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PLANT NUTRITION
INSTITUTE

Are We Applying Our Nitrogen Inputs Wisely?

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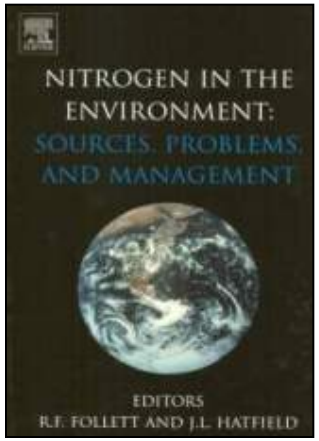
Nitrogen Program Director, Conway, Arkansas, USA

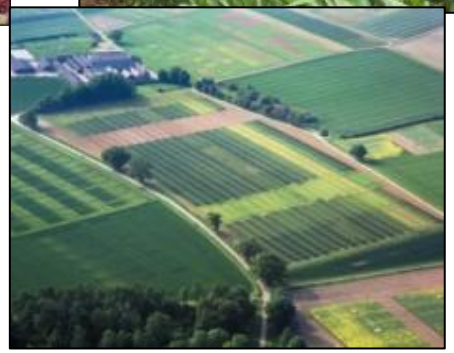
USDA Agriculture Outlook Forum

Arlington, VA *February 20, 2014*

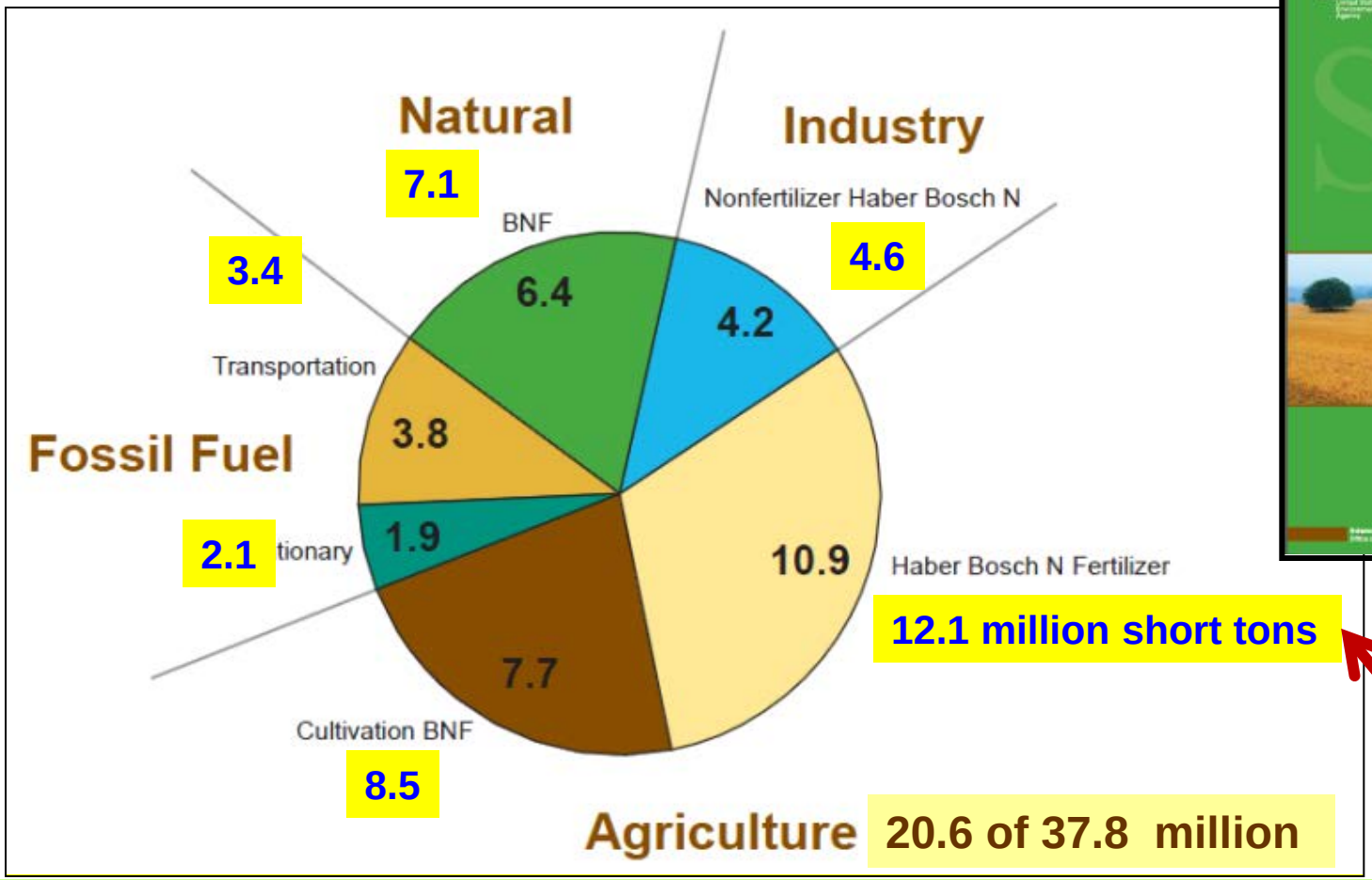
Nitrogen Recovery Efficiency by Major Cereals

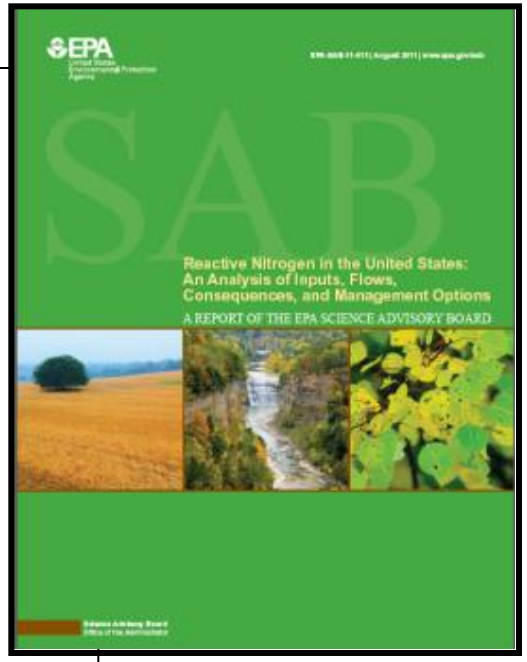
- **Nitrogen use efficiency … "rarely exceeds 70% ……. often ranges from 30-60%"**
- **"conversion of N inputs to products for arable crops can be 60-70% or even more" (Kitchen and Goulding, 2001)**





Sources of Reactive N (Nr) Introduced into U.S. in 2002 (Tg N/yr)





32% of N inputs

EPA SAB 2011 report: suggests crop N-uptake efficiencies be **increased by up to 25%** over current practices through a combination of knowledge-based practices and advances in fertilizer technology (such as controlled release and inhibition of nitrification) within the next two decades.

Clean Water, Clean Air, Productive Soil ……

- We all want these on our farm, in our community, in our world
- For us, our neighbors, our children, grandchildren, … and the global human family
- **Water quality (N and P)**
  - groundwater **nitrate-N** contamination
  - surface water **N and P** contamination
    - eutrophication: lakes, streams/rivers, estuaries, and coastal waters
- **Ag needs profitability**

U.S. EPA Reports that Nutrients (N and/or P)

- **Are Causing Water Quality Impairments:**
- **>100,000 miles of rivers and streams,**
- **Approx. 2.5 million acres of lakes, reservoirs and ponds,**
- **> 800 square miles of bays and estuaries in the U.S.**
- **166 coastal hypoxic areas or "dead zones" nationwide**
- **"nutrient pollution is widespread": 27% have high N, 40% of river and stream miles have high P**
- **Stream biological condition:**
  - **55% poor, 23% fair;**
  - **9% more "good" N condition, 19% fewer "good" P condition**

Source: 2013 EPA website: http://water.epa.gov/type/rsl/monitoring/riverssurvey/index.cfm , http://www2.epa.gov/nutrientpollution/effects-environment , http://www2.epa.gov/nutrientpollution/where-occurs-lakes-and-rivers

