Phosphorus Management Challenges Confronting the Midwest

Heidi Peterson
Phosphorus Program Director
Stillwater, Minnesota

AGVISE Soil Fertility Seminars
Granite Falls, Watertown, and Grand Forks
January 8-10, 2019

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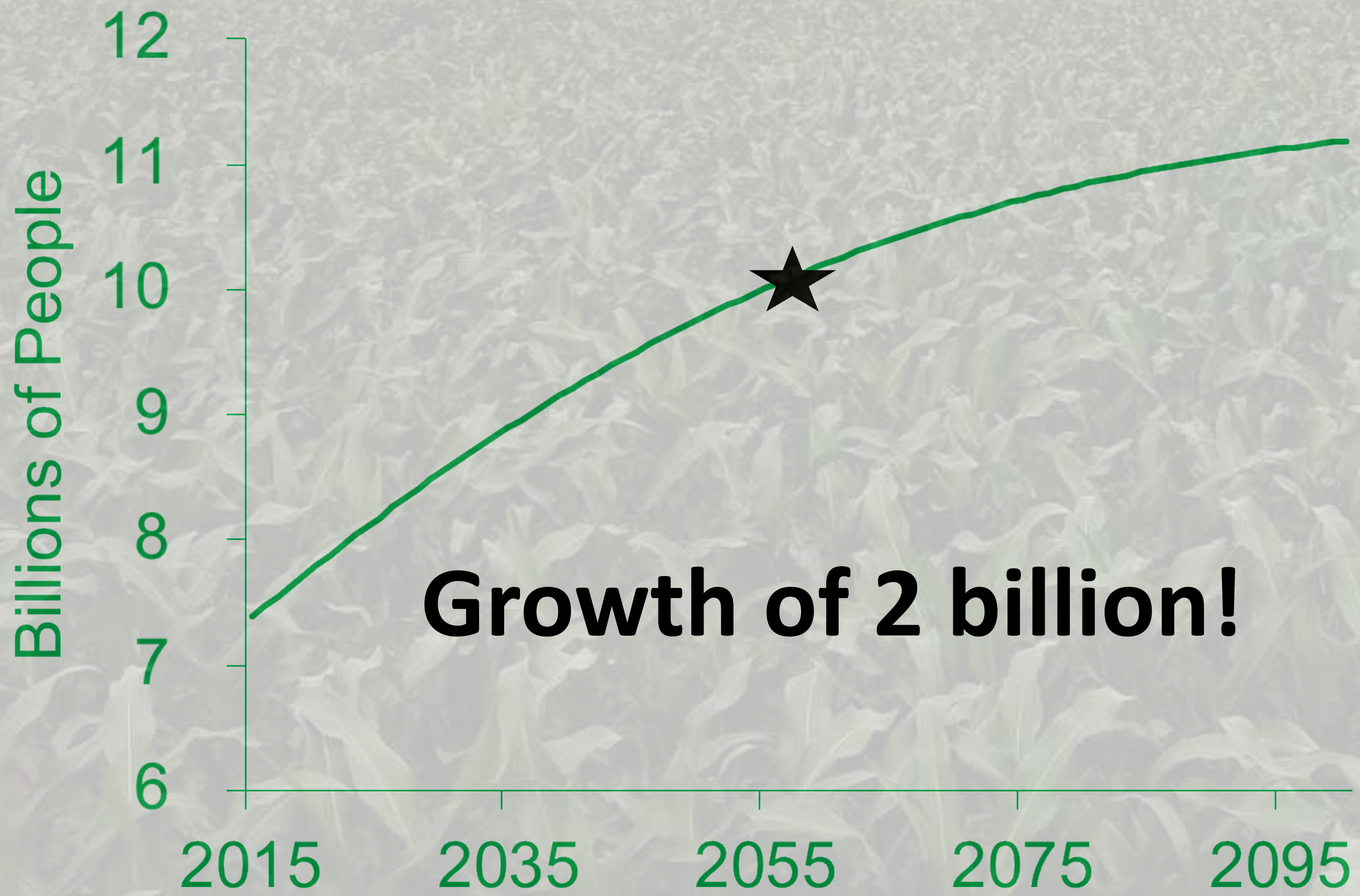
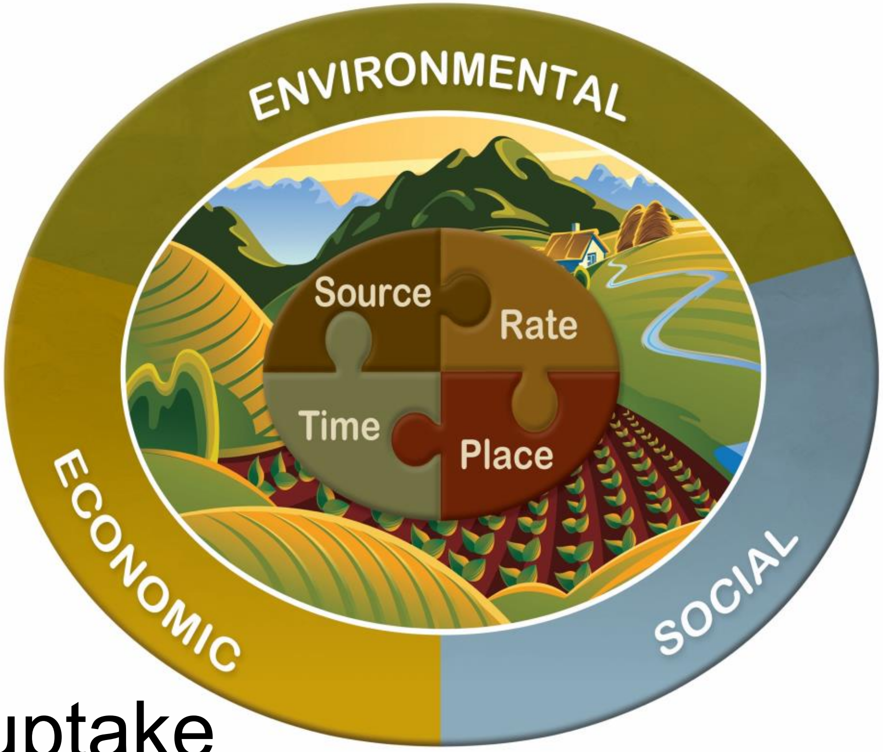
Global population >9 billion by 2050



Data Source: UN, 2017

4R Nutrient Stewardship:



Right **Source** of fertilizer

Right **Rate** for crop needs

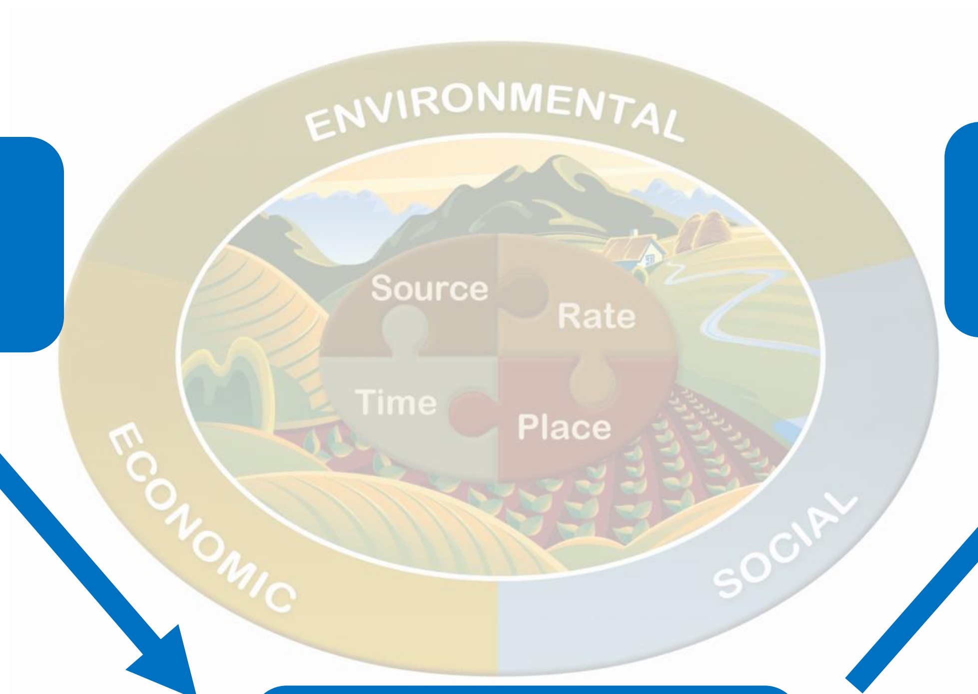
Right **Time** to match crop uptake

Right **Place** so crops can utilize

nutrient stewardship

Nutrient Stewardship Metrics for Sustainable Crop Nutrition

Enablers
(process metrics)



Outcomes
(impact metrics)

Actions
(adoption metrics)

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

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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

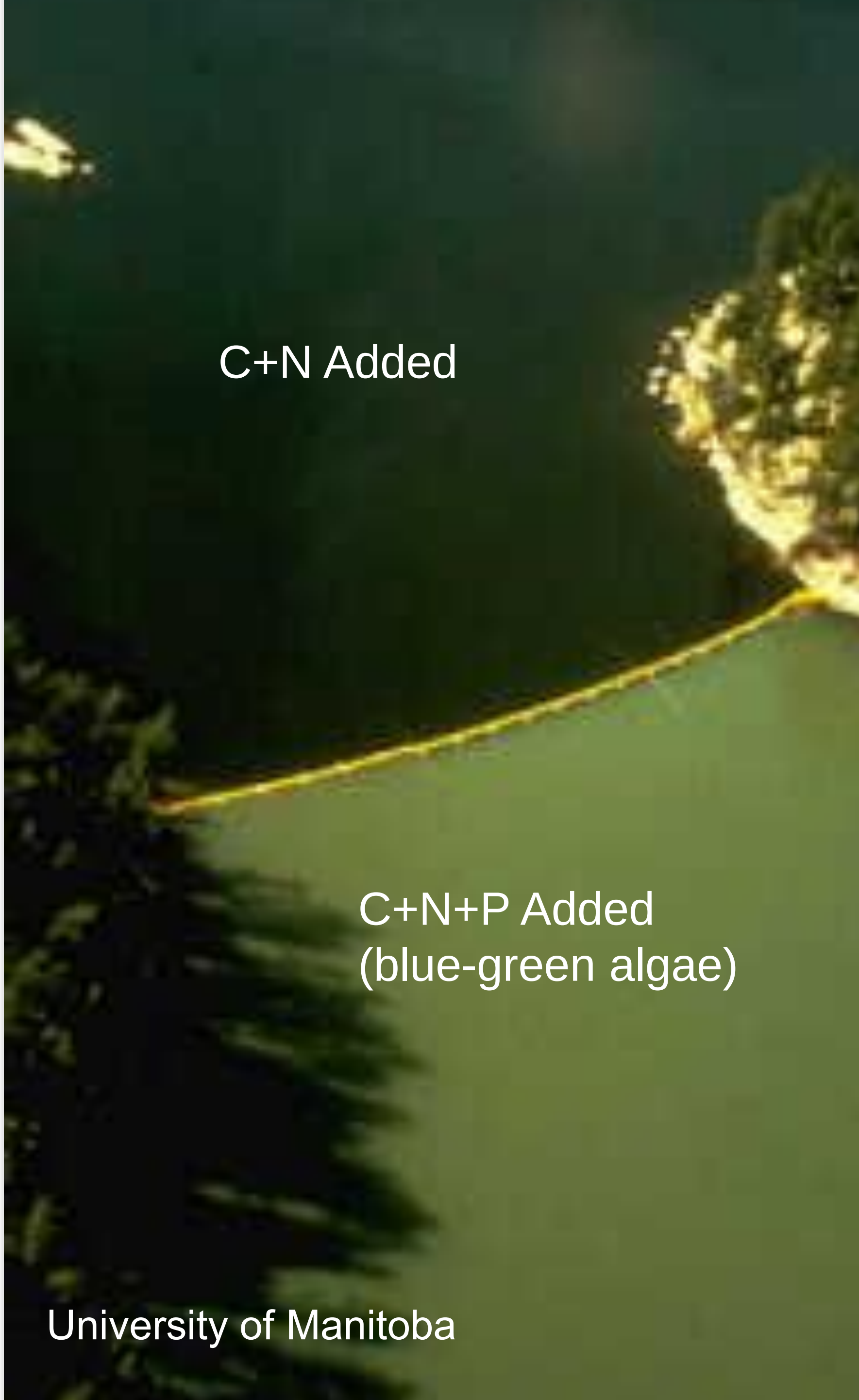
P Fertilizer and the Soil

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

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



P in the Red River Basin

5-year fight removes less than 1% of phosphorus from Lake Winnipeg basin

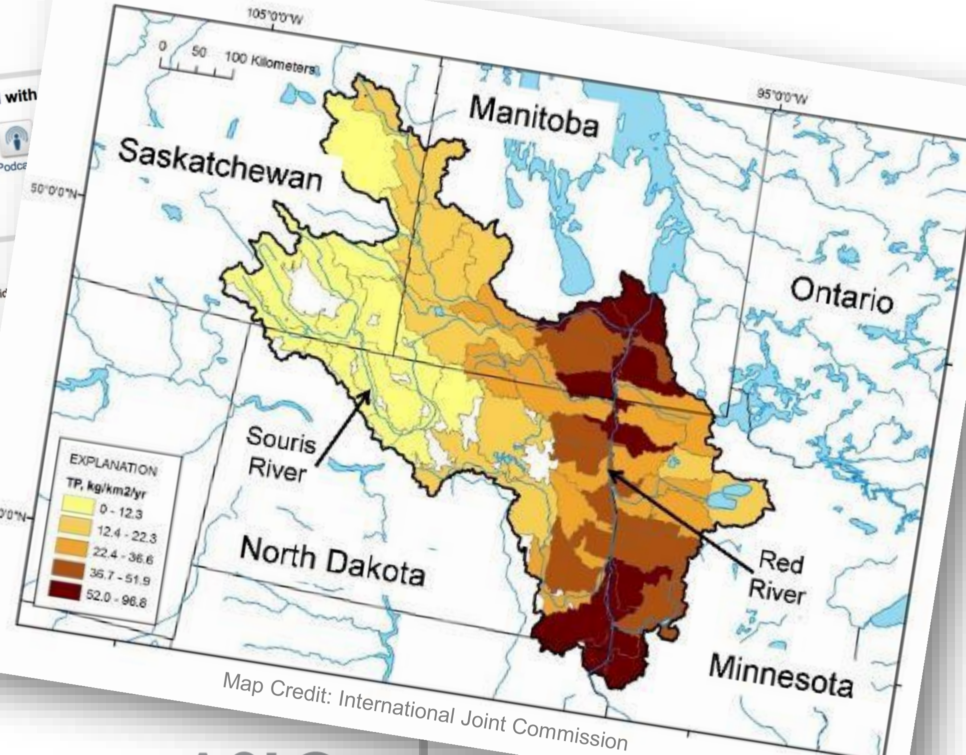
Targeted action needed against nutrient causing toxic algae blooms, scientists and advocates say

By Cameron MacLean, CBC News   Posted: Sep 17, 2017 4:00 AM CT | Last Updated: Sep 17, 2017 11:02 AM CT

Blue-green algae coats rocks at Victoria Beach on July 27, 2017. (Kristie Pearson)

658 shares

After five years and millions of dollars spent, a federal program aimed at ... the health of Manitoba's biggest lake has barely made a dent in



Map Credit: International Joint Commission

LIMNOLOGY and OCEANOGRAPHY

ASLO

Limnol. Oceanogr. 61, 2016, 2090–2107

doi: 10.1002/lno.10355

Increased variability and sudden ecosystem state change in Lake Winnipeg, Canada, caused by 20th century agriculture

L. Bunting,[1] P.R. Leavitt,*[1,2] G.L. Simpson,[2] B. Wissel,[2] K.R. Laird,[3] B.F. Cumming,[3] A. St. Amand,[4] D.R. Engstrom[5]

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[4]PhycoTech Inc., Saint Joseph, Michigan
[5]St. Croix Watershed Research Station, Science Museum of Minnesota, St. Croix, Minnesota

