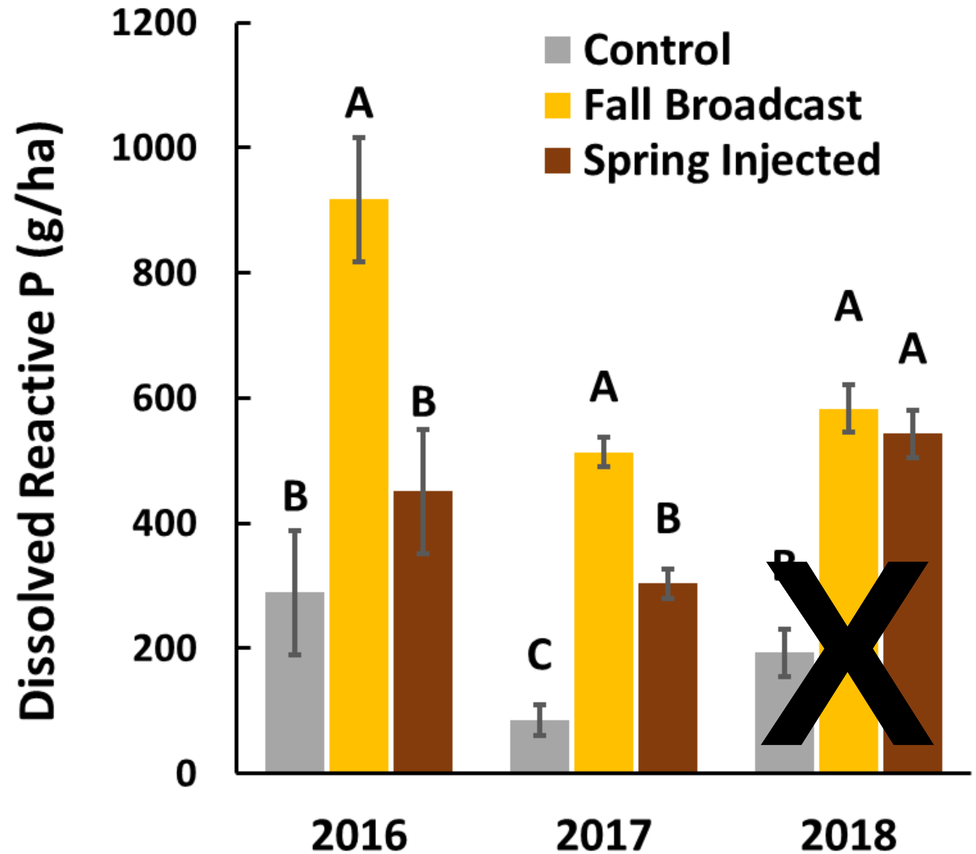


Total P

~30%

Cover crops increased dissolved P runoff losses by 60%

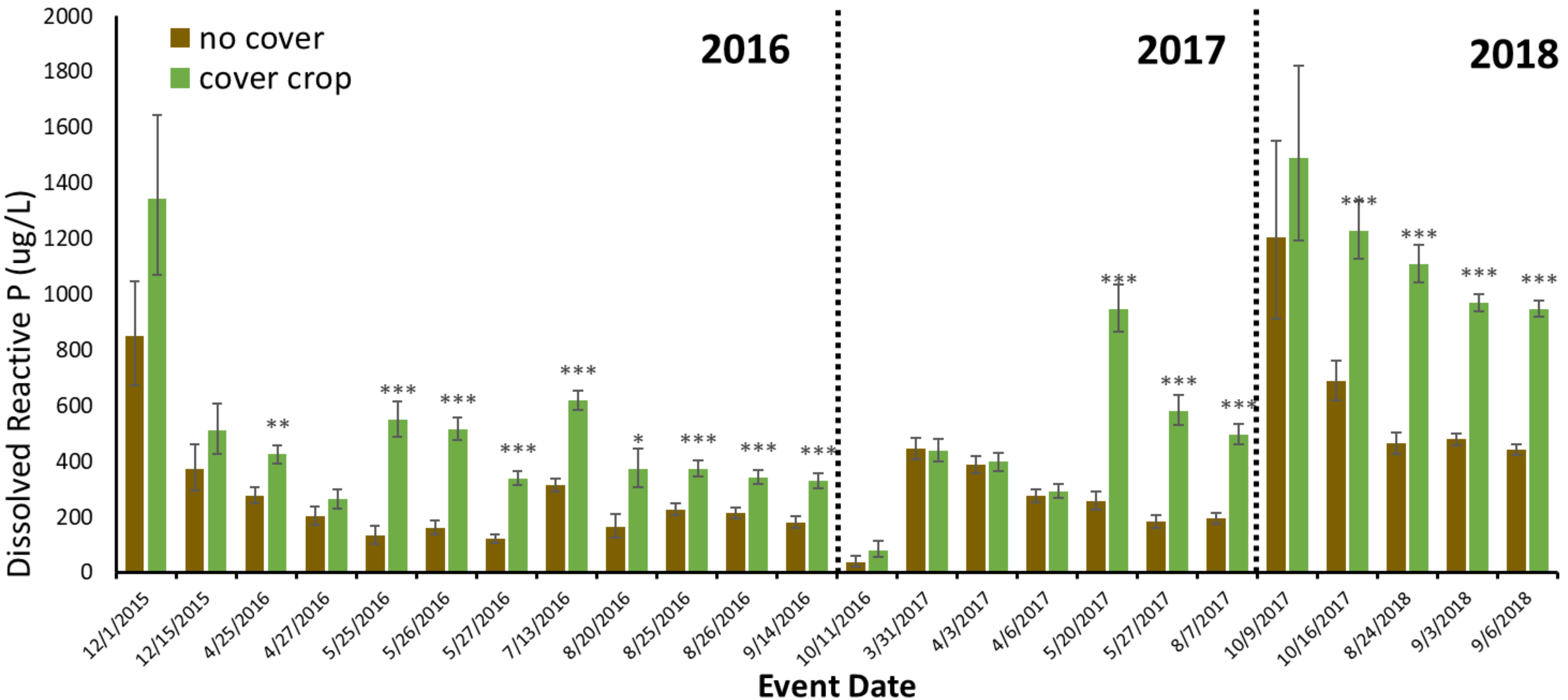




Dissolved P

40-50%

Cover crops doubled dissolved P runoff concentrations



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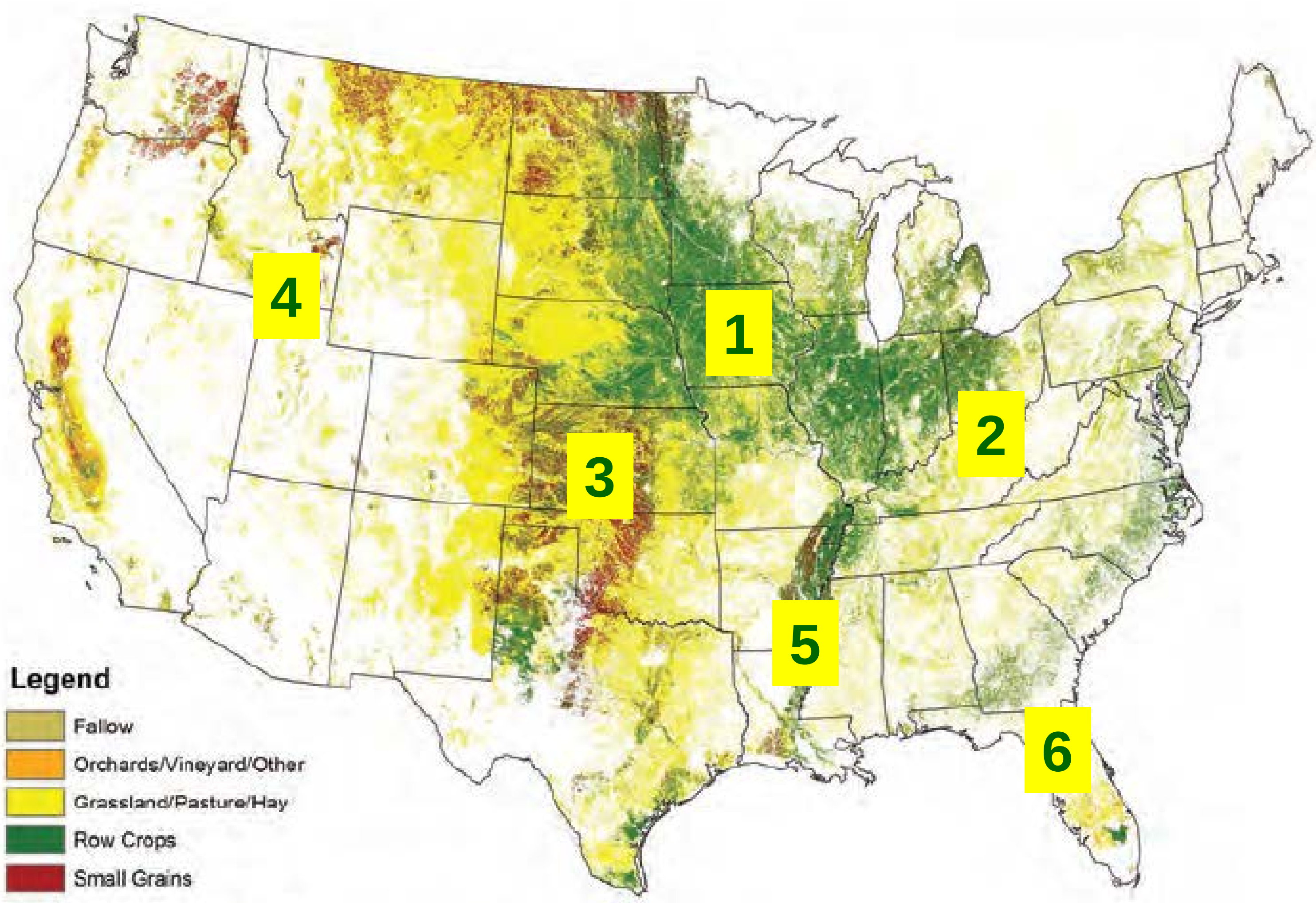
4R P Management

1. Western Corn and Soybean Region



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

4R Phosphorus Practices for Western Crops (Includes MN & IA)

Basic

Source: known or guaranteed analysis

Rate: recommended soil sampling and soil test interpretation

Time: avoid frozen and snow-covered soils, forecast rainfall

Placement: subsurface band encouraged; on surface only for no-till when risk index is low

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Intermediate

Source: manure nutrient analysis

Rate: as in basic, plus: P index used

Time: as in basic, & use P Index and avoid seasonal rainfall intensity

Placement: as in basic, plus avoid furrows of furrow-irrigated crops

Advanced

Source: as in intermediate

Rate: as in intermediate, plus: **zone-specific** based on soil sampling every 2 years, and crop yield maps

Time: 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.

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Our cropping systems are dynamic.

Overcoming P challenges requires….

an adaptive P management approach, focusing on the 4Rs to <u>optimize recovery</u>, and <u>minimize losses</u>.

Photo Credit: Guentzel

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Thank you!

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