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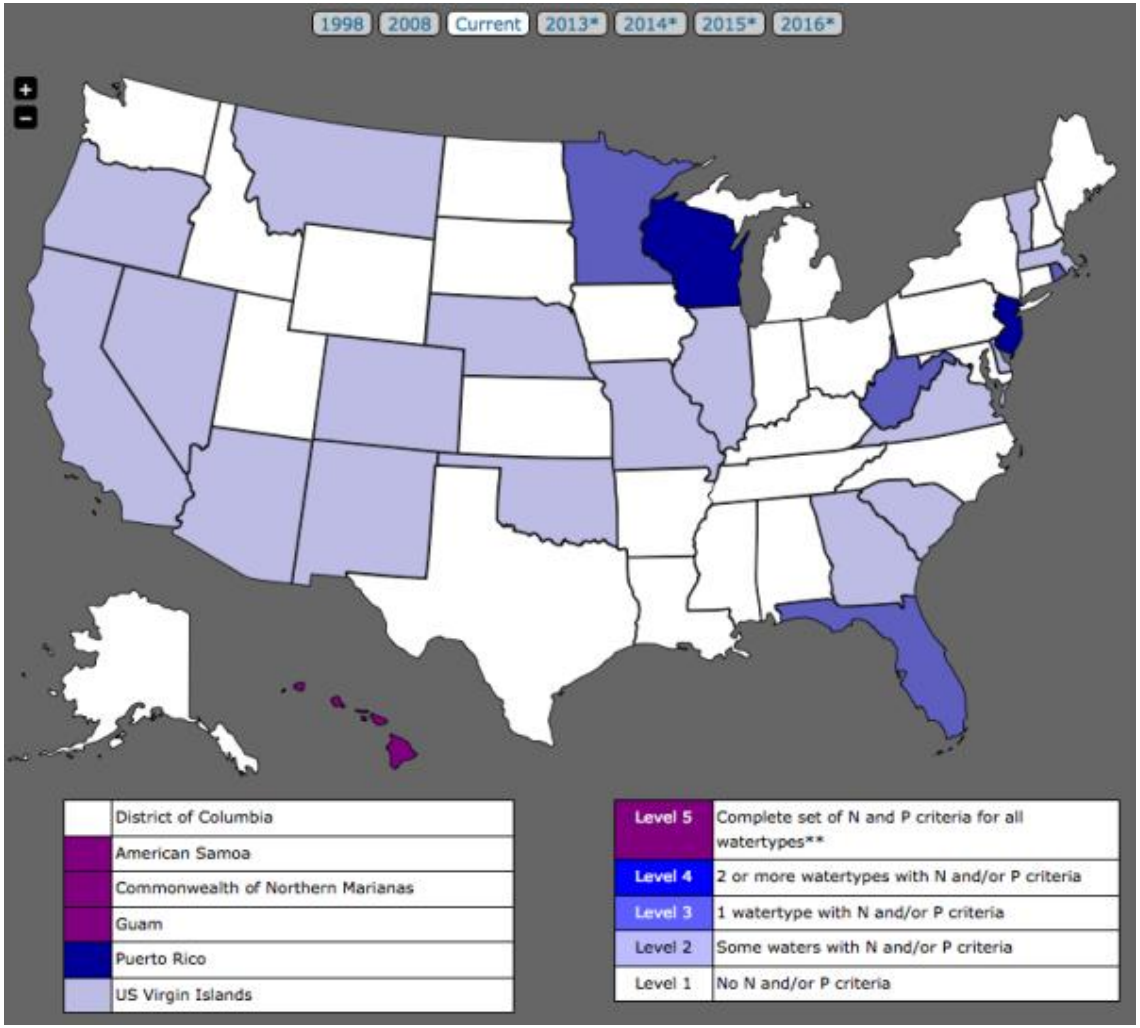
States with Numeric Nutrient Criteria - 2013



Several states have site-specific criteria for streams and rivers; only Wisconsin and Florida have statewide criteria supported by peer-reviewed and technical papers documenting the process of criteria development

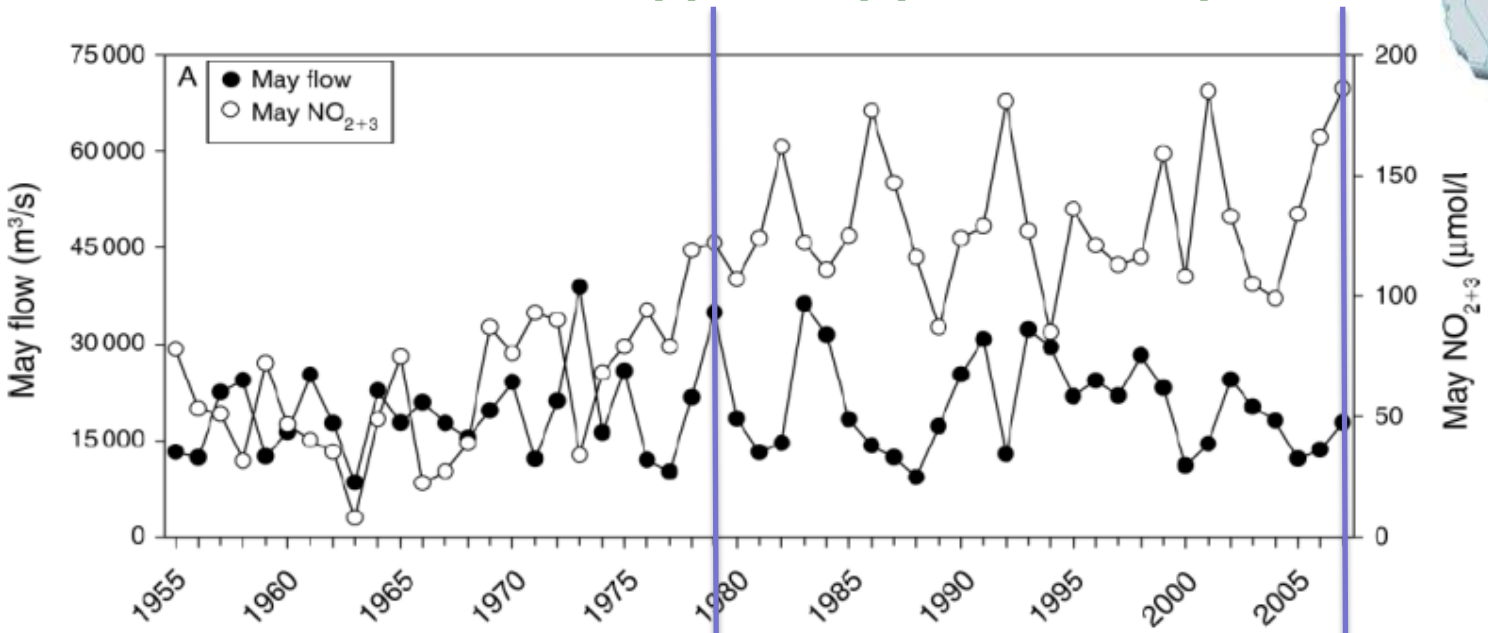
6 states TN; 11 states TP

http://cfpub.epa.gov/wqsits/nnc-development/

Evans-White, Haggard and Scott. 2013. J. Environ. Qual. 42:1002-1014

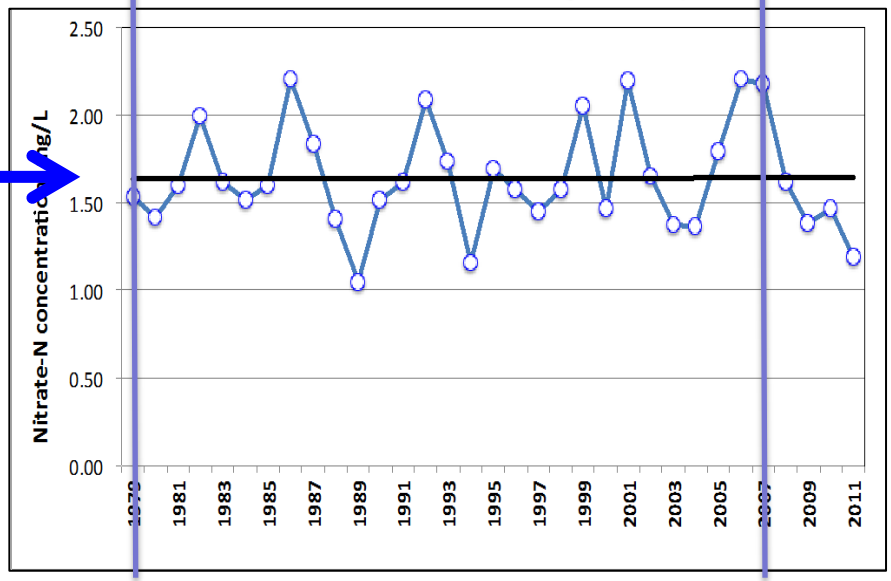
MARB River Flow and NO_3 Concentration in May

(Greene et al., 2009. Ecol. Applic.19(5):1161–1175)