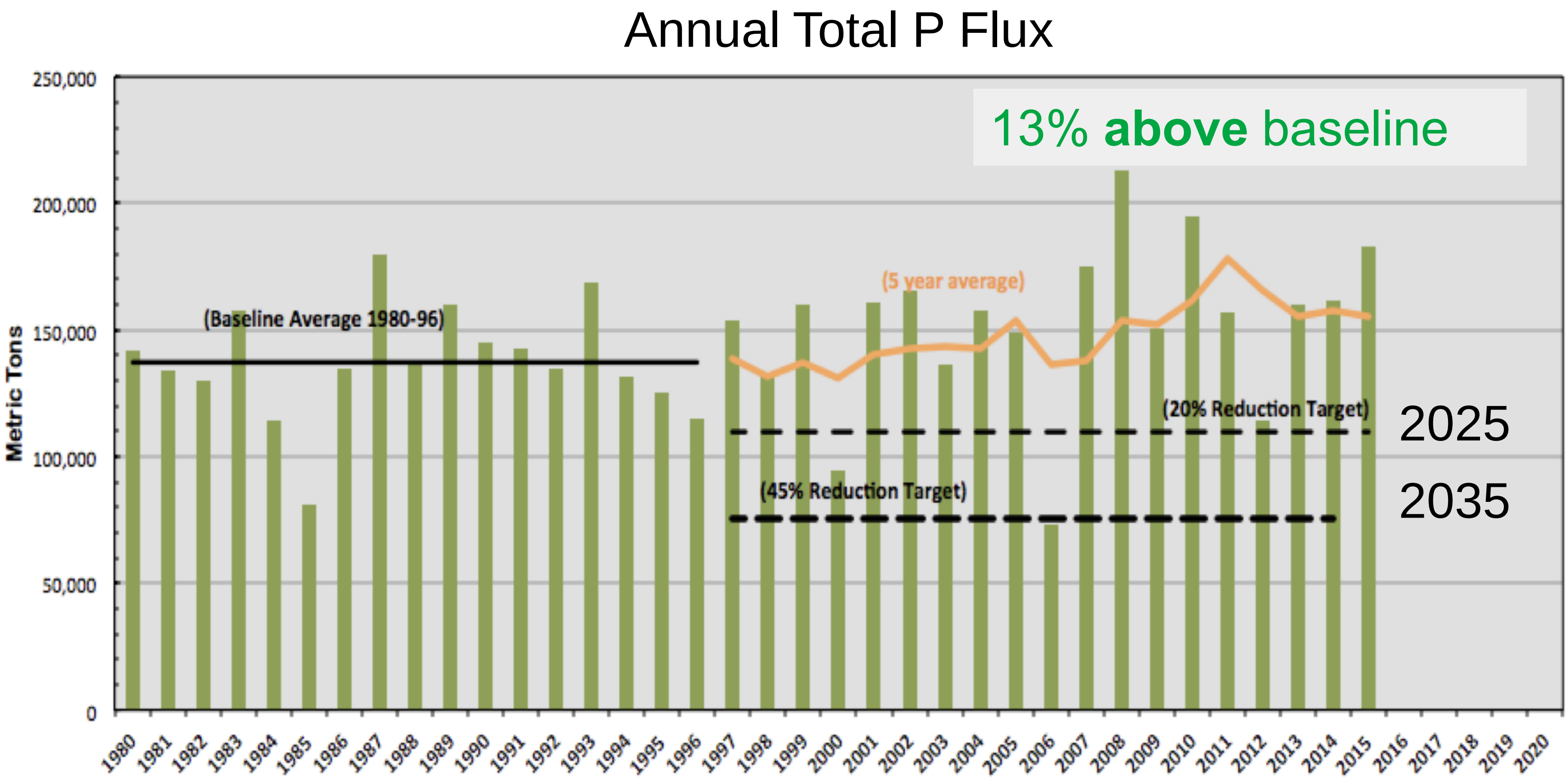
Abstract

Mississippi River Basin

Produces 40% of the world's corn!

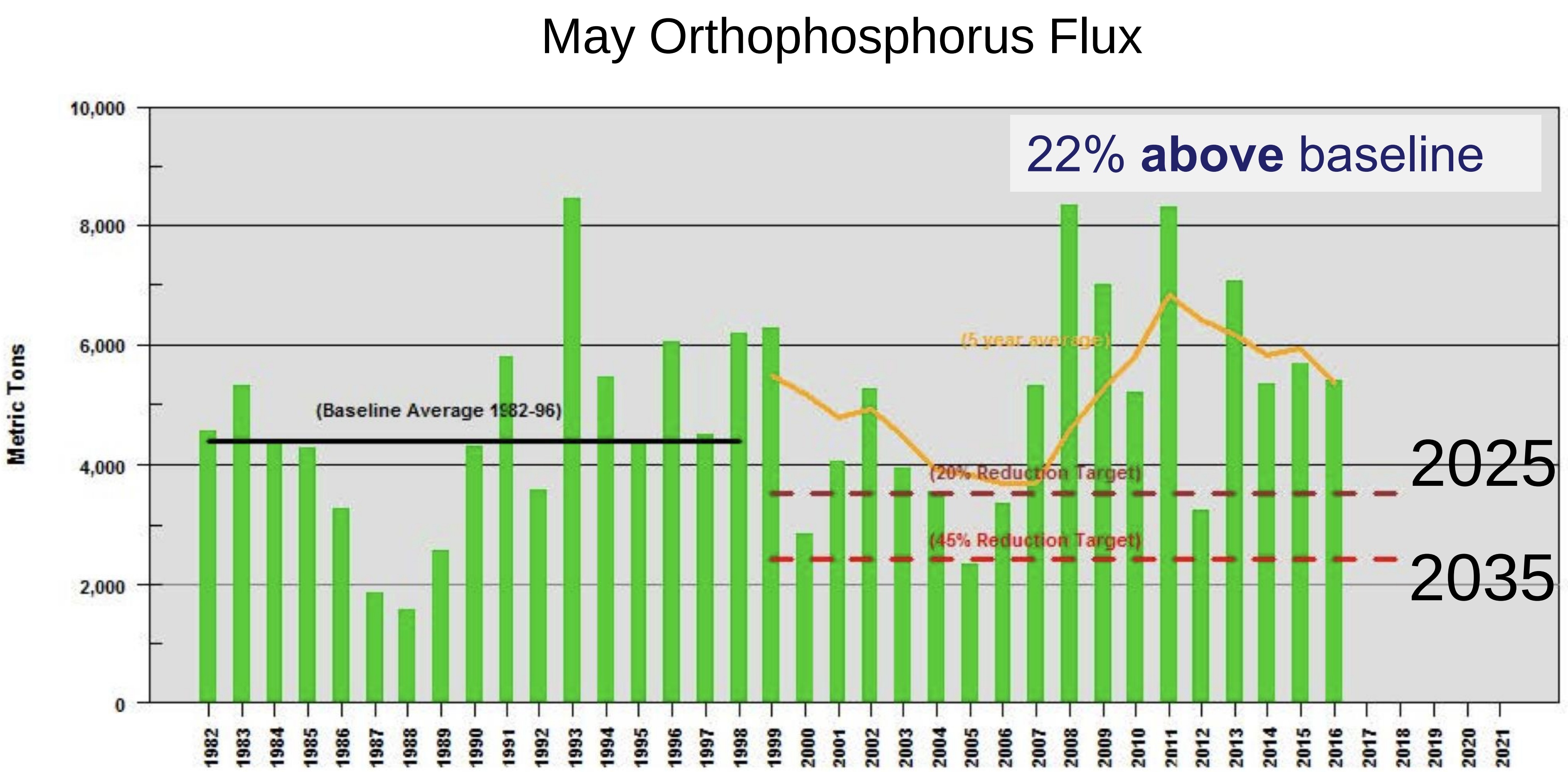
Gulf of Mexico Hypoxia

Total P Load to Gulf of Mexico



Graph from the HTF 2017 Report to Congress

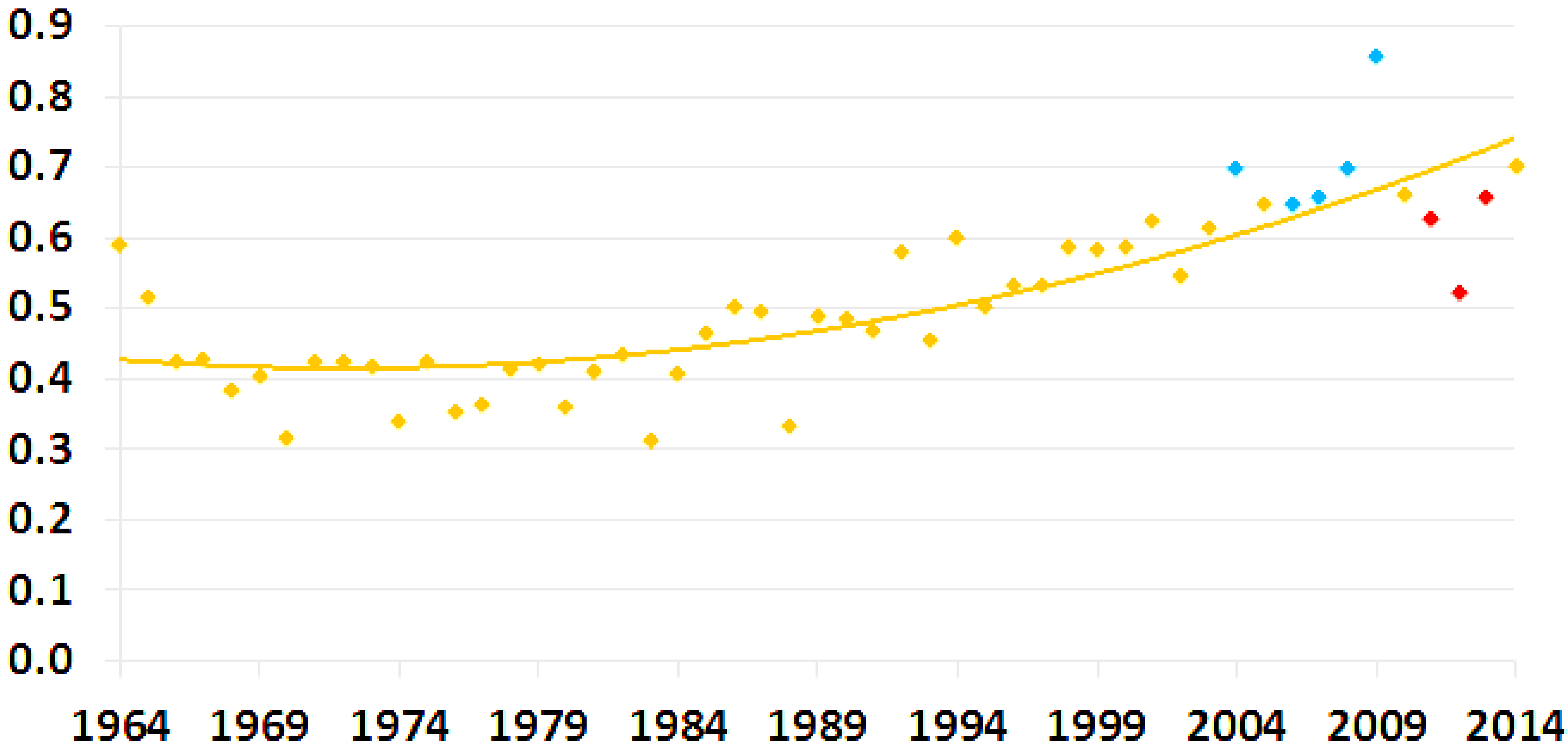
Ortho P Flux to Gulf of Mexico



Graph from the HTF 2017 Report to Congress

US Fertilizer Use Efficiency in Corn Doubled between 1980 and 2014

Partial Factor Productivity for N + P_2O_5 + K_2O
Bushels corn/ lb fertilizer nutrients



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.

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.

Order Book

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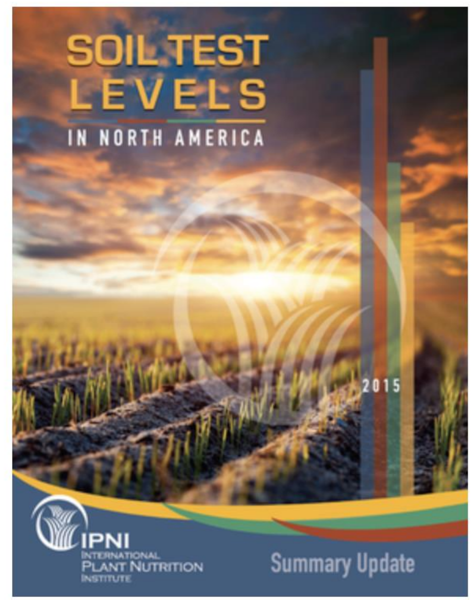