Nitrate-N concentration

< 1.7 mg/L (ppm)



http://toxics.usgs.gov/hypoxia/mississippi/flux_ests/delivery/index.html

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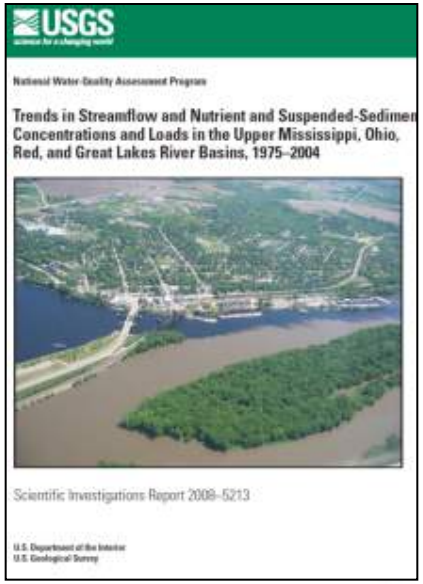
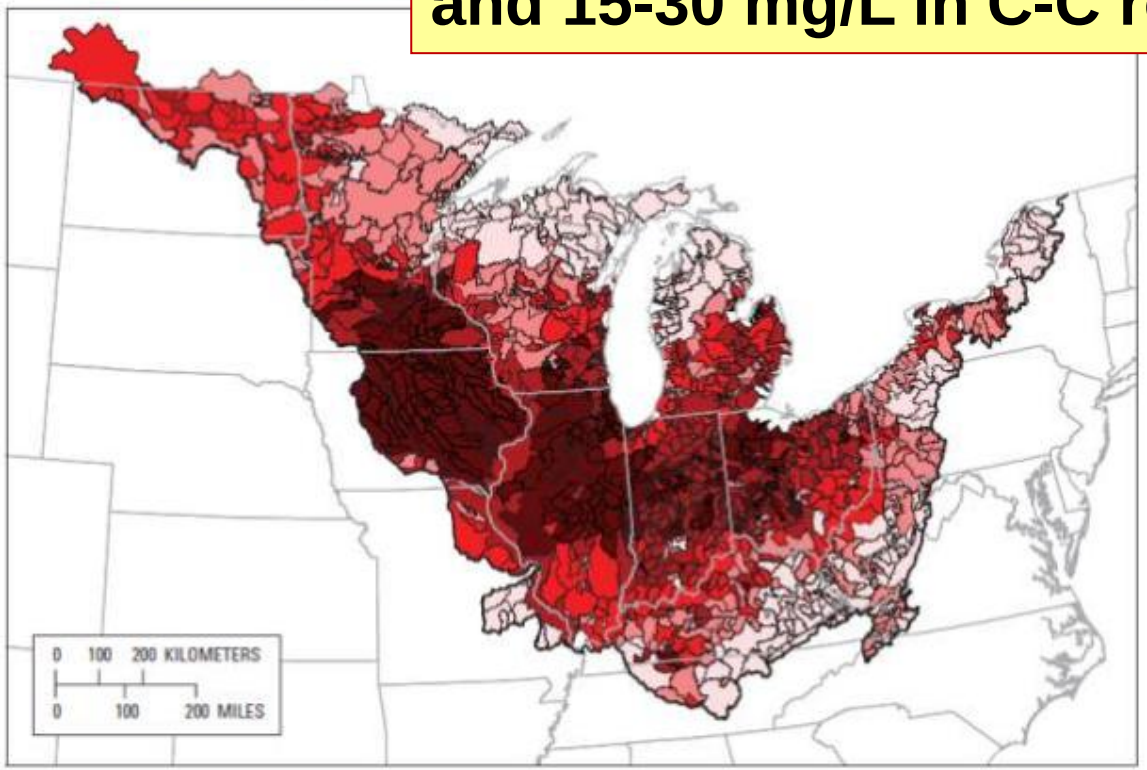


Trends in Streamflow and Nutrient and Suspended-Sediment Concentra
Upper Mis
Great Lak
2004 (Lore

Sawyer and Randall. 2008. UMRSHNC Report (ASABE)

Corn systems where no fertilizer in 20^{+} years NO_3-N 3-10 mg/L , can increase to 10-20 mg/L in S-C and 15-30 mg/L in C-C rotations

A. Median total nitrogen co



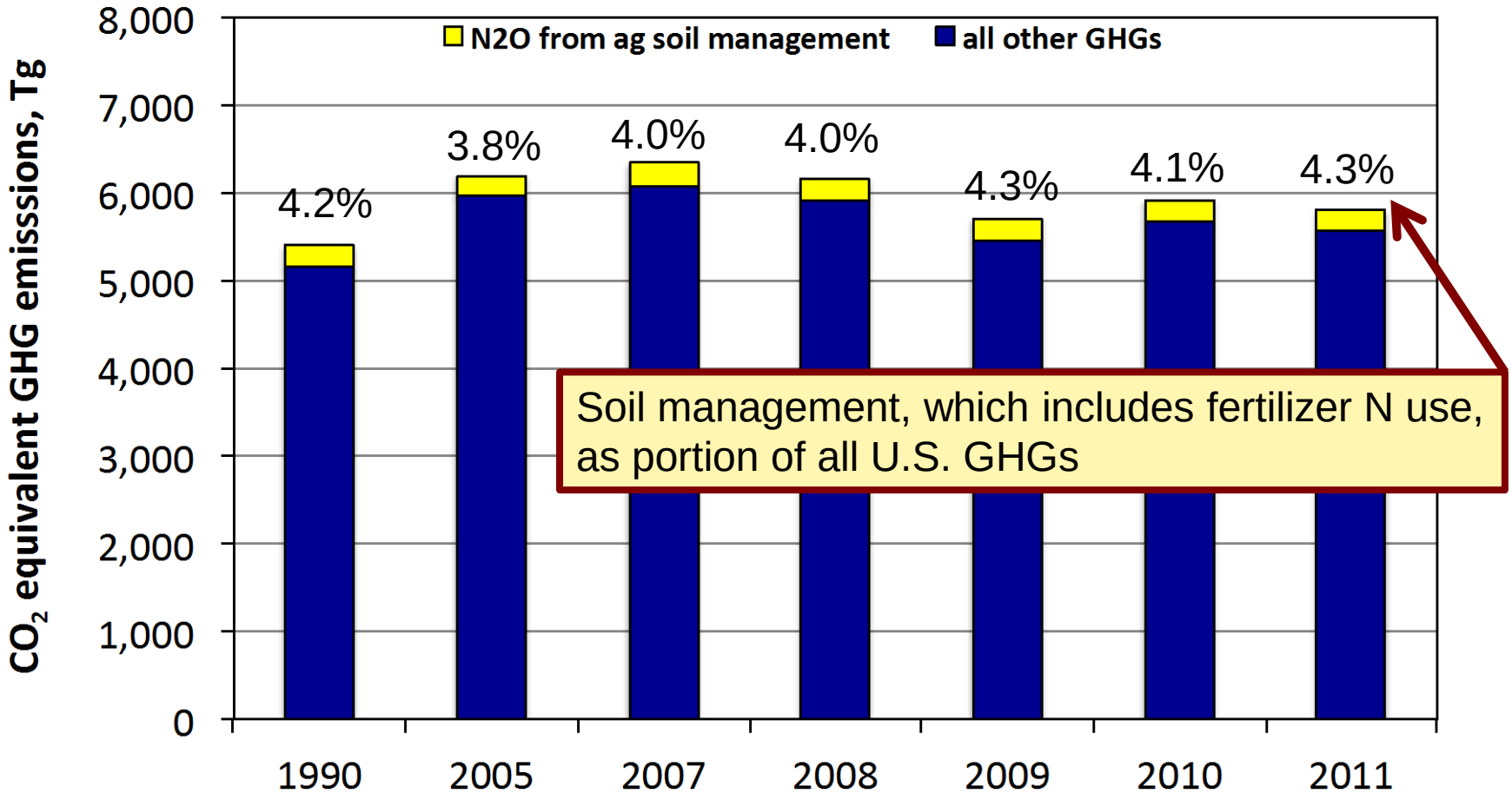
EXPLANATION

Median total nitrogen concentration, in milligrams per liter

- 0.102 – 0.774
- 0.775 – 1.34
- 1.35 – 2.20
- 2.21 – 4.21
- 4.22 – 206

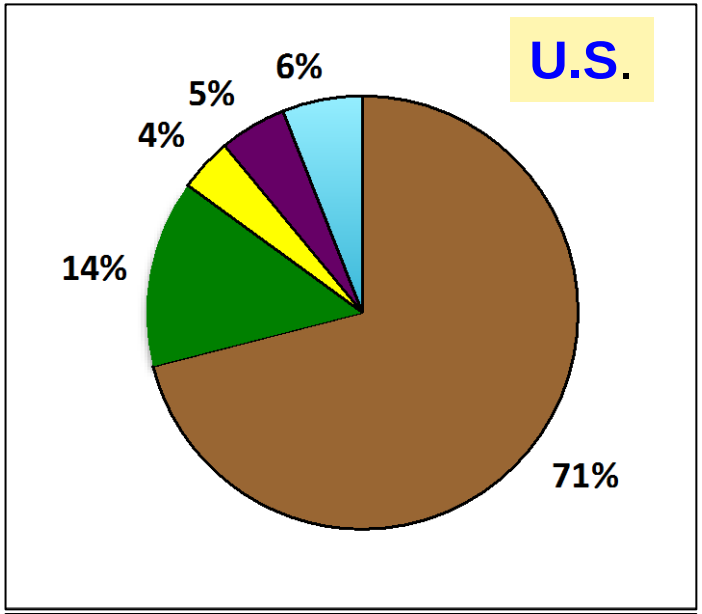
- Study area
- State boundary
- Basin boundary

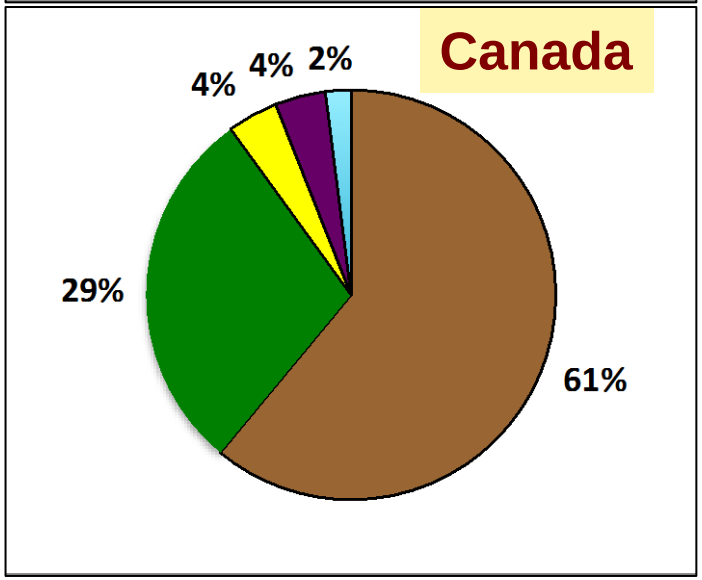
U.S. N_2O Emissions – Small Portion of All GHGs, and Little Increase Since 1990

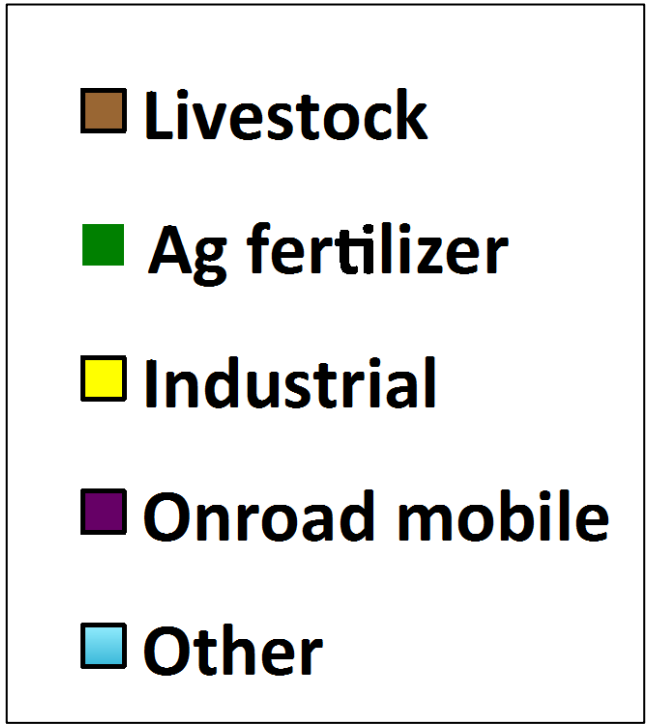


Source: U.S. EPA Annual U.S. GHG Inventory, 2013 Report

U.S. and Canada Ammonia Emissions

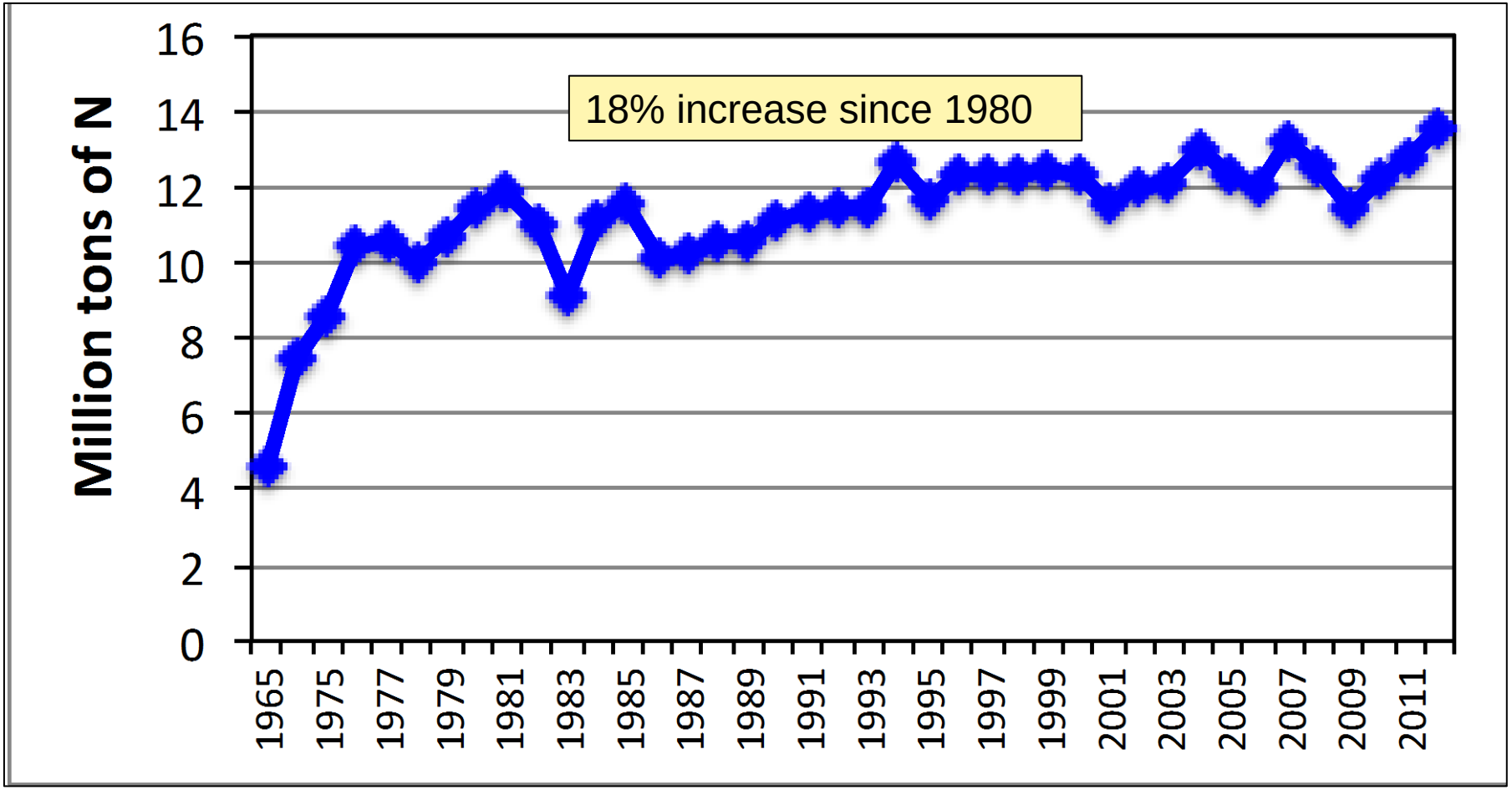






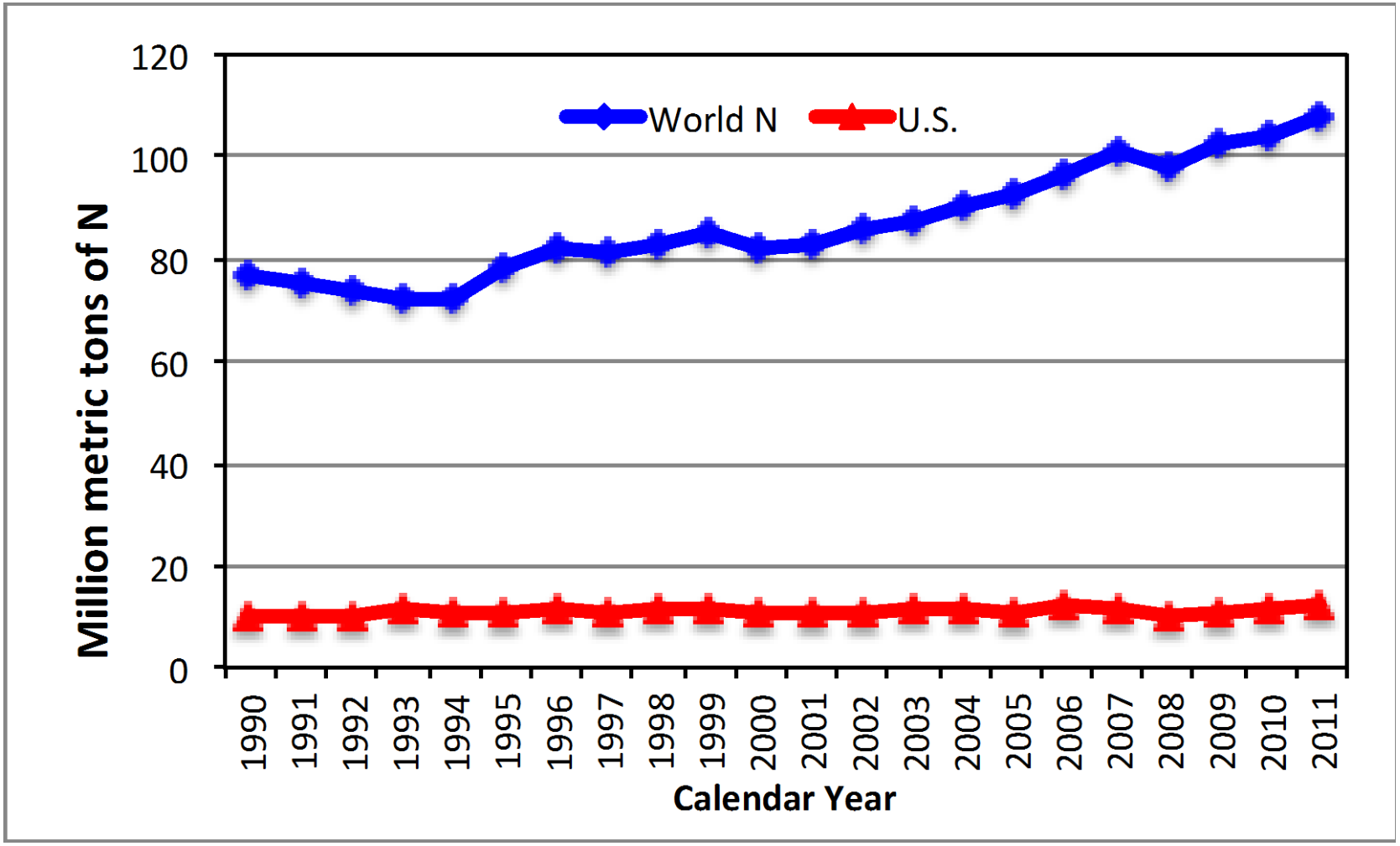
Bittman & Mikkelsen. 2009. Better Crops 93(1): 28-31
(data from USEPA, 2005; Environ. Canada, 2006)