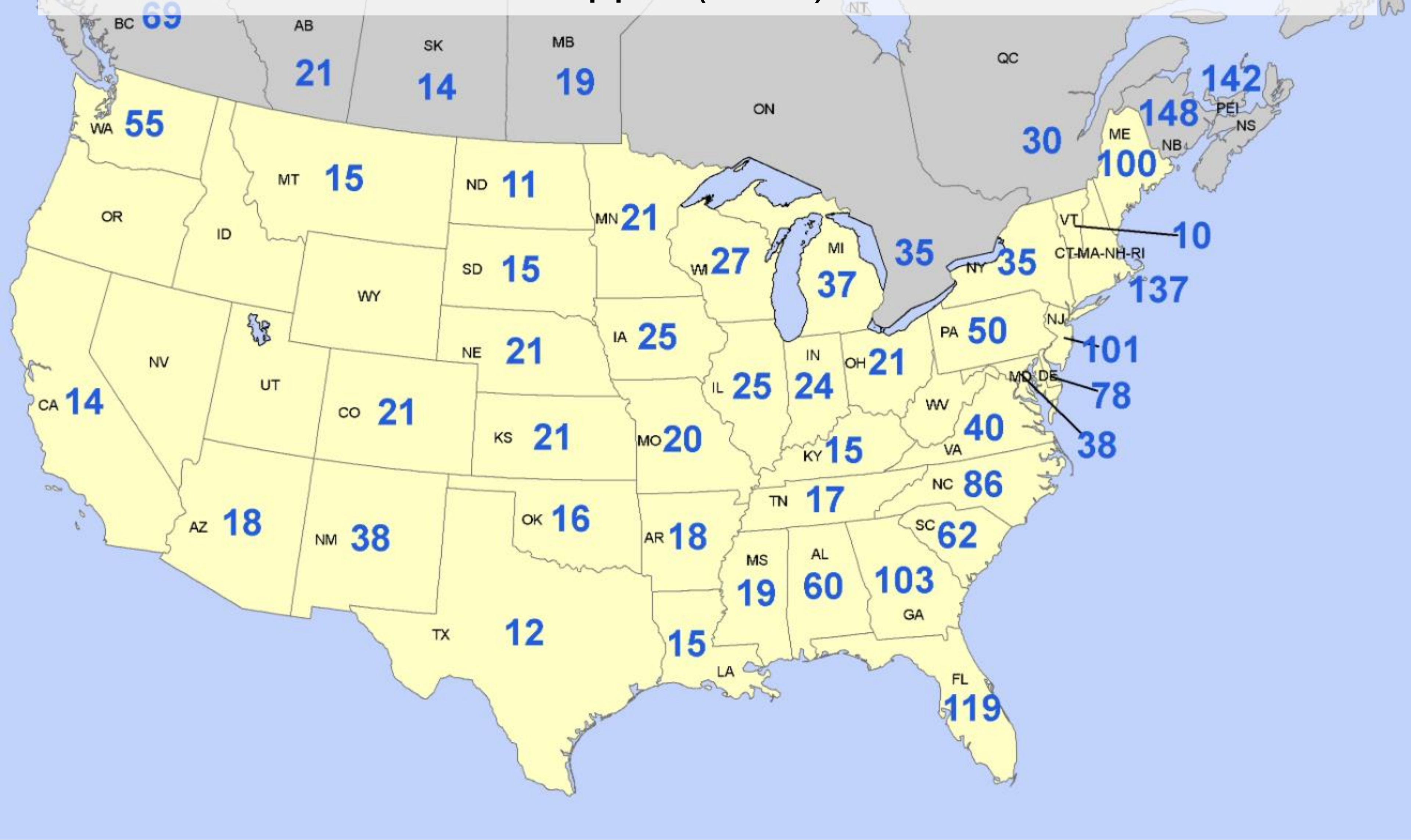
Related Content

Visit Store
Soil Test Levels in North America: 2015 Summary Update

From the Soil Test Summary Archive

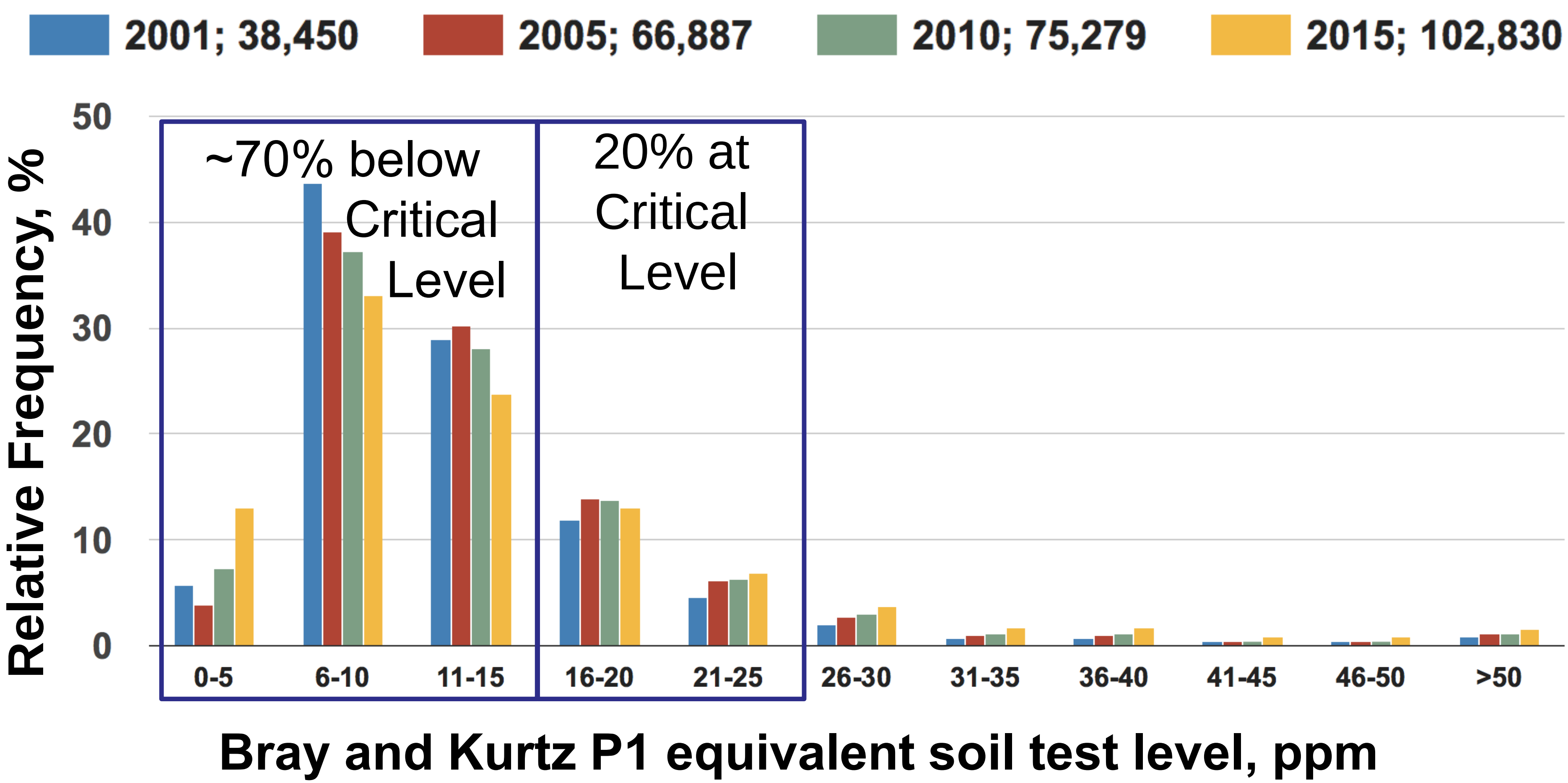
Better Fertilizer Recommendations
More on this topic.

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



http://soiltest.ipni.net/

STP Distribution in North Dakota



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

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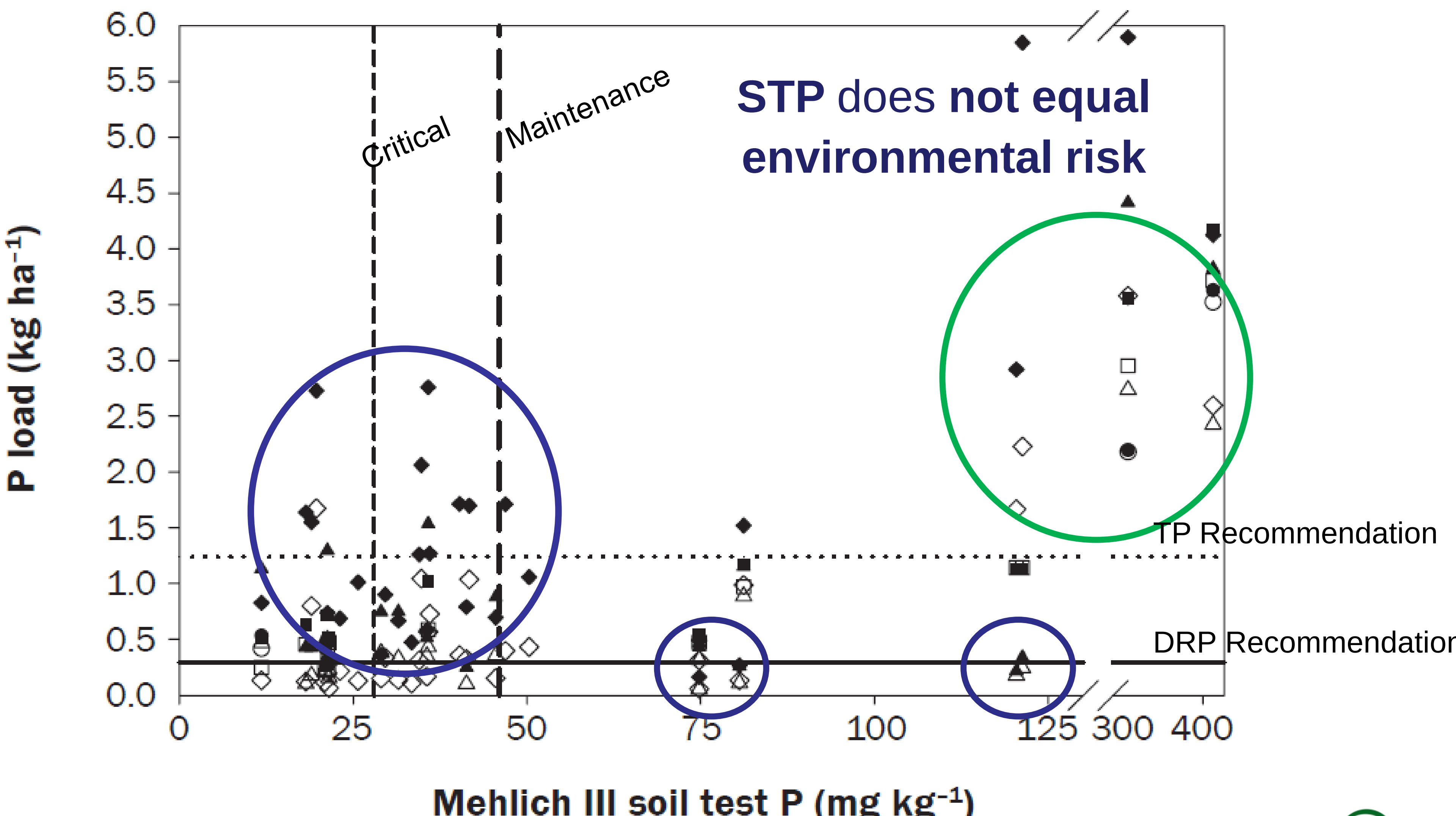
STP **above** recommended rates <u>poses</u> environmental risk …..**BUT**



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

Phosphorus Use Efficiency

Partial Nutrient Balance

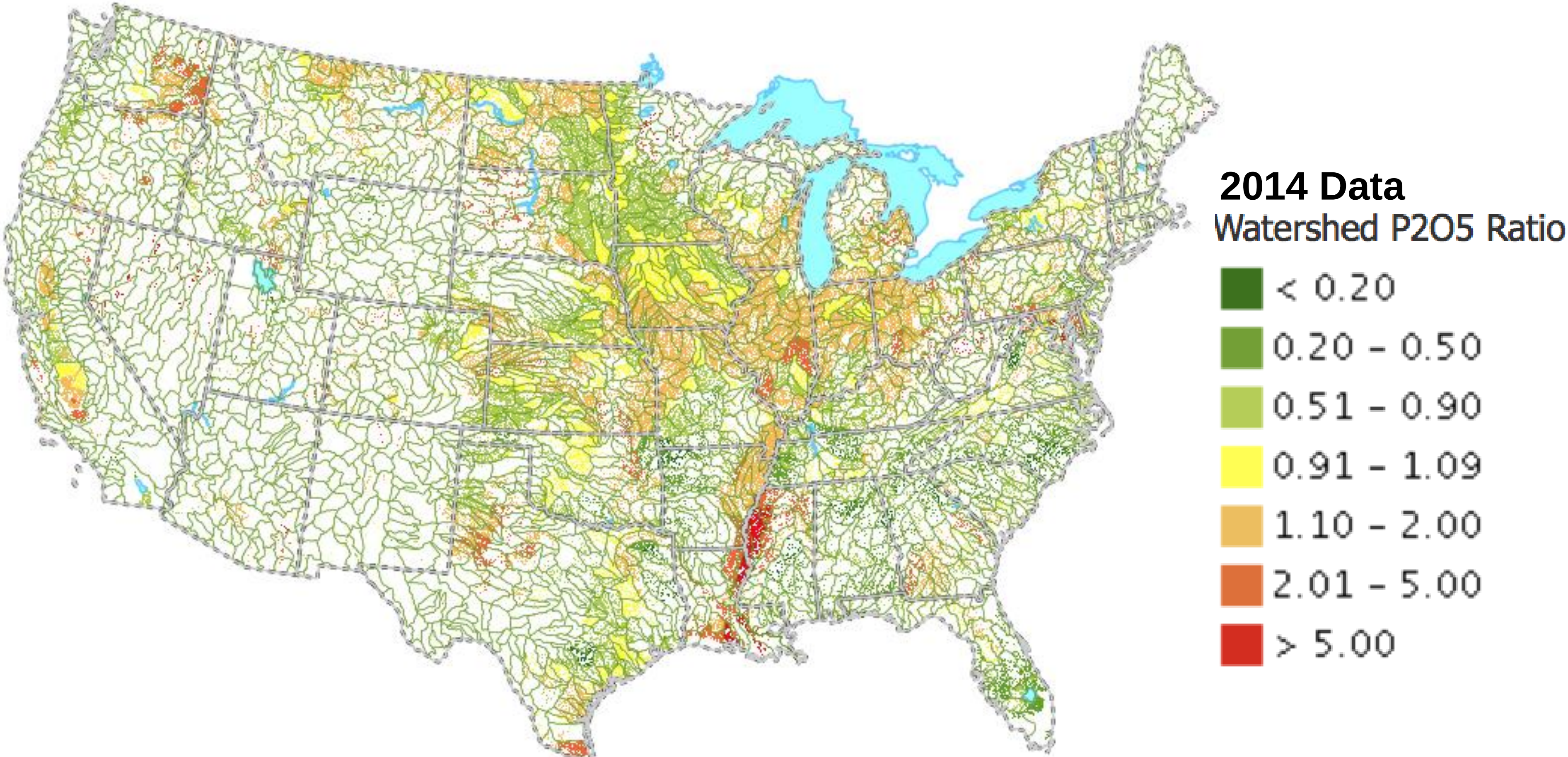
$$\textbf{Crop PUE} = \frac{\textbf{crop P removal}}{\textbf{fertilizer P + manure P applied}}$$

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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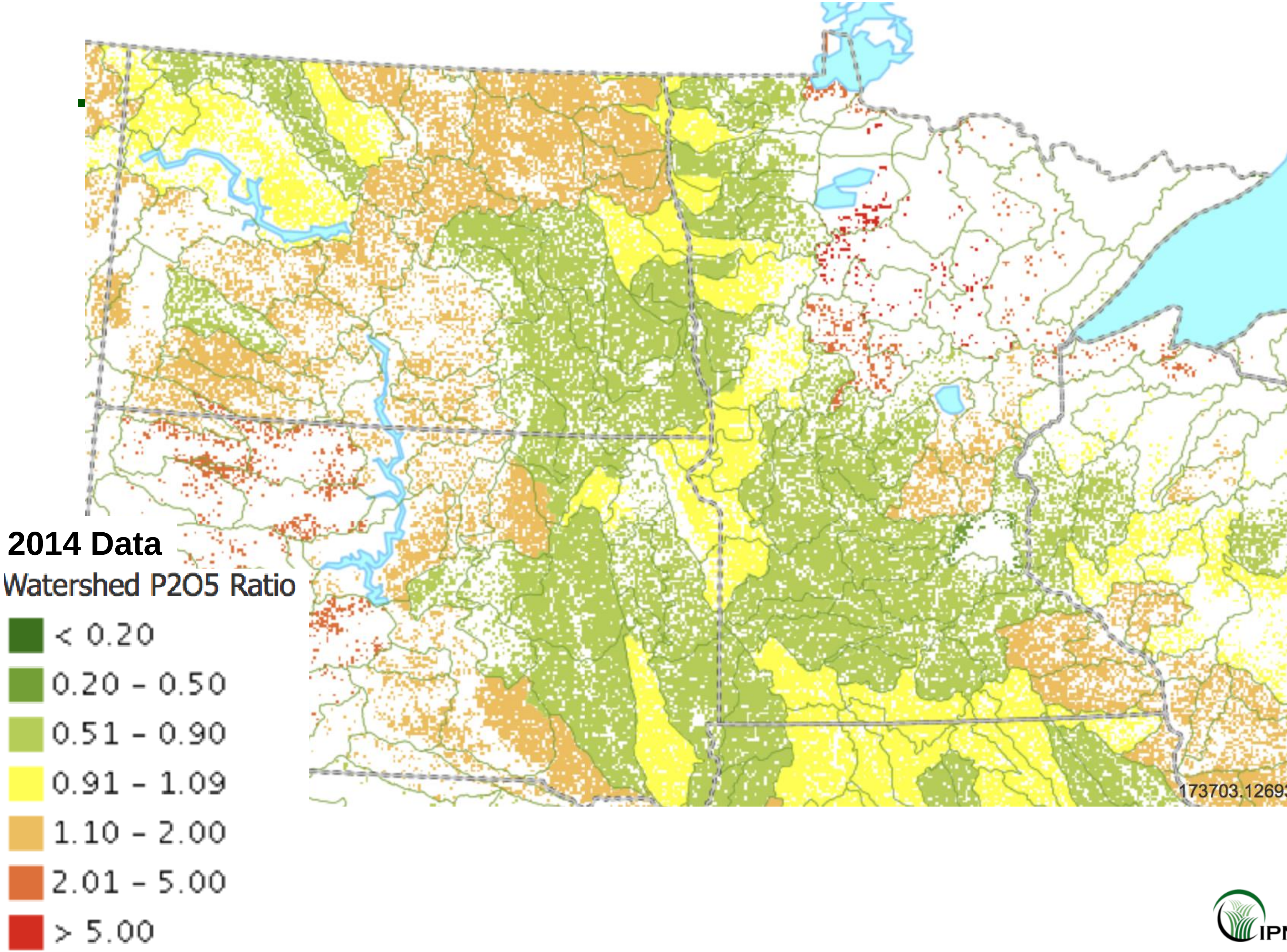
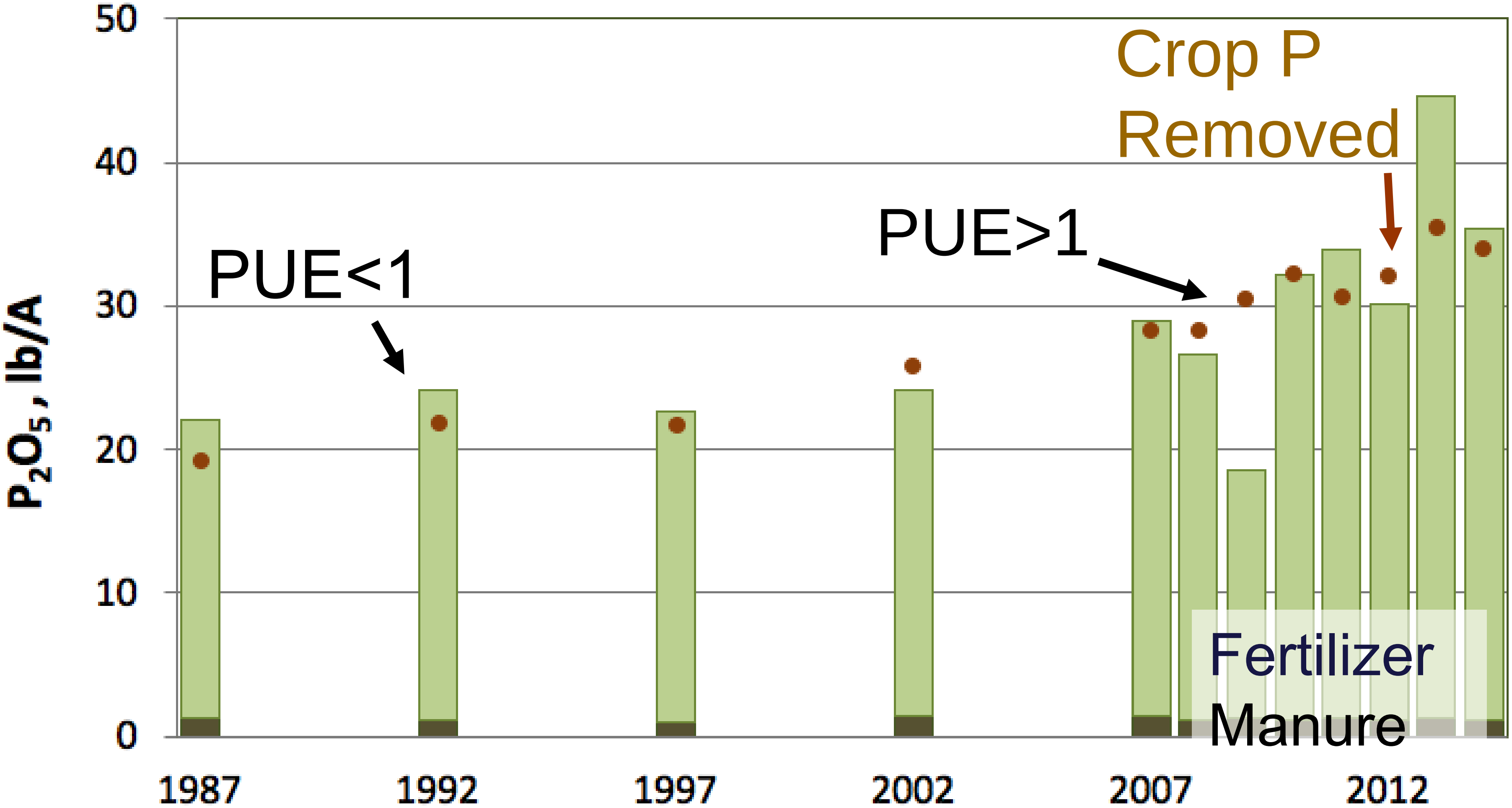
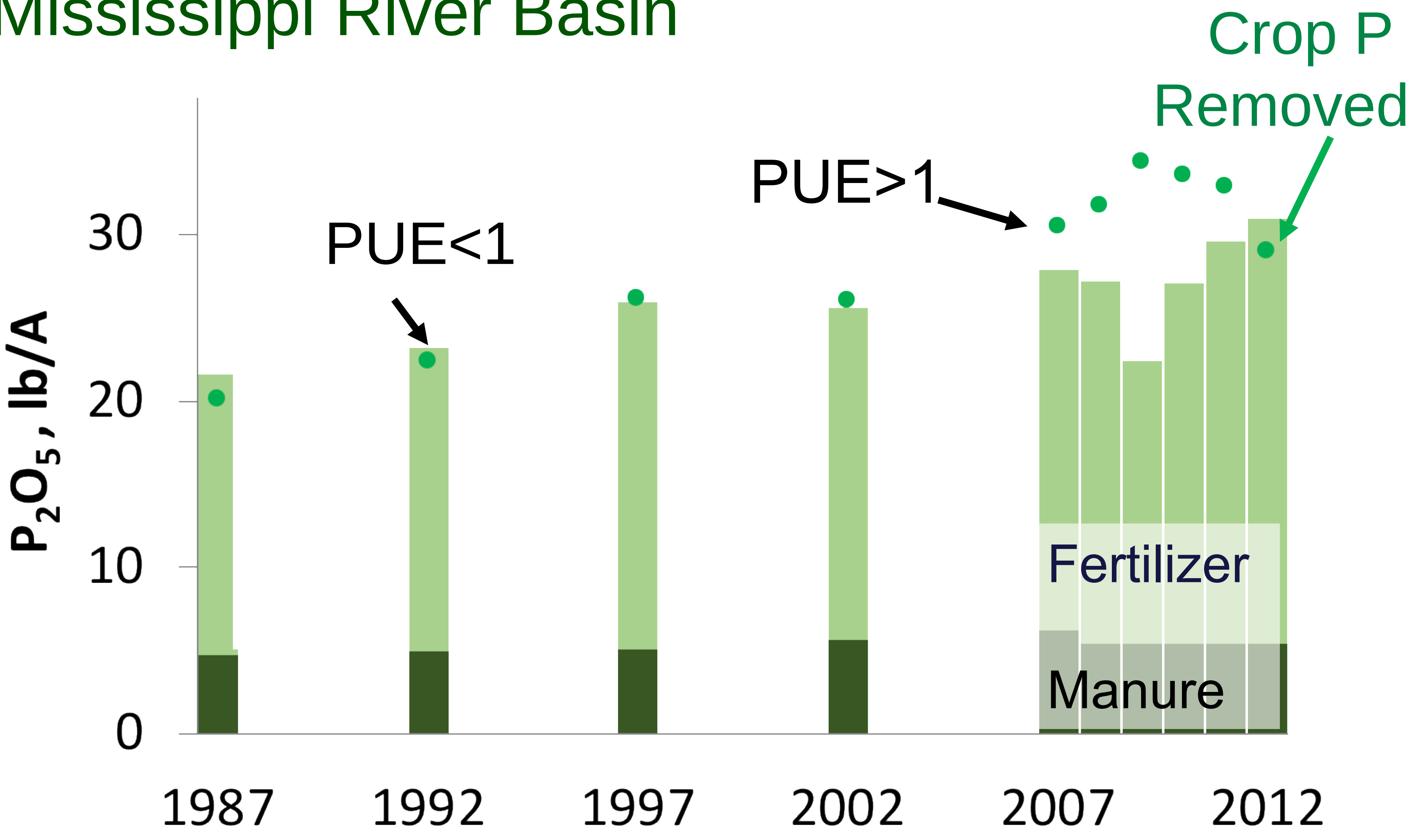