U.S. Fertilizer N Consumption



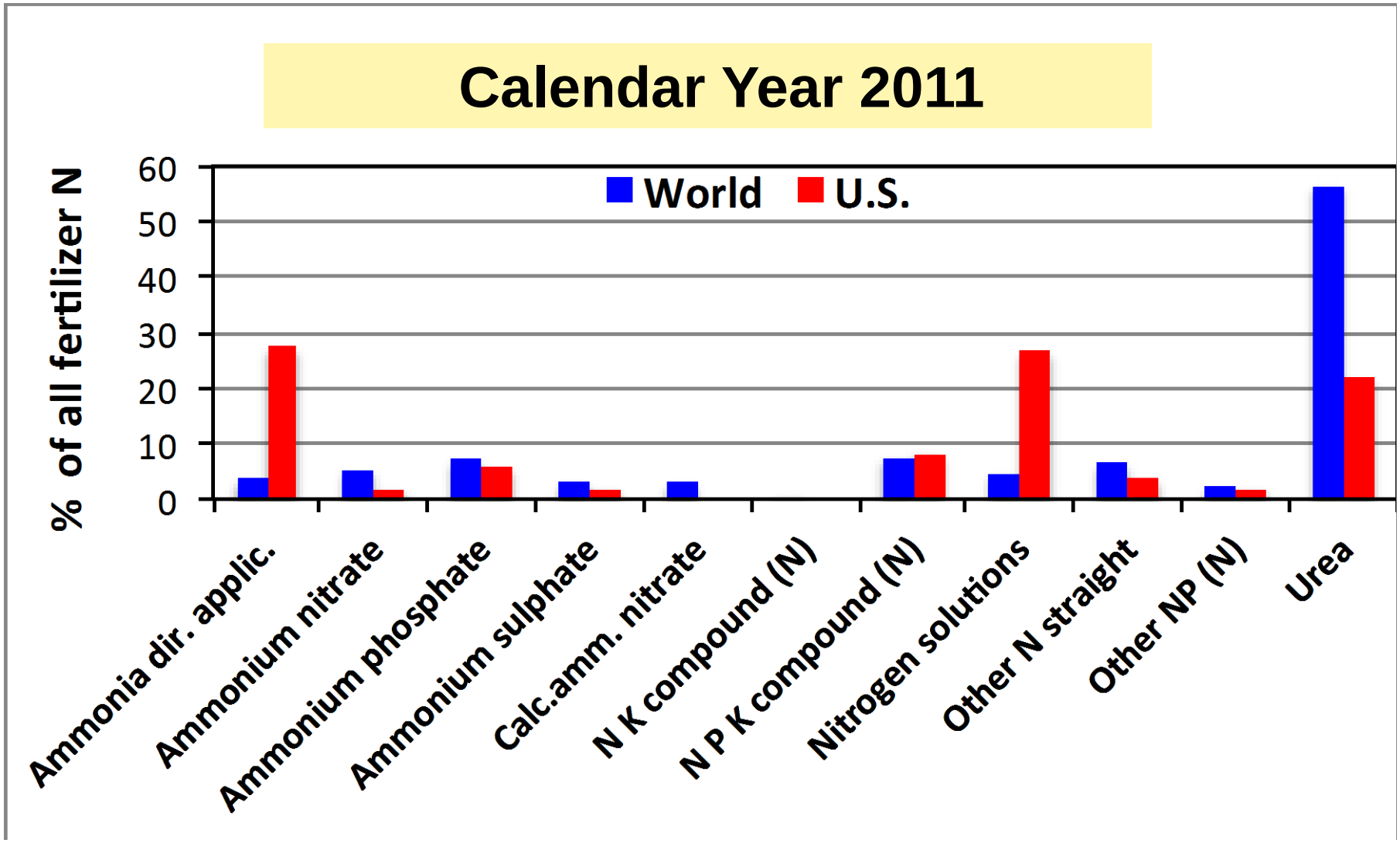
Source: AAPFCO and TFI Commercial Fertilizers Reports

U.S. Fertilizer N Consumption is Becoming a Smaller Share of World Total



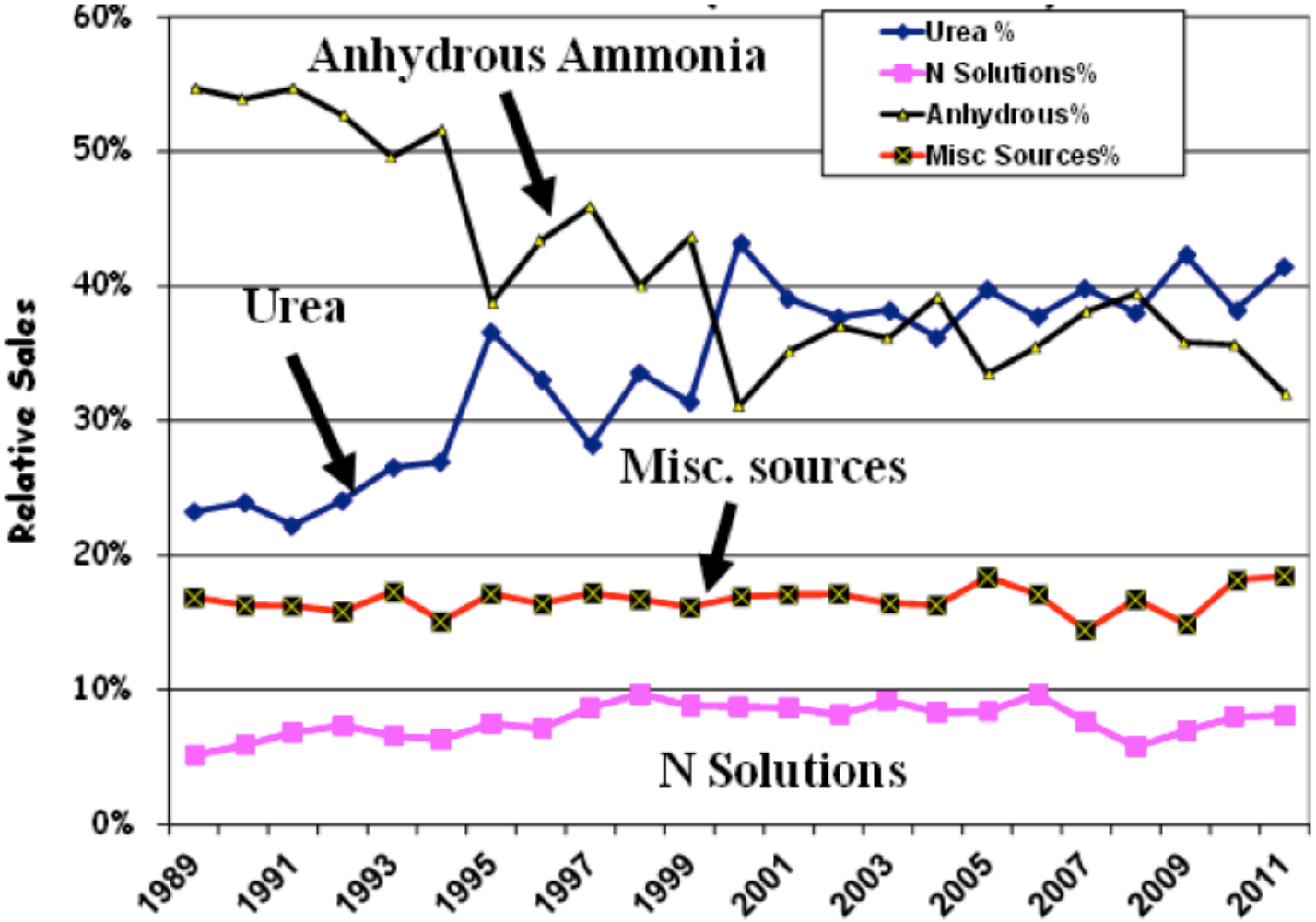
Source: IFA Statistics, 2014

Fertilizer N Sources Used: World and U.S.