2014 Data
Watershed P2O5 Ratio
< 0.20
0.20 - 0.50
0.51 - 0.90
0.91 - 1.09
1.10 - 2.00
2.01 - 5.00
> 5.00
173703.12693

P Inputs > Crop Removal,

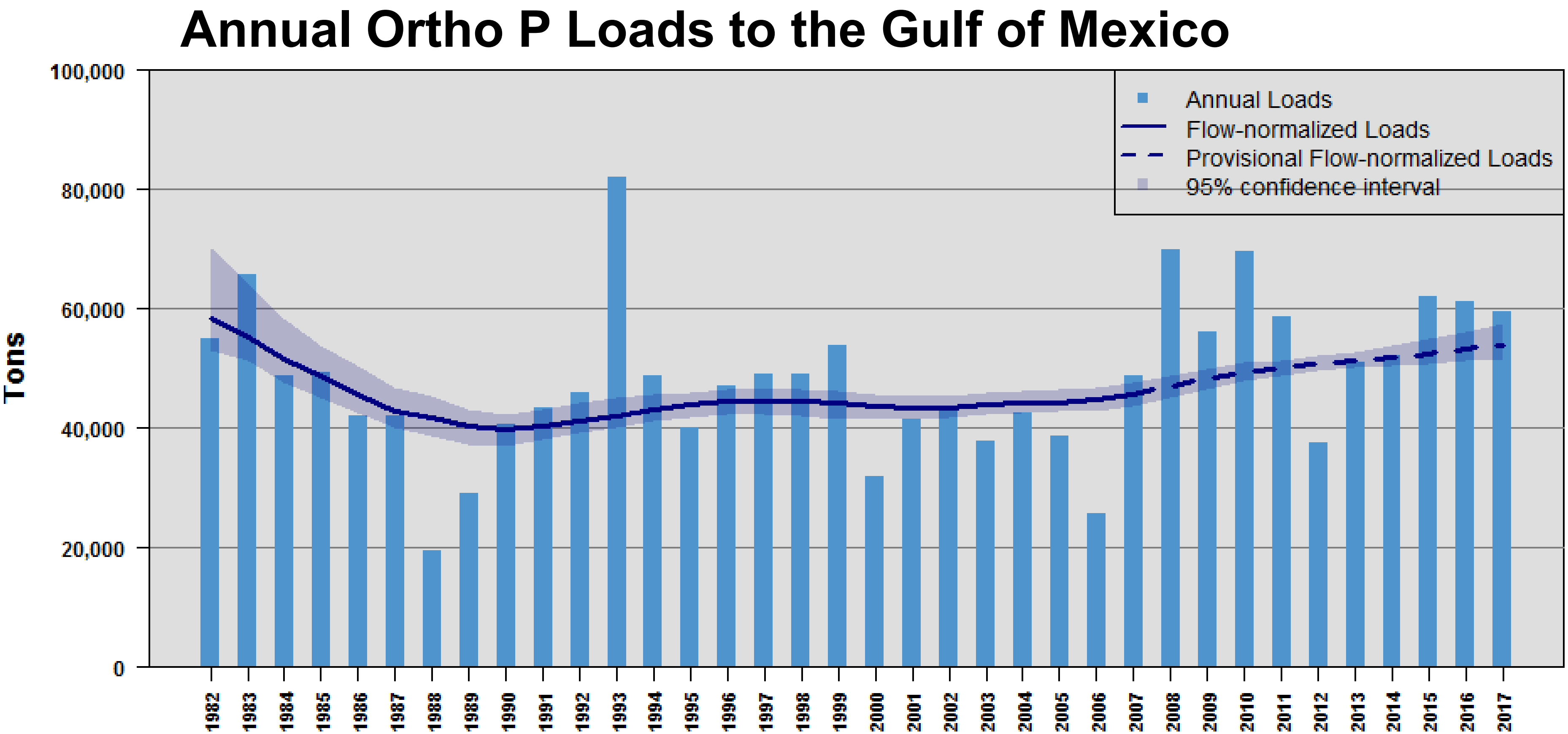
Souris-Red-Rainy Basin



P Inputs < Crop Removal,
Mississippi River Basin



Increased Ortho P Load Exceeds Natural Variability



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

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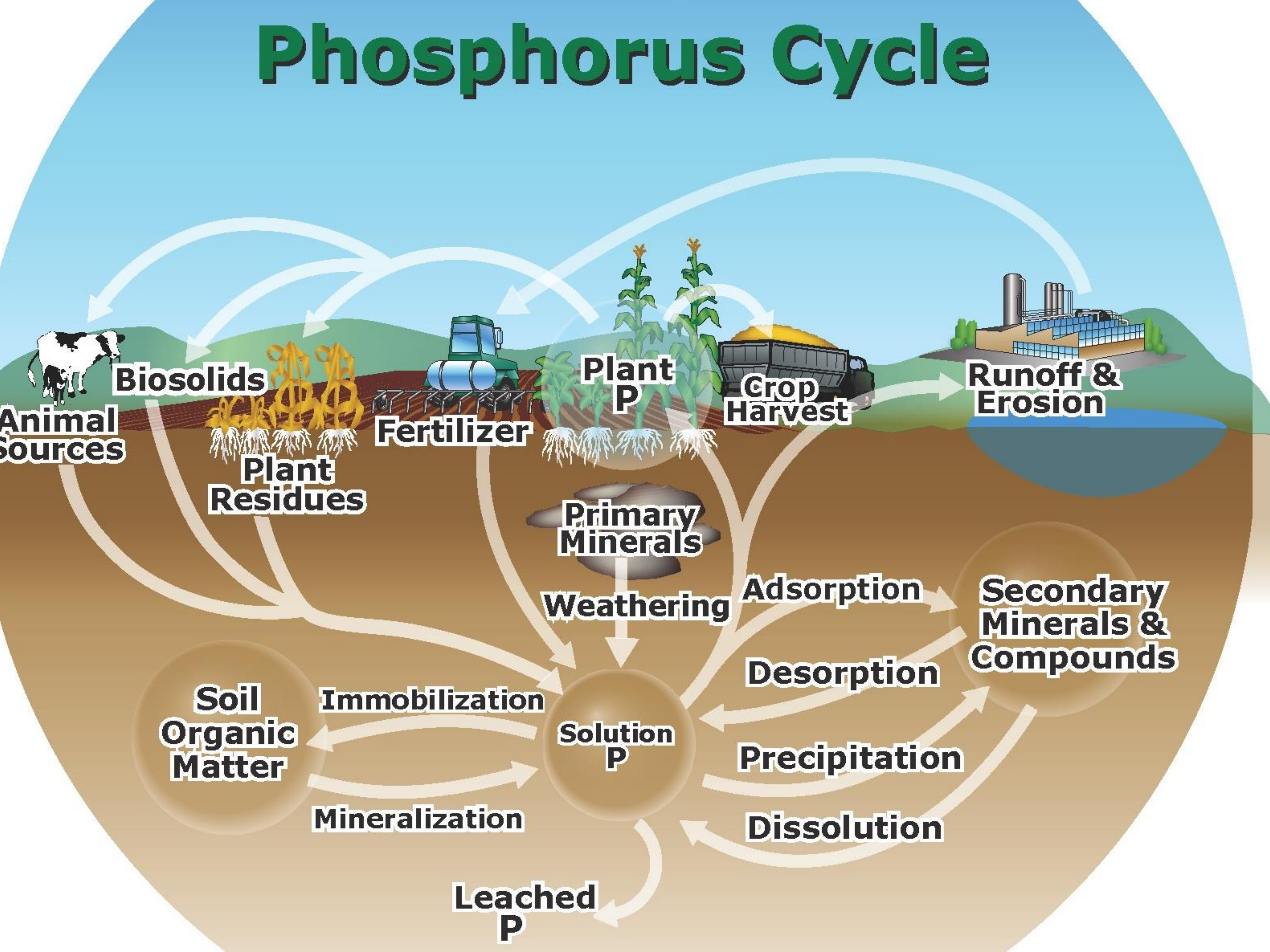
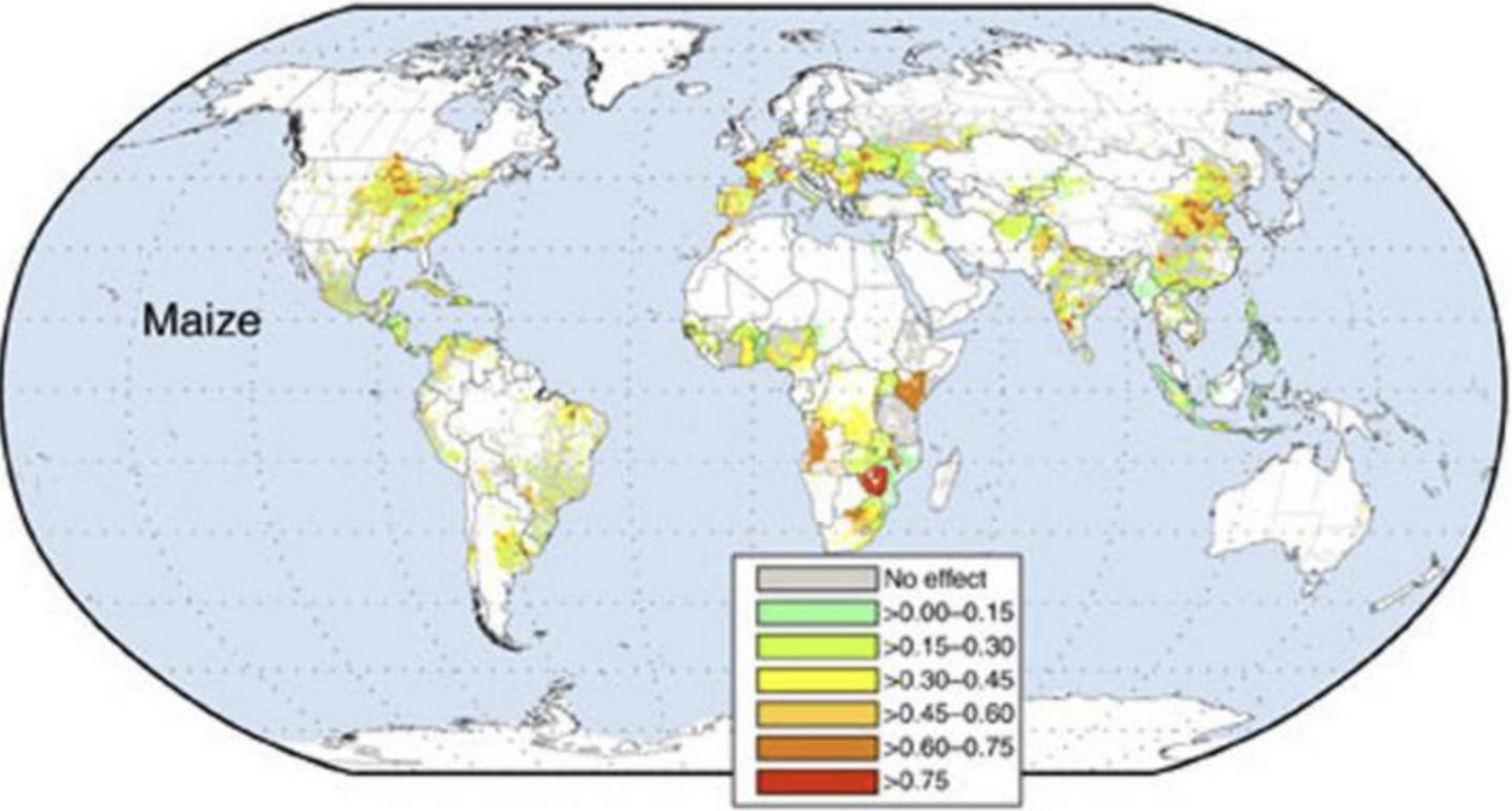

Phosphorus Cycle
Biosolids
Animal Sources
Plant Residues
Fertilizer
Plant P
Crop Harvest
Runoff & Erosion
Primary Minerals
Weathering
Adsorption
Secondary Minerals & Compounds
Desorption
Soil Organic Matter
Immobilization
Solution P
Precipitation
Mineralization
Dissolution
Leached P

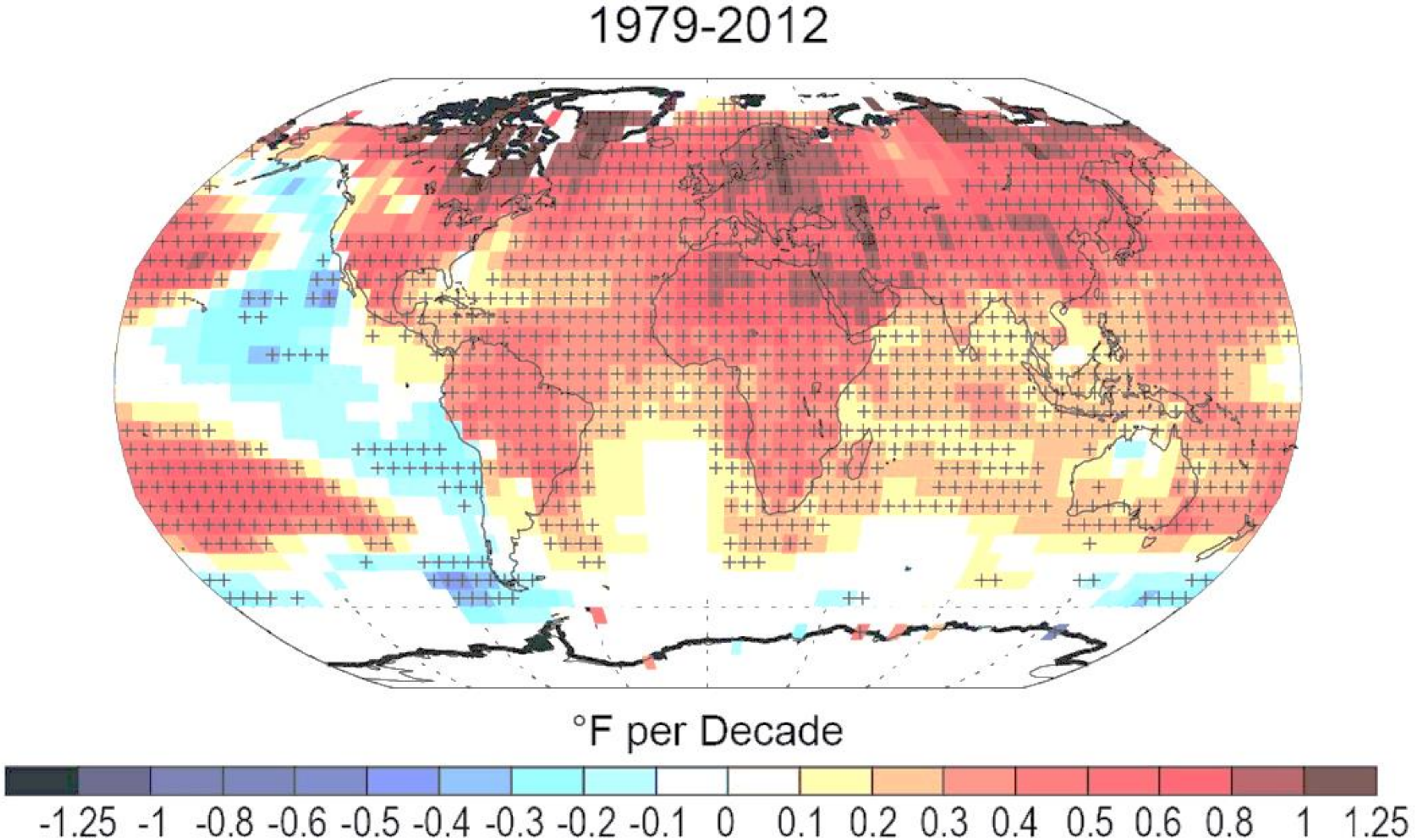
Globally, 39% of Annual Corn Yield Variability Climate Related



(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!

May 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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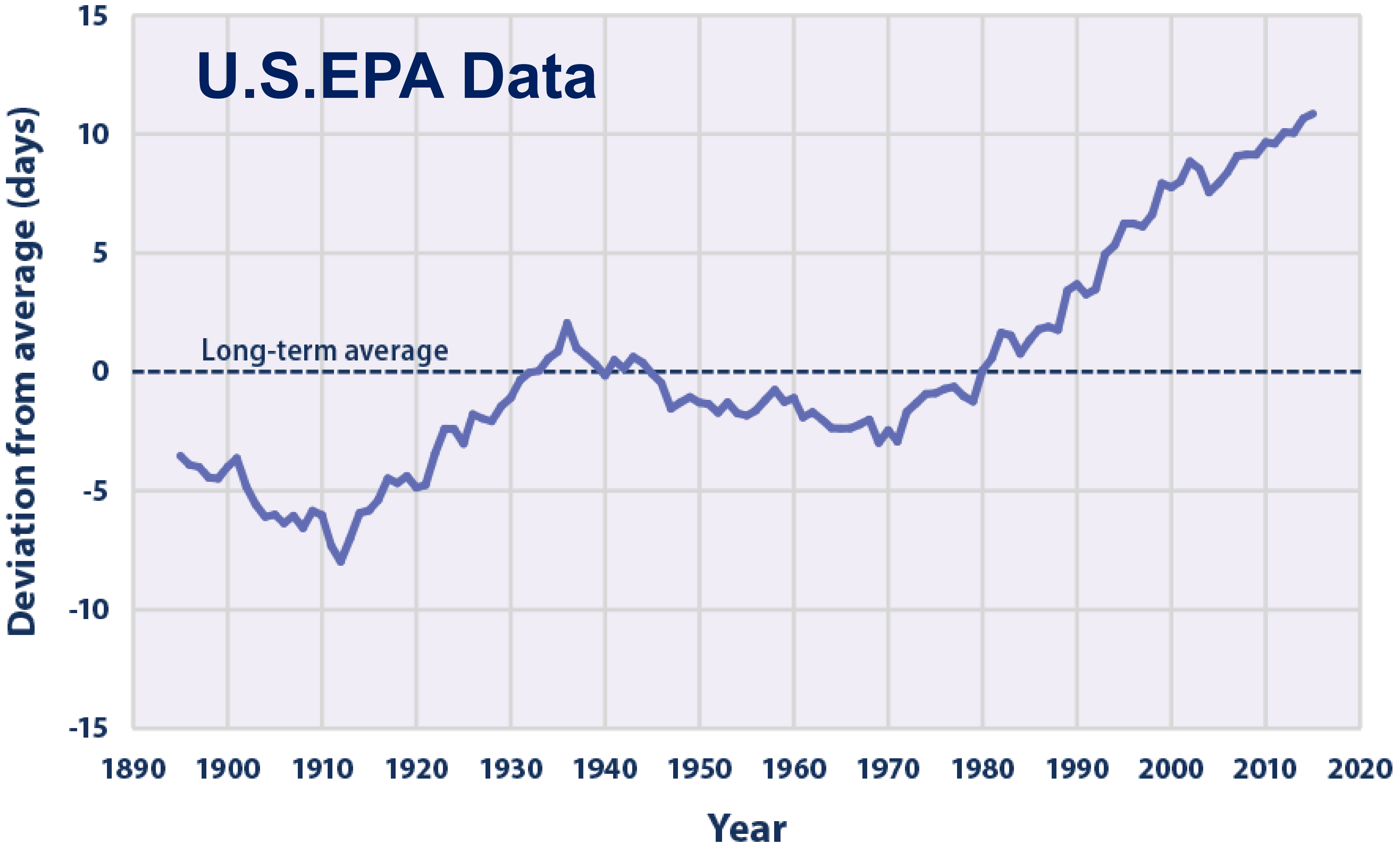
Long-term experiments are valuable for detecting slow changes!

Geissler and Scow. 2014. Soil Bio & Biochem

Growing Seasons are Getting Longer



(Figure source: Kunkel, 2016)

Response to Longer Growing Seasons…..

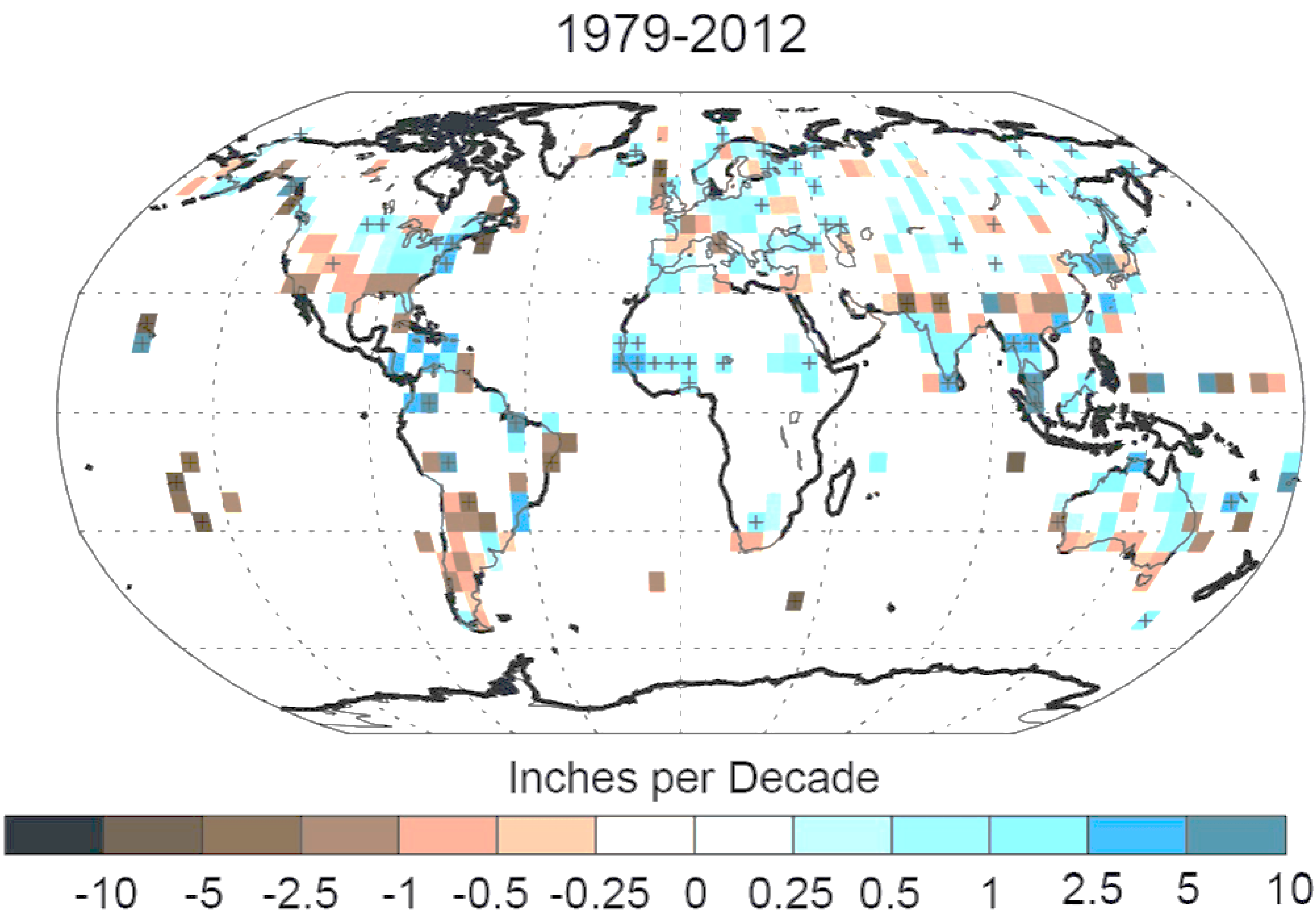
Cropping systems *in areas receiving adequate rainfall* may produce greater yields and longer-maturing crops.

Increased adoption of double cropping.

More inputs to respond to greater output?

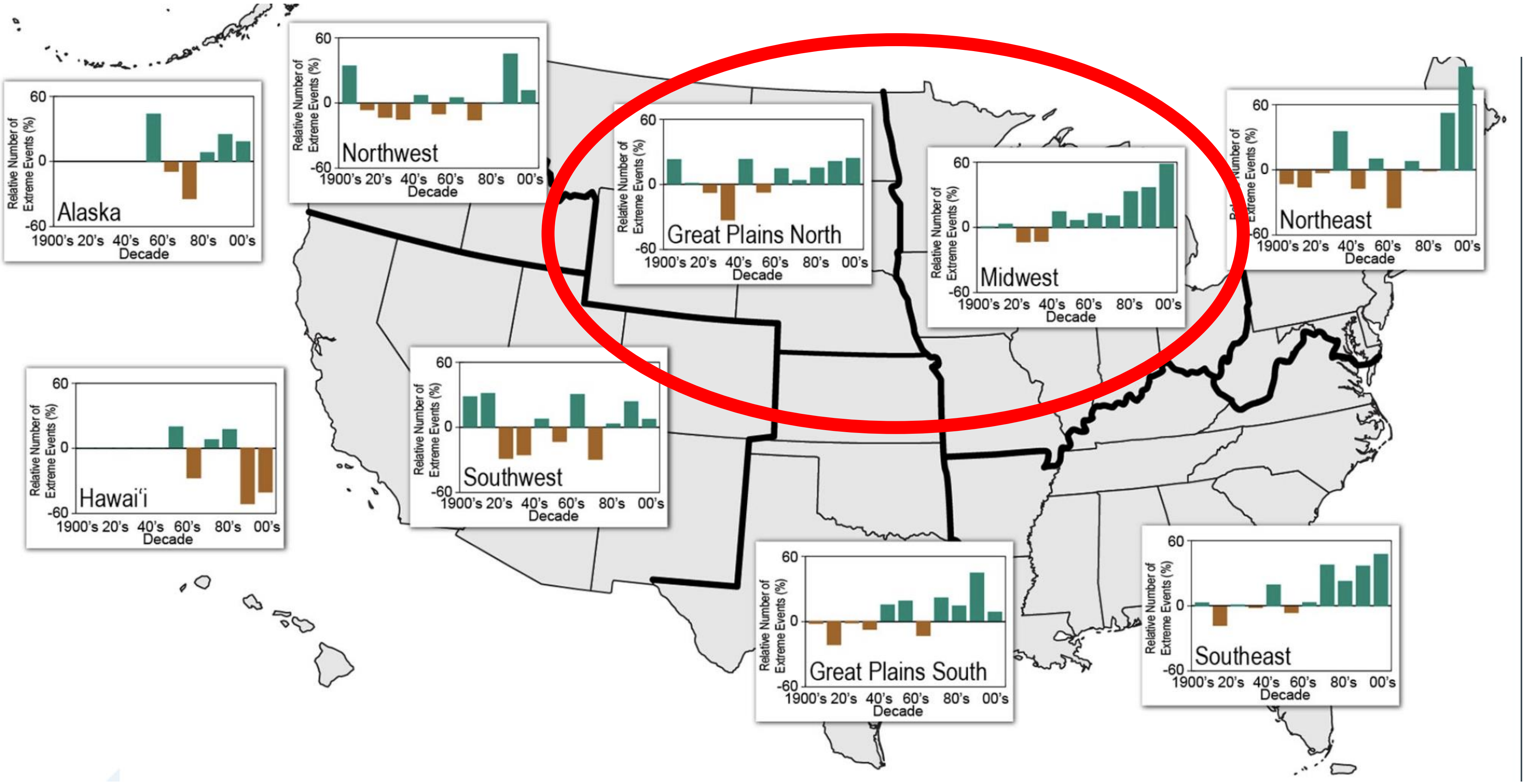
(Mueller et al., 2015)