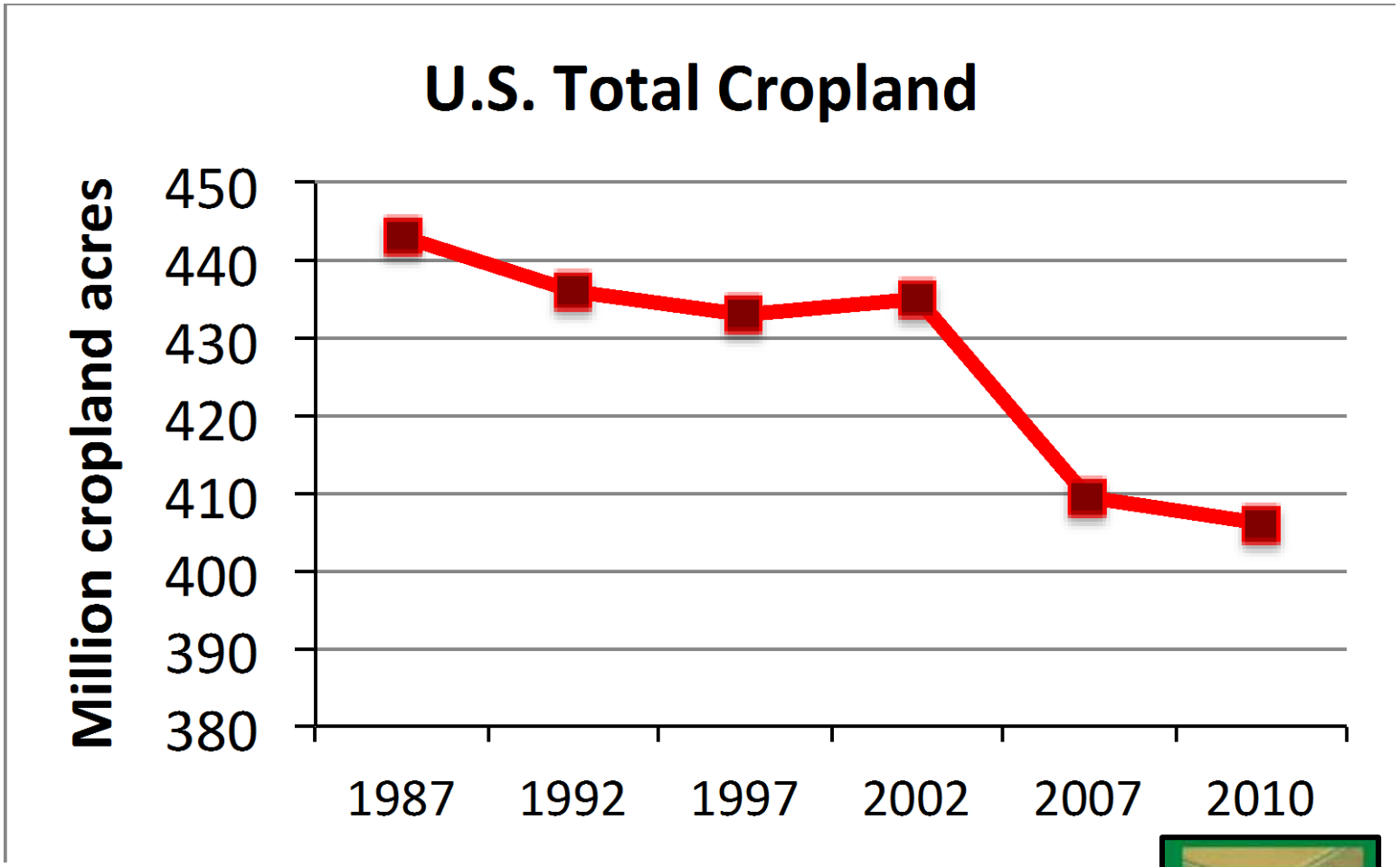
Data Source: IFA Statistics. 2014

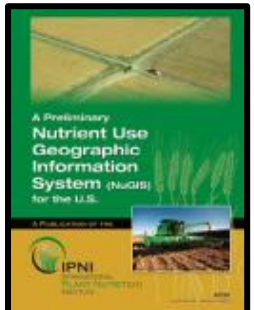
Shifts in N Source Selection Are Occurring: in Minnesota for example



Source: Minnesota Department of Agriculture, 2013

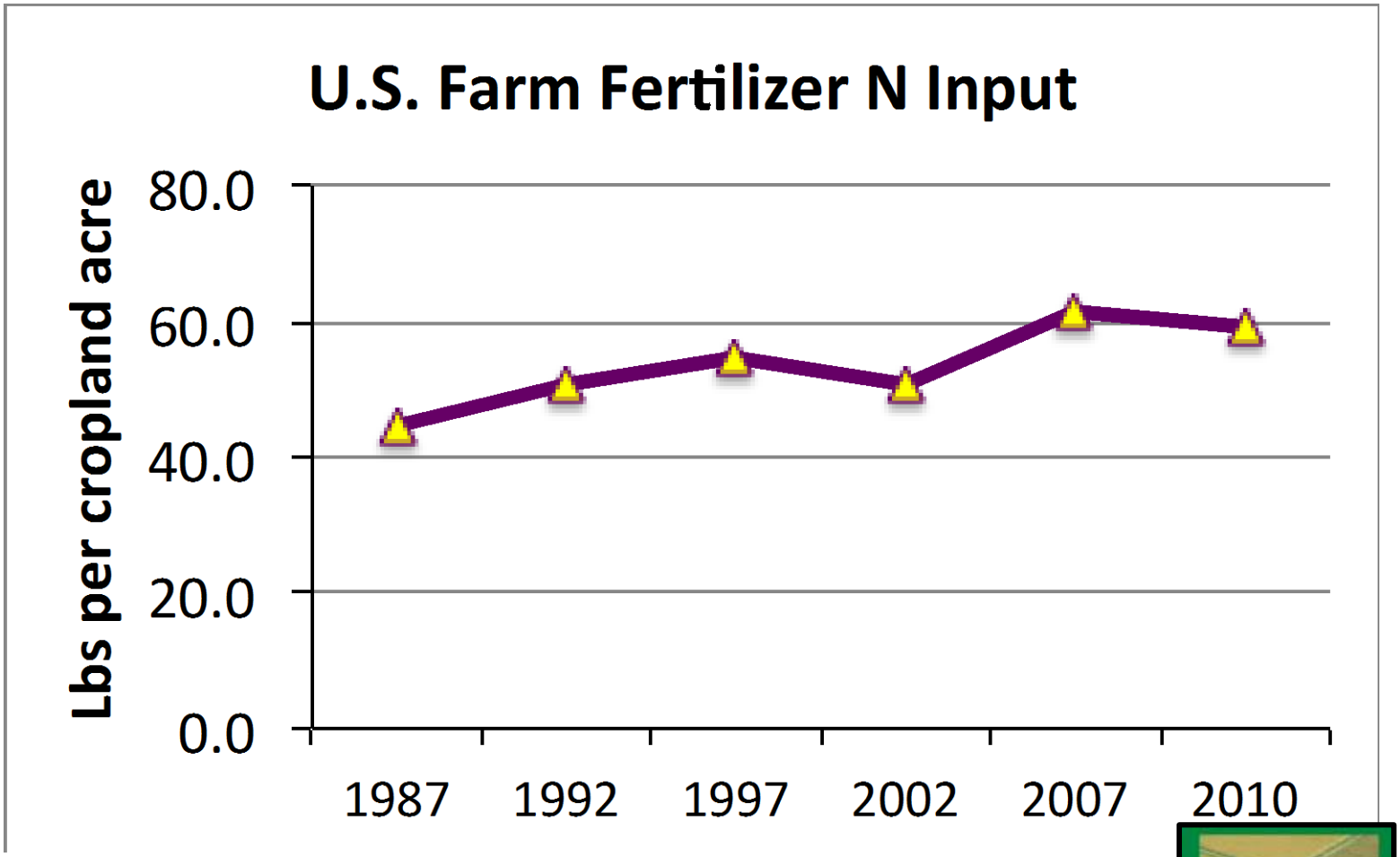
Total Cropland Acres Have Declined

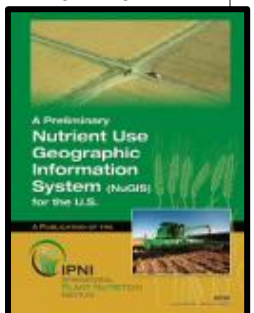




Source: NuGIS, IPNI; using USDA data

Total Farm Fertilizer N Inputs Have Risen





Source: NuGIS, IPNI; using USDA and AAPFCO data

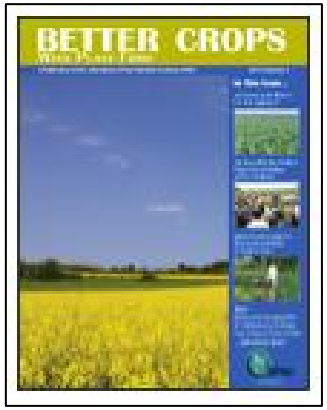
Are Midwest Corn Farmers Over-Applying N?