Wet Areas are Wetter; Dry Areas Drier



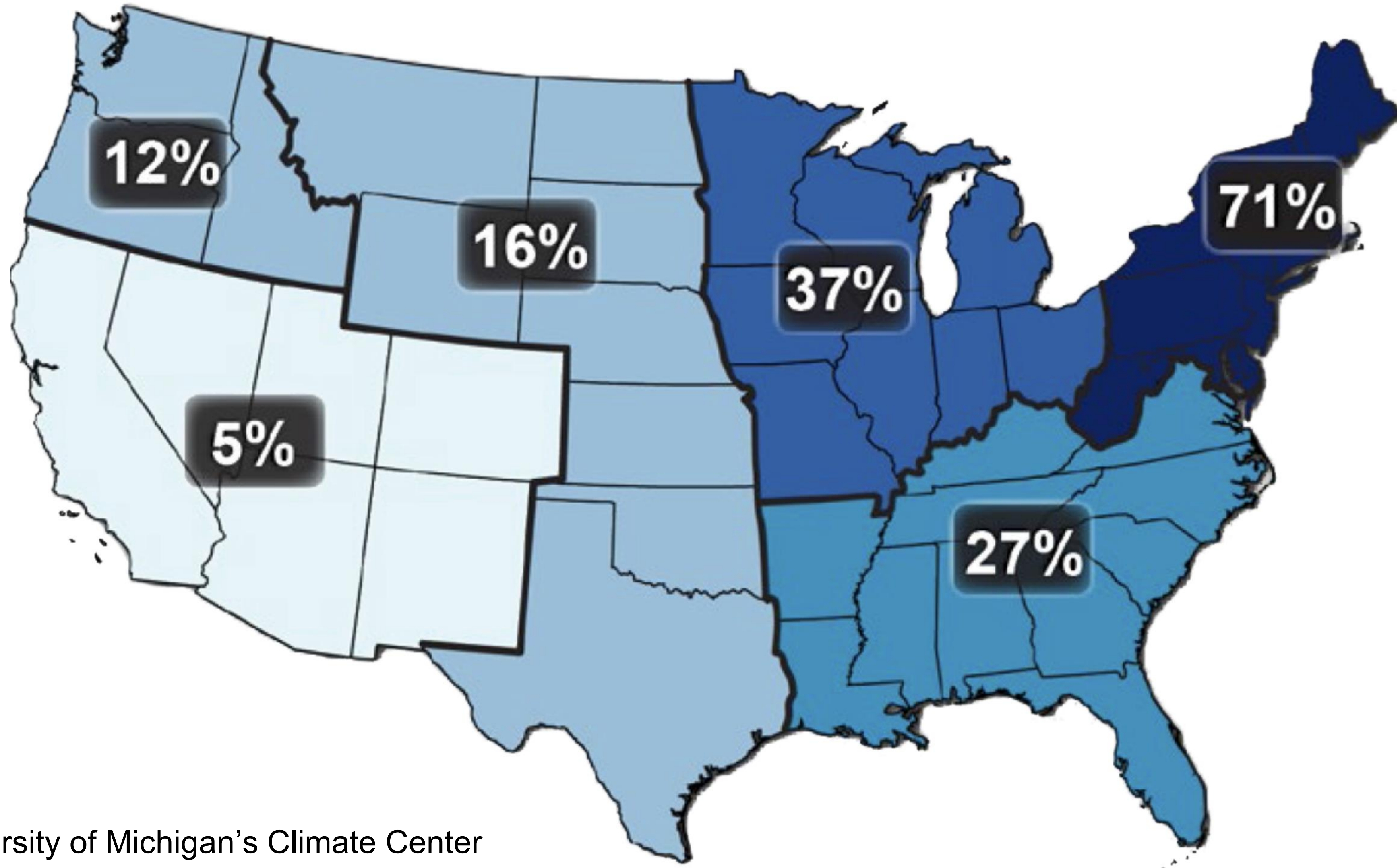
(Figure source: NOAA NCDC/CICS-NC

Increase in Extreme Precipitation Events



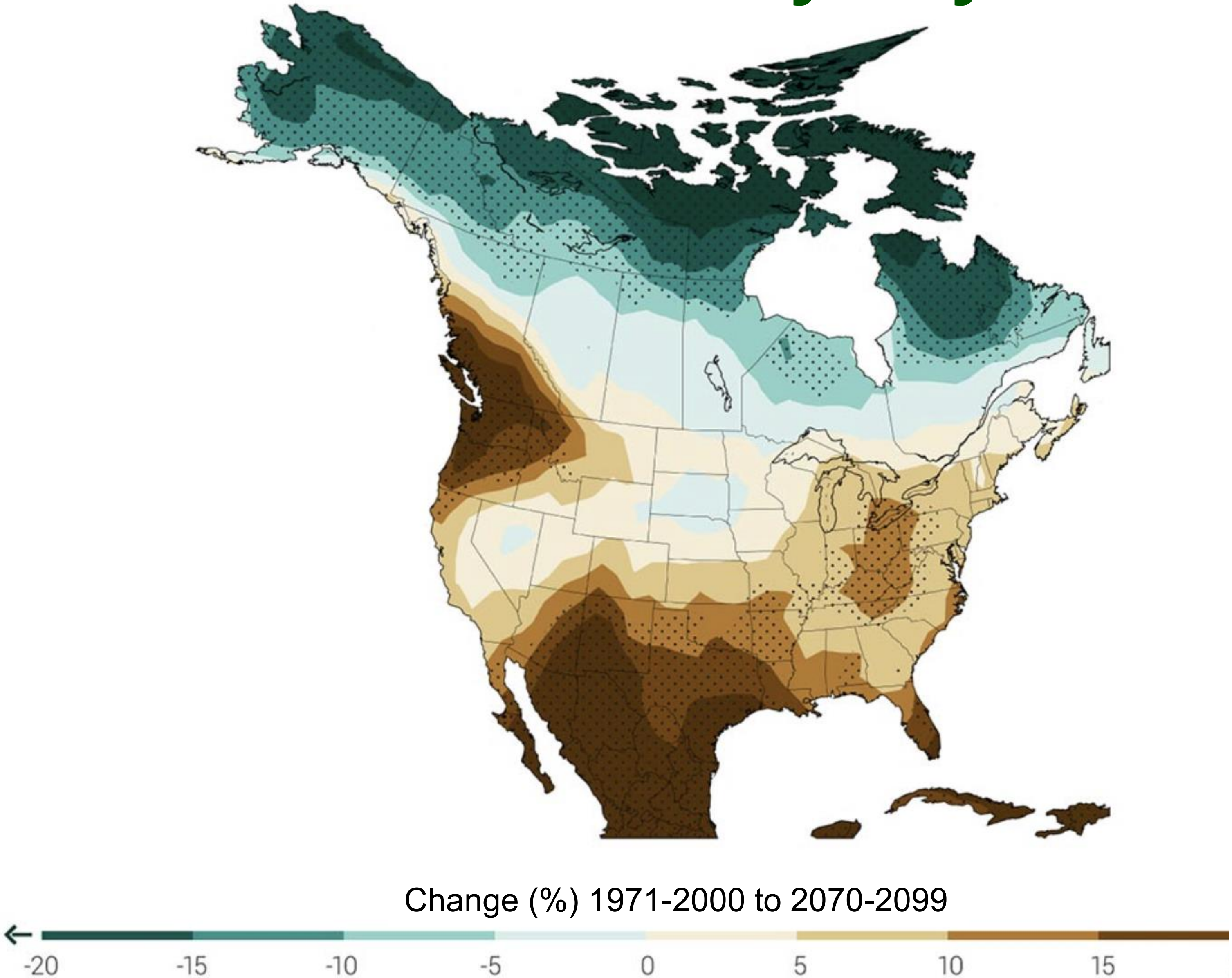
(Figure source: Melillo et al., 2014, updated from Kunkel et al., 2013)

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



University of Michigan's Climate Center

Maximum Number of Dry Days Increasing



(Figure source: NOAA NCDC/CICS-NC)

(He and Dkjkstra, 2014)

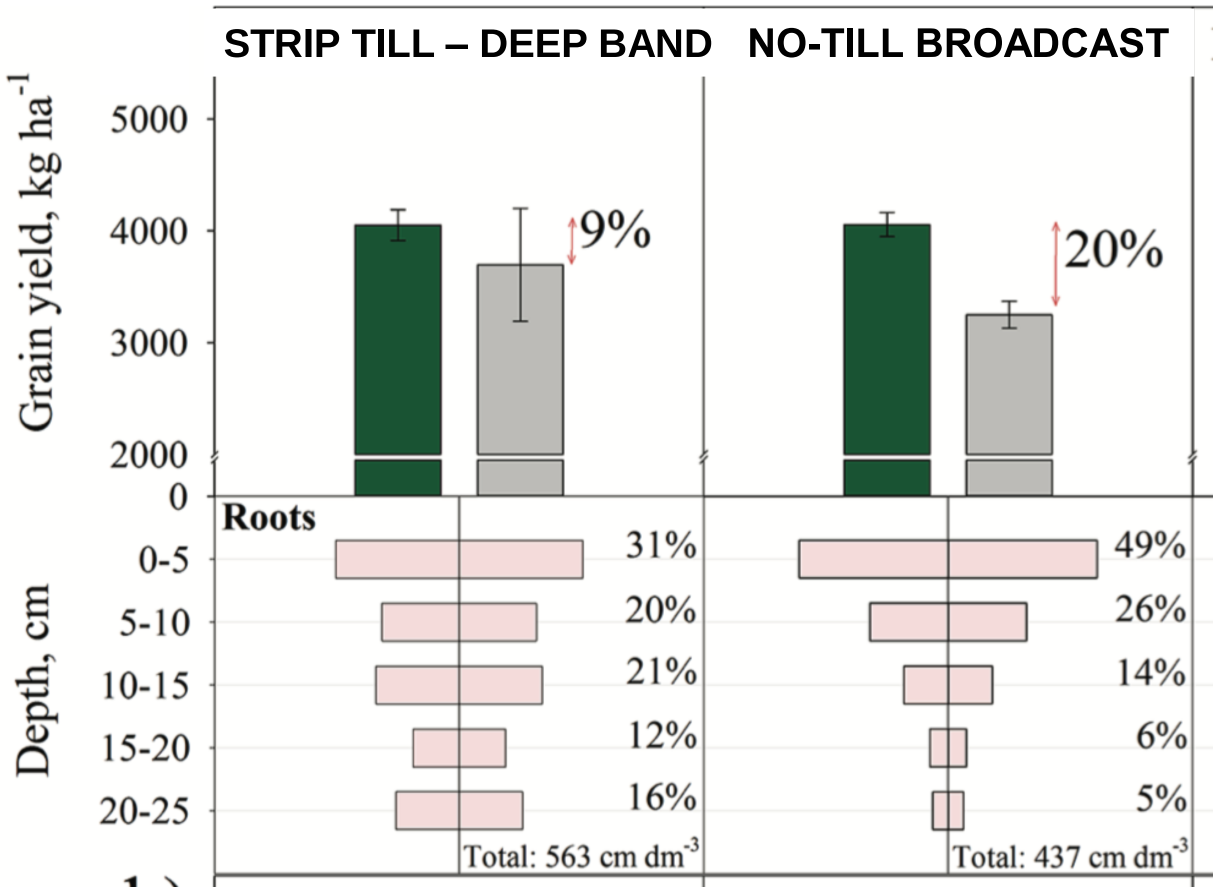
Drought stress could result in less plant available P.

- ↓ 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.

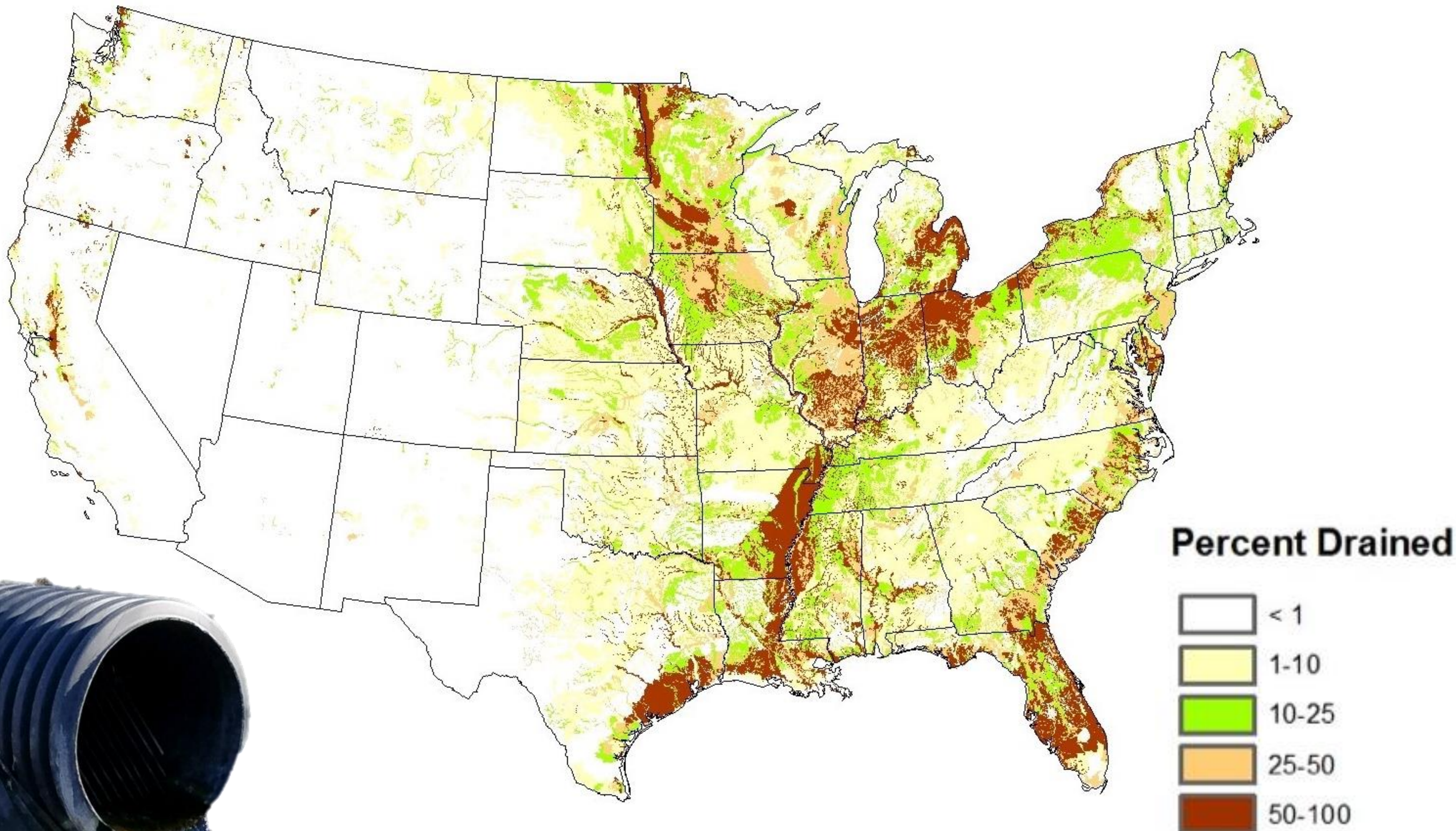
Soybean root growth at deeper soil layers improve resilience to induced drought.



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	?	

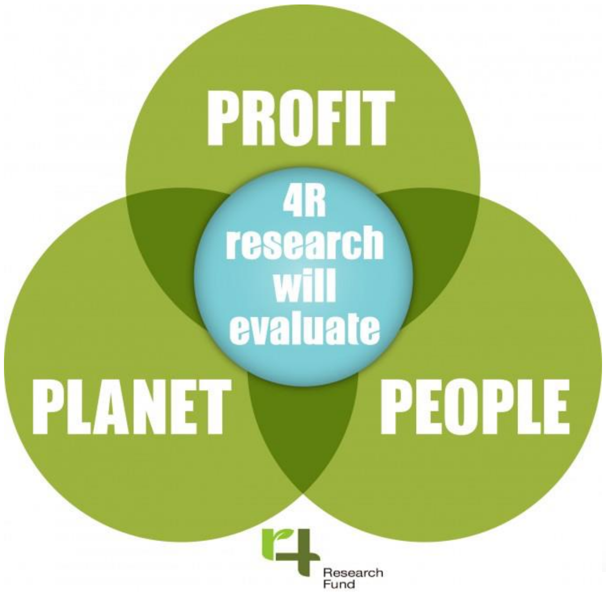
more photos

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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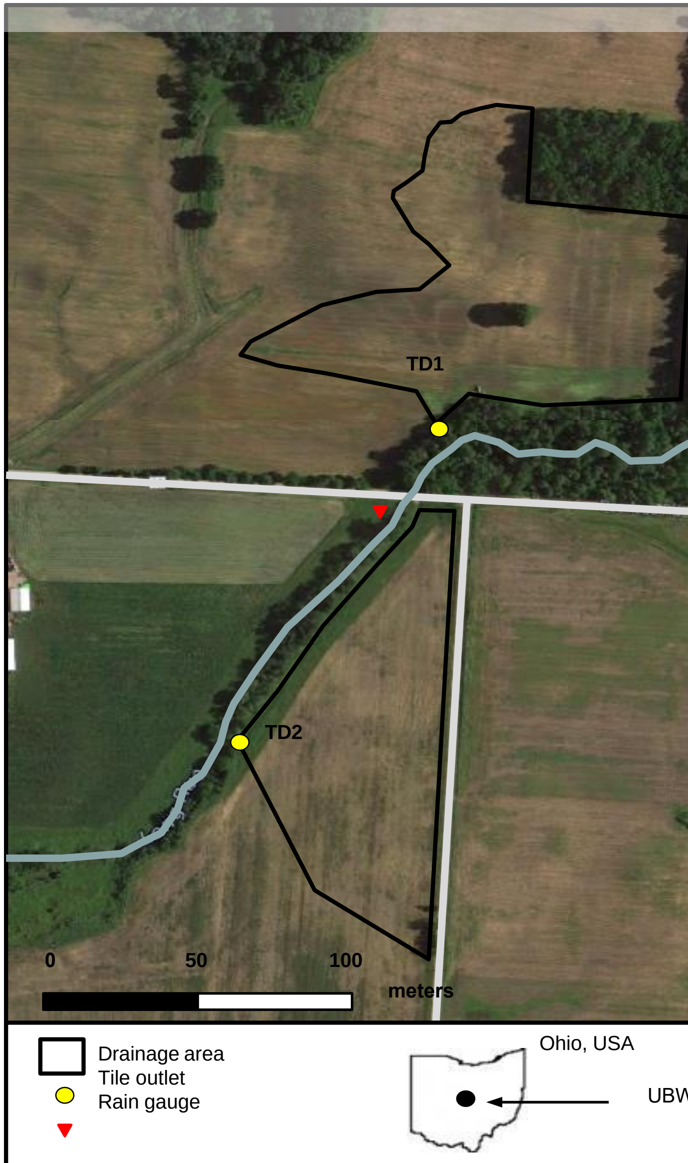
Right Place: Tile Drains & Fertilizer Placement

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



2014 management

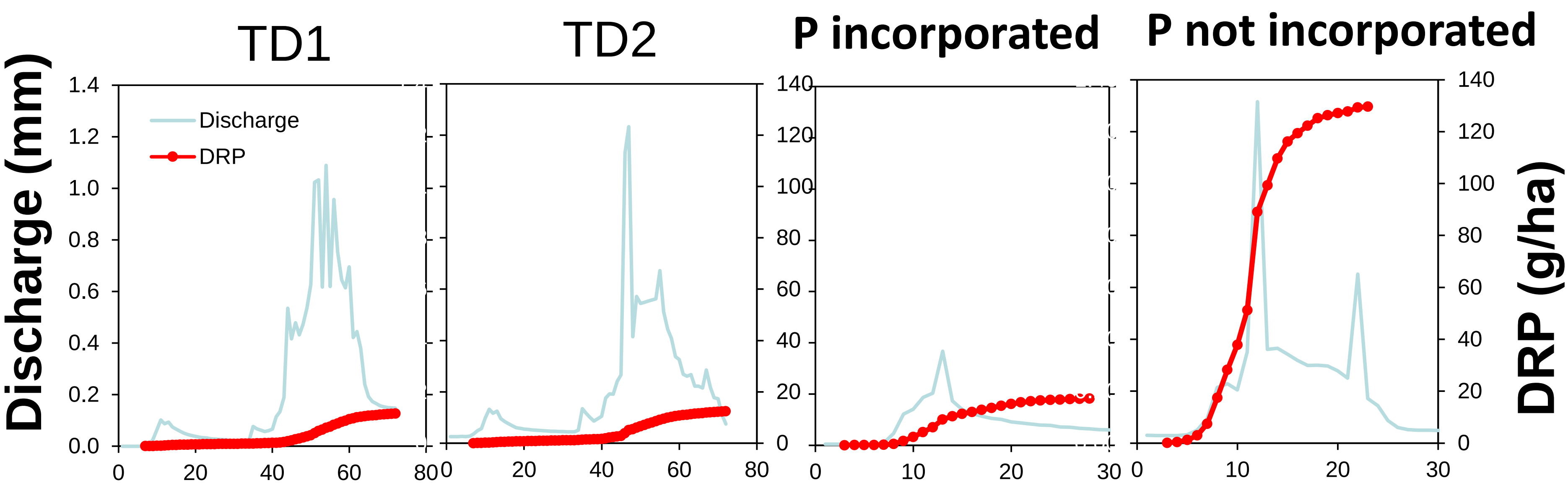
May 6th – Applied MAP @ 40 lb P/acre
May 8th – Tilled field TD1 (disc),
TD2 no-till

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

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Tillage, Tile and Fertilizer Placement

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

Photo Credit: Russell Derickson

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

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

ELSEVIER

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 the 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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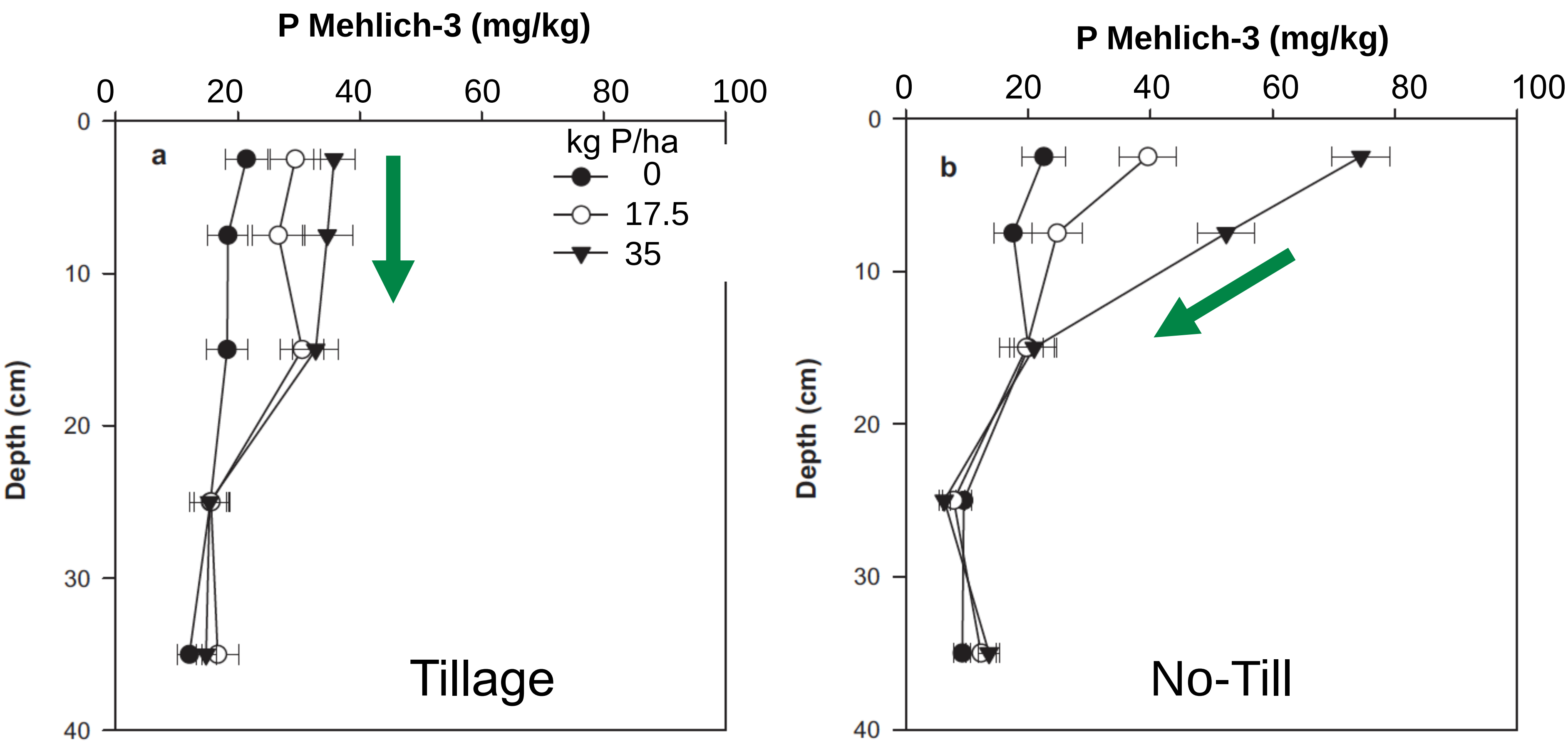
E-mail addresses: mark.williams2@ars.usda.gov (M.R. Williams), kevin.king@ars.usda.gov (K.W. King), emily.duncan@ars.usda.gov (E.W. Duncan), lindsay.pease@ars.usda.gov (L.A. Pease), chad.penn@ars.usda.gov (C.J. Penn).

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

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Site Description:

Maumee River Watershed

Flat, Poorly Drained

SL/SiCL Soils

Rotations:

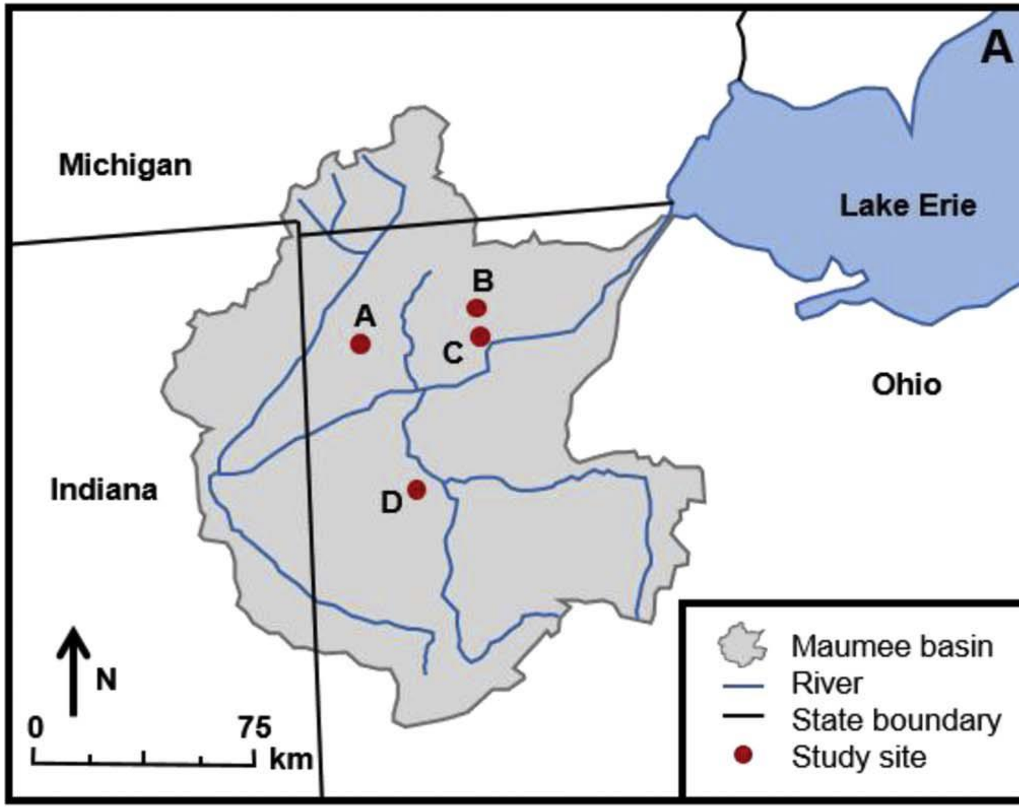
Corn/Soybean/Wheat

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)

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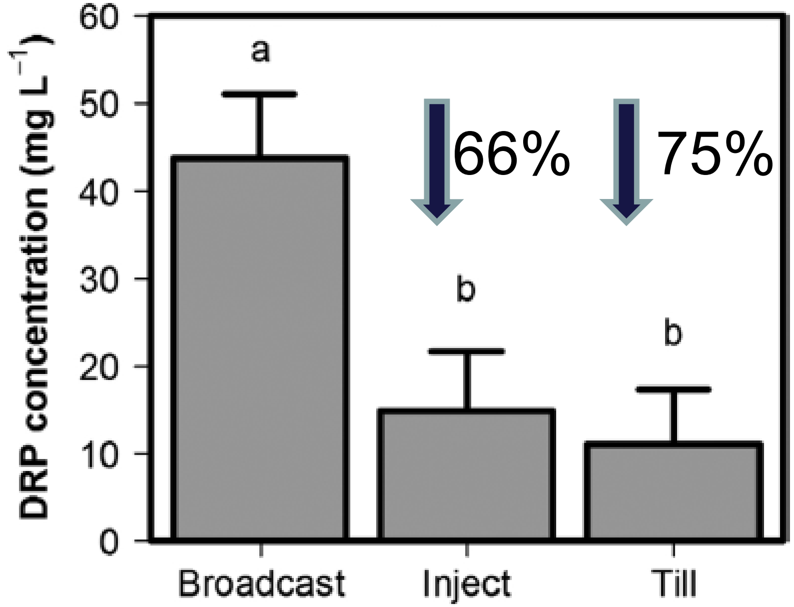
Leachate P Loss Greatest with Broadcasting



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.

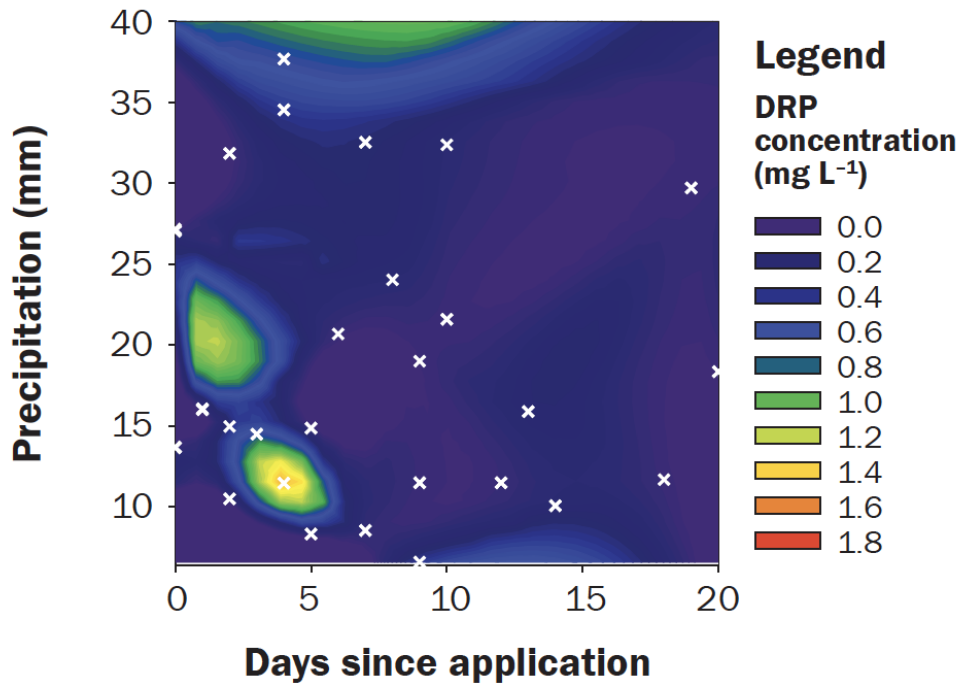
Disruption of macropore network not likely primary mechanism responsible for decreased leachate P concentrations.

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.

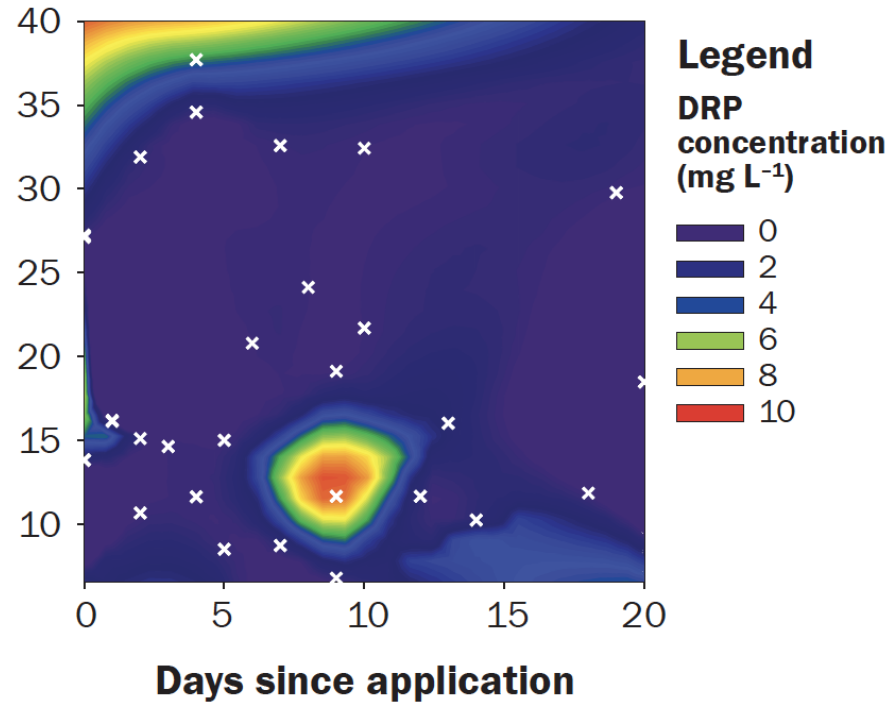
Subsurface injection of fertilizer in fine-textured soils may limit dissolved P leaching and minimize surface disturbance.