States included in comparison: IA, IL, IN, MI, MN, OH, WI	Year 2000	2005	2010	Avg
	N, lb/A			
University recommended rate[1]	148	133	154	**145**
Avg USDA-surveyed rate[2]	138	143	138	**140**
Difference	**-11**	**10**	**-15**	**-5**

[1]Maximum rate of return using the 'Corn N Rate Calculator' for corn following soybeans. [2]For corn acres receiving N.

Iowa State U.

Hoeft– U. of Illinois



Snyder. 2012. Better Crops 96(2): 3-4

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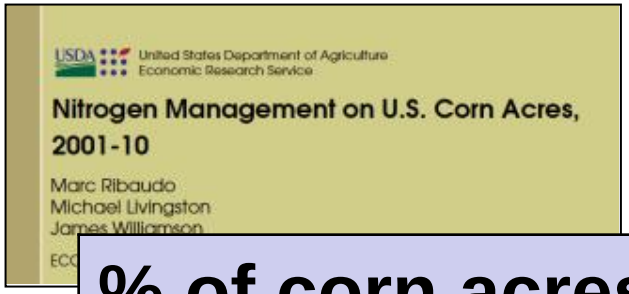

N rates >40% above crop grain harvest N removal were considered "excess"

% of corn acres not meeting N rate "criteria"

	2001	2005	2010
Appalachia	52	66	56
Corn Belt	46	38	30
Lake States	46	34	29
Southwest	31	32	28
TOTAL	**41**	**35**	**31**

"Despite improvements in N application rates, about 66 percent of corn acreage does not achieve the rate, timing, and method criteria that minimize environmental losses of N."

http://www.ers.usda.gov/publications/eb-economic-brief/eb20.aspx#.UkXILrx4MlY

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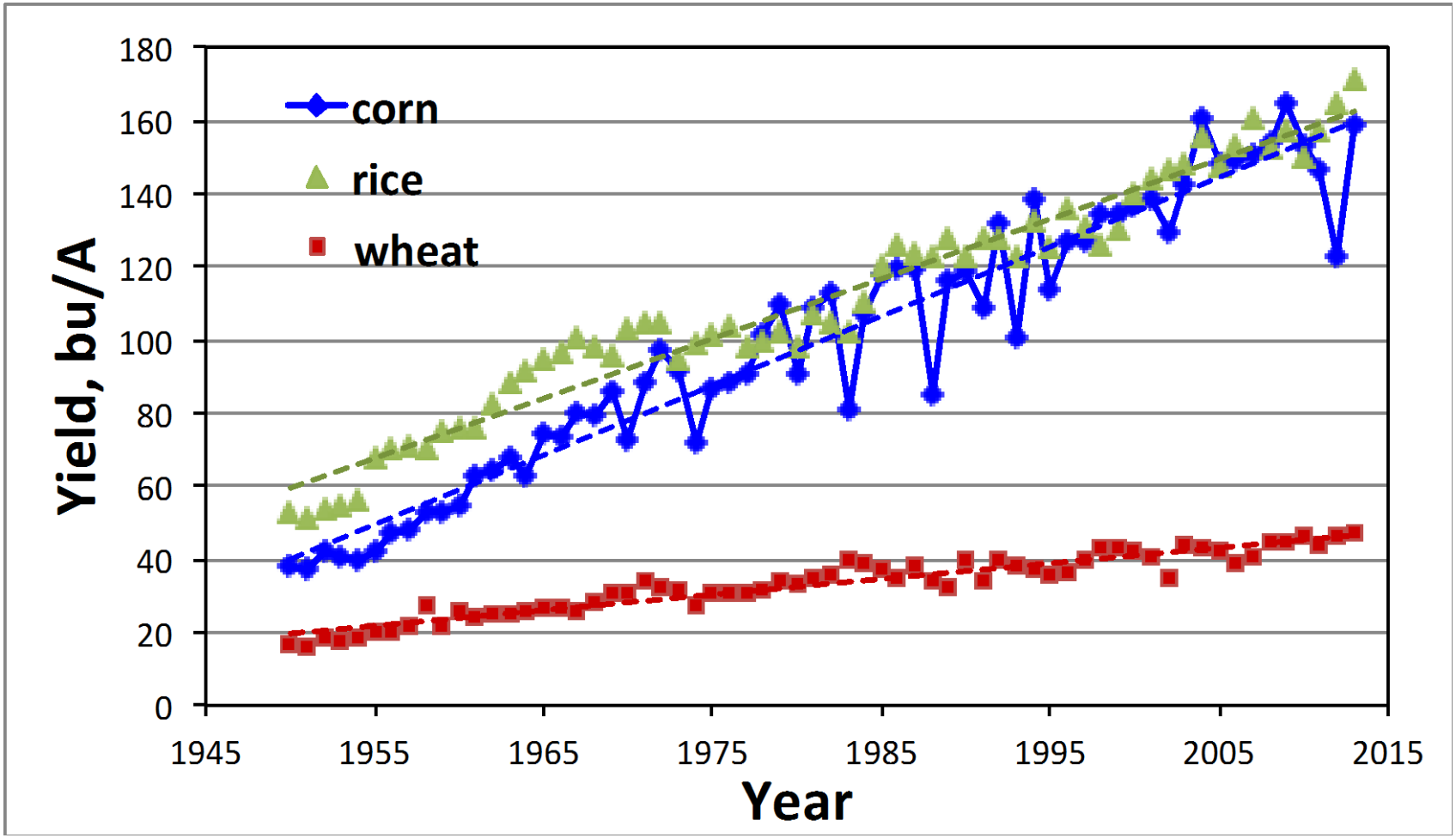
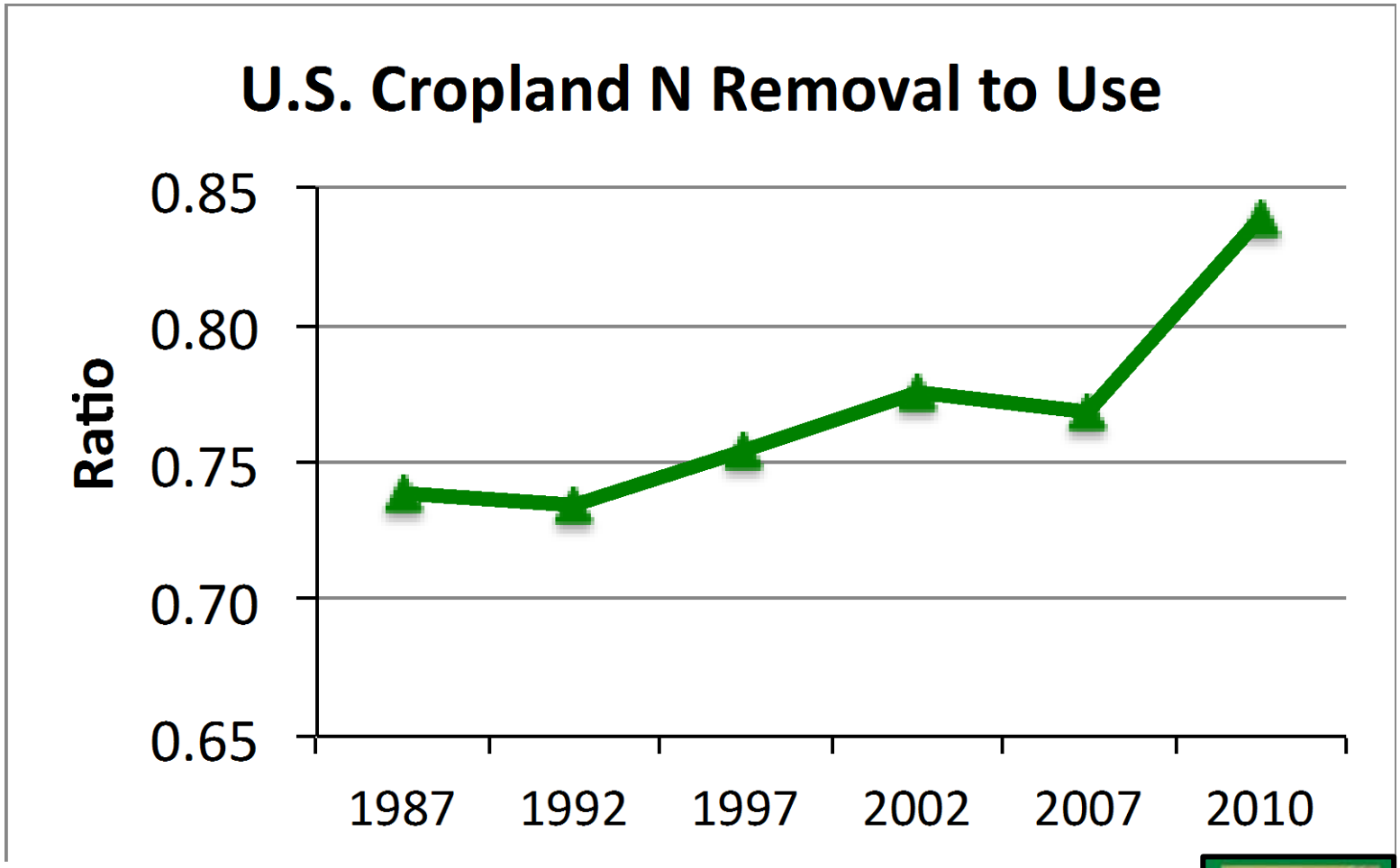
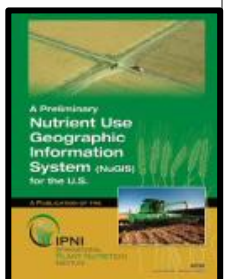
Yield Trends of Major U.S. Cereal Grains