Avoid P Application Immediately Prior to Precipitation

Sub—Surface Losses



Surface Losses



(Figure source: King et al., 2018)

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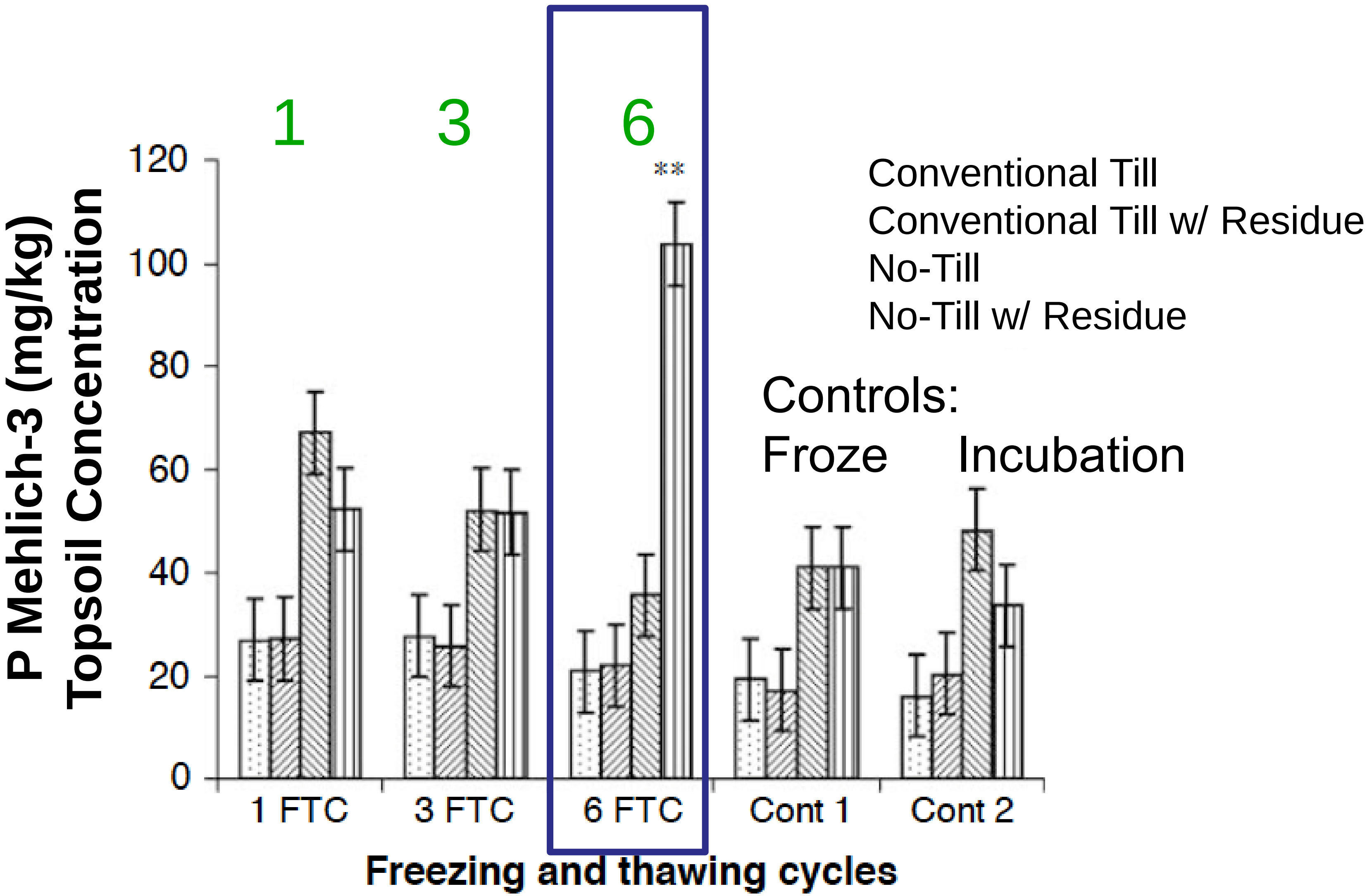
Freeze-thaw cycles in no-till increase available P.



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

Can cover crops increase available P?

Longer-term research is still needed.

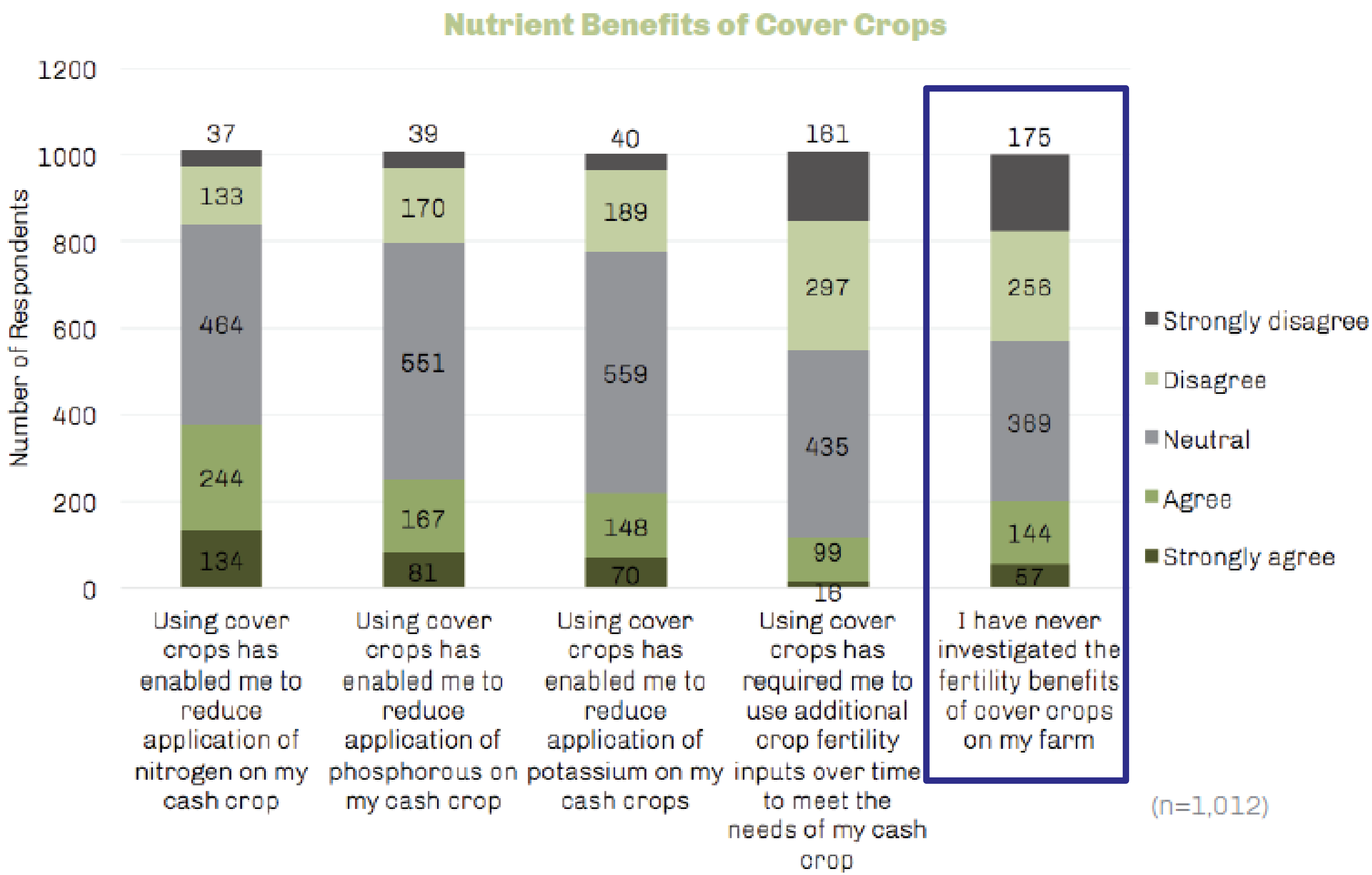
HOWEVER,

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

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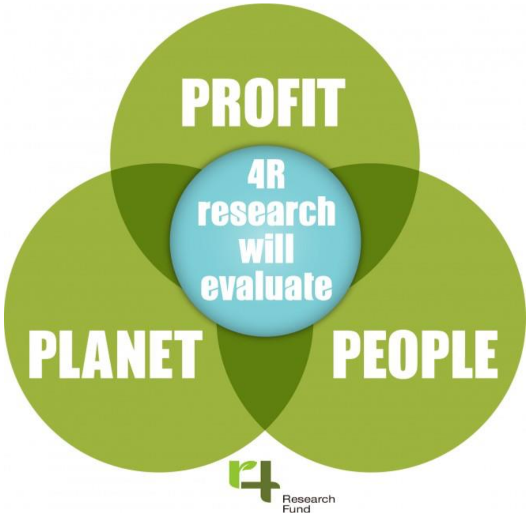
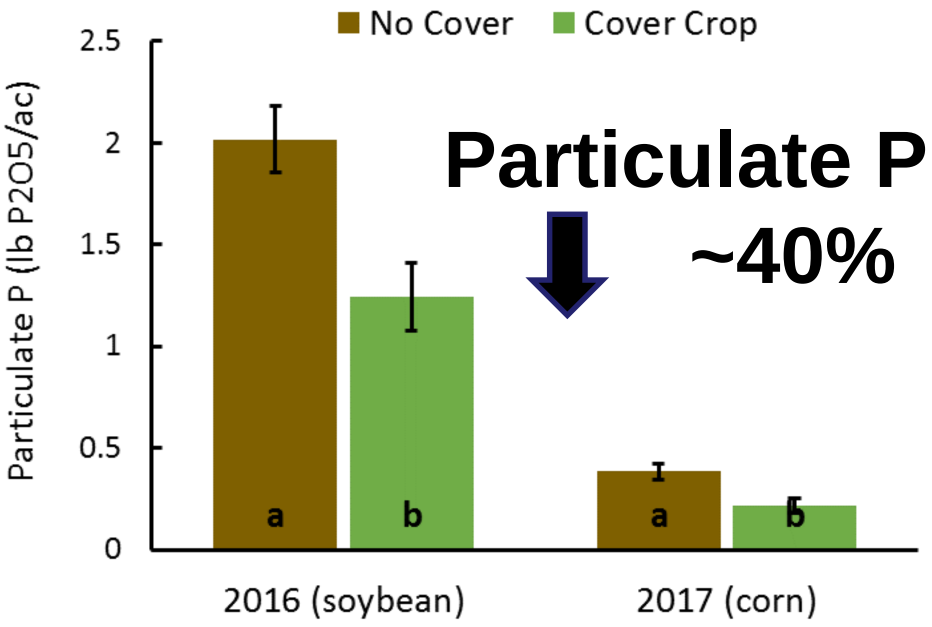
4R Research Fund

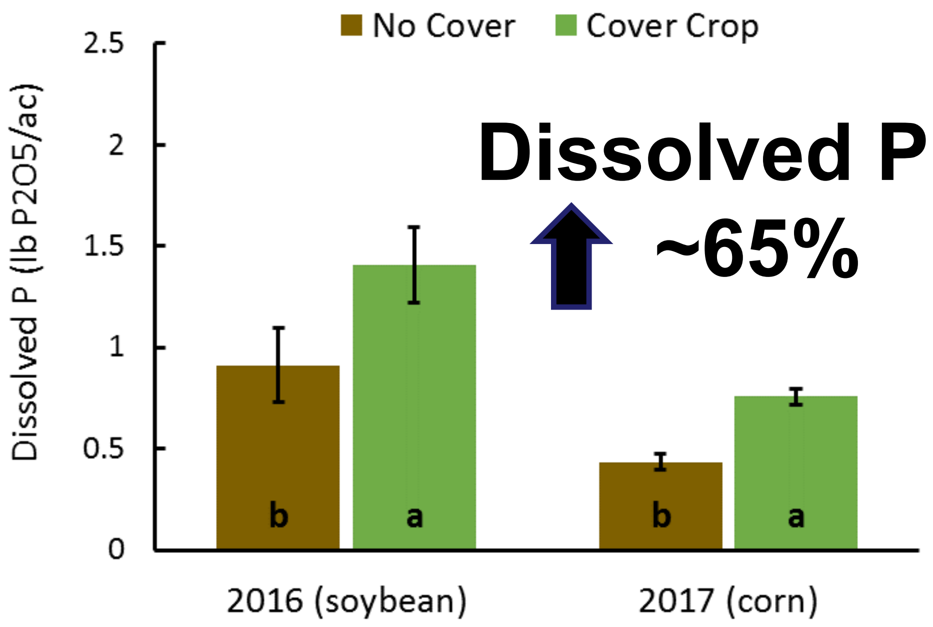
Minimizing P Loss with 4R Stewardship and Cover Crops

Dr. Nathan Nelson
Kansas State University



Cover Crops Reduce Particulate P, Increase Dissolved P





Project is ongoing.

Slide modified from Nathan Nelson, KSU.

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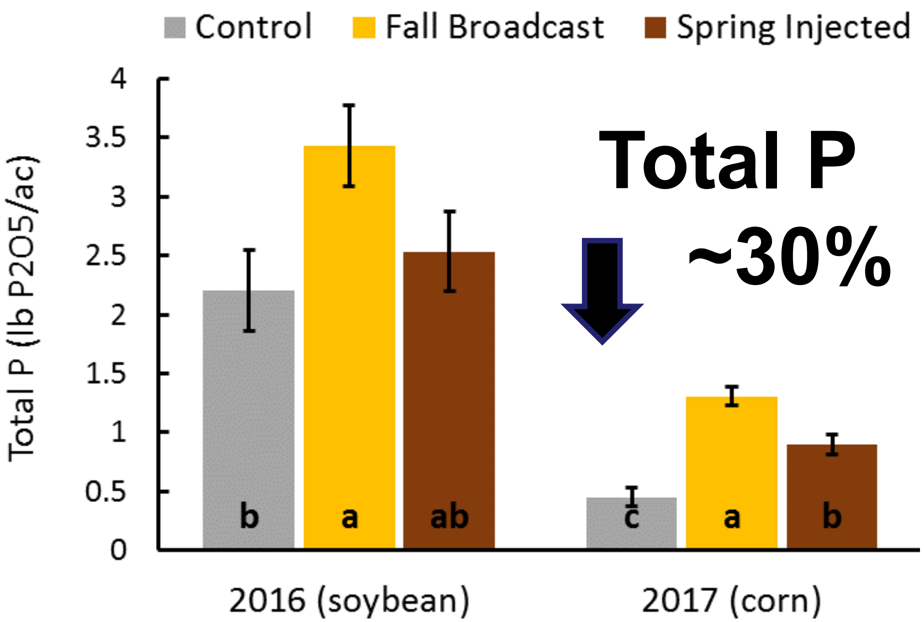
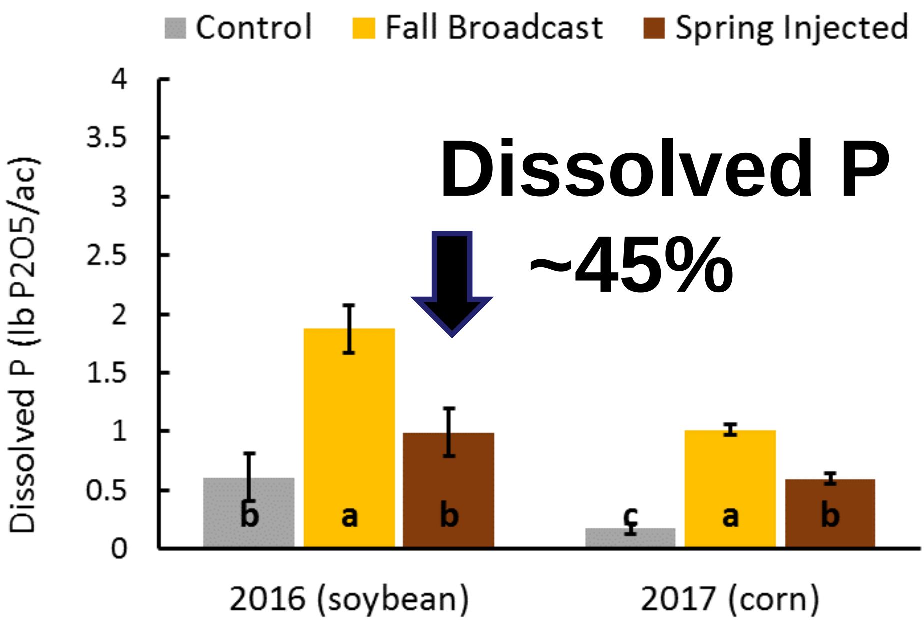
Injecting P Reduces Total and Dissolved P





Project is ongoing.

Slide modified from Nathan Nelson, KSU.

Our cropping systems are dynamic.

Overcoming P challenges requires….

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

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International
Plant Nutrition
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Thank you!

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