Source: USDA NASS data

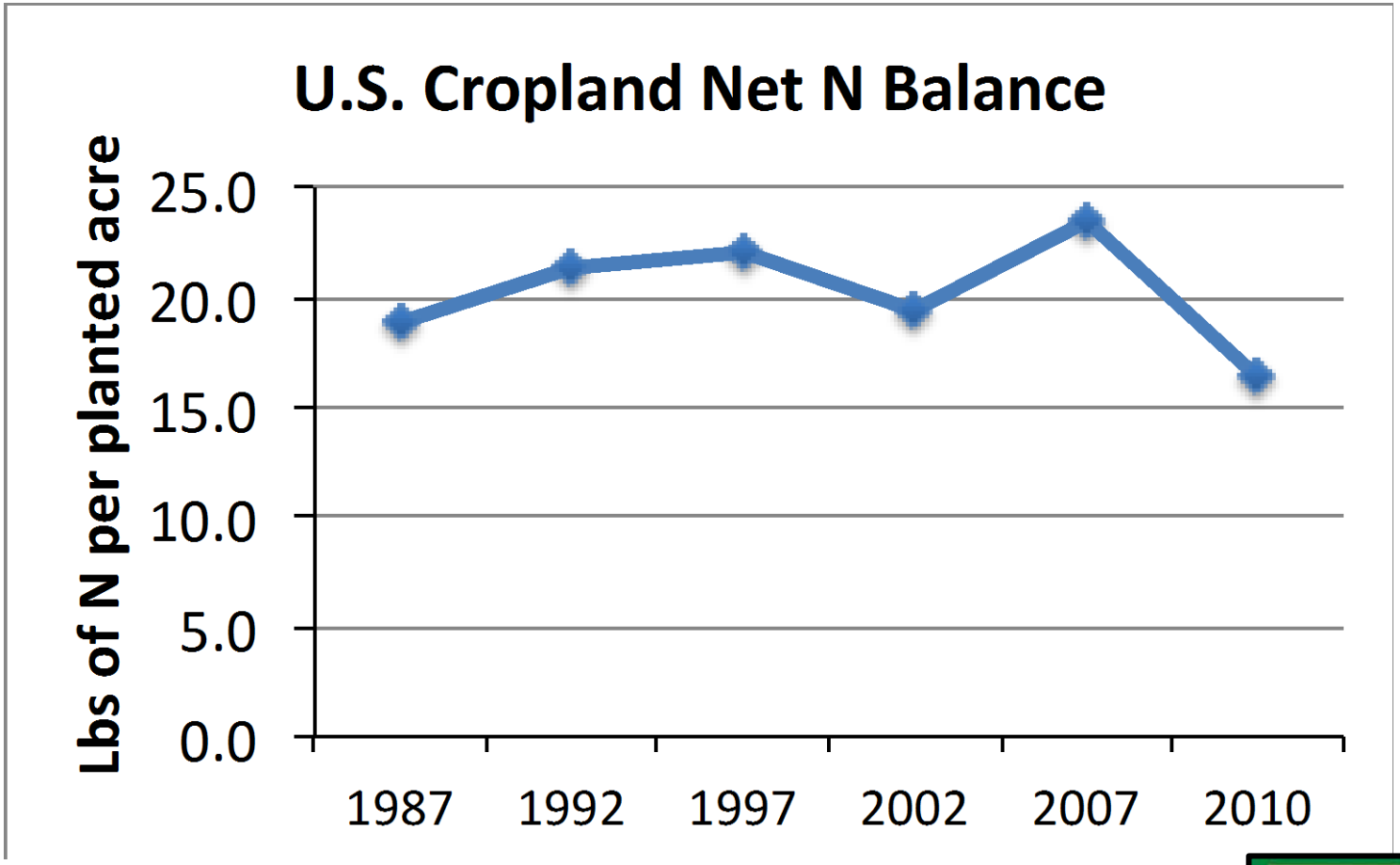
Crop N Removal to Use Ratio Has Increased

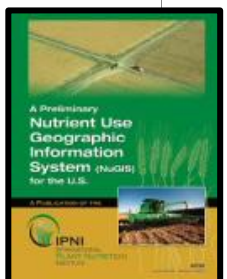




Source: NuGIS, IPNI; using USDA and AAPFCO data

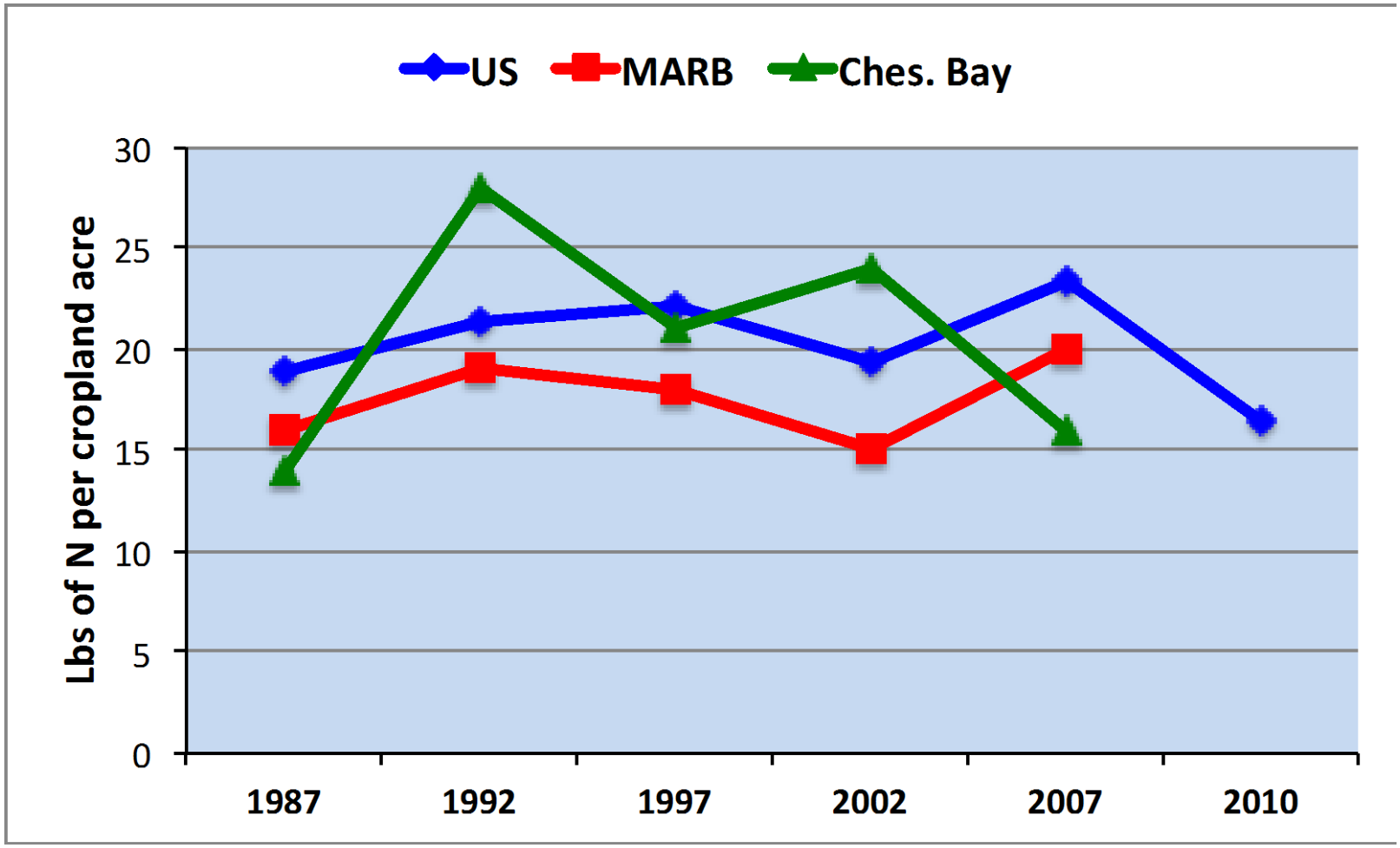
Cropland Net N Balance Has Varied, but May be Trending Downward

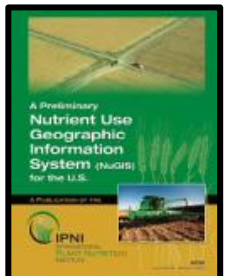




Source: NuGIS, IPNI; using USDA and AAPFCO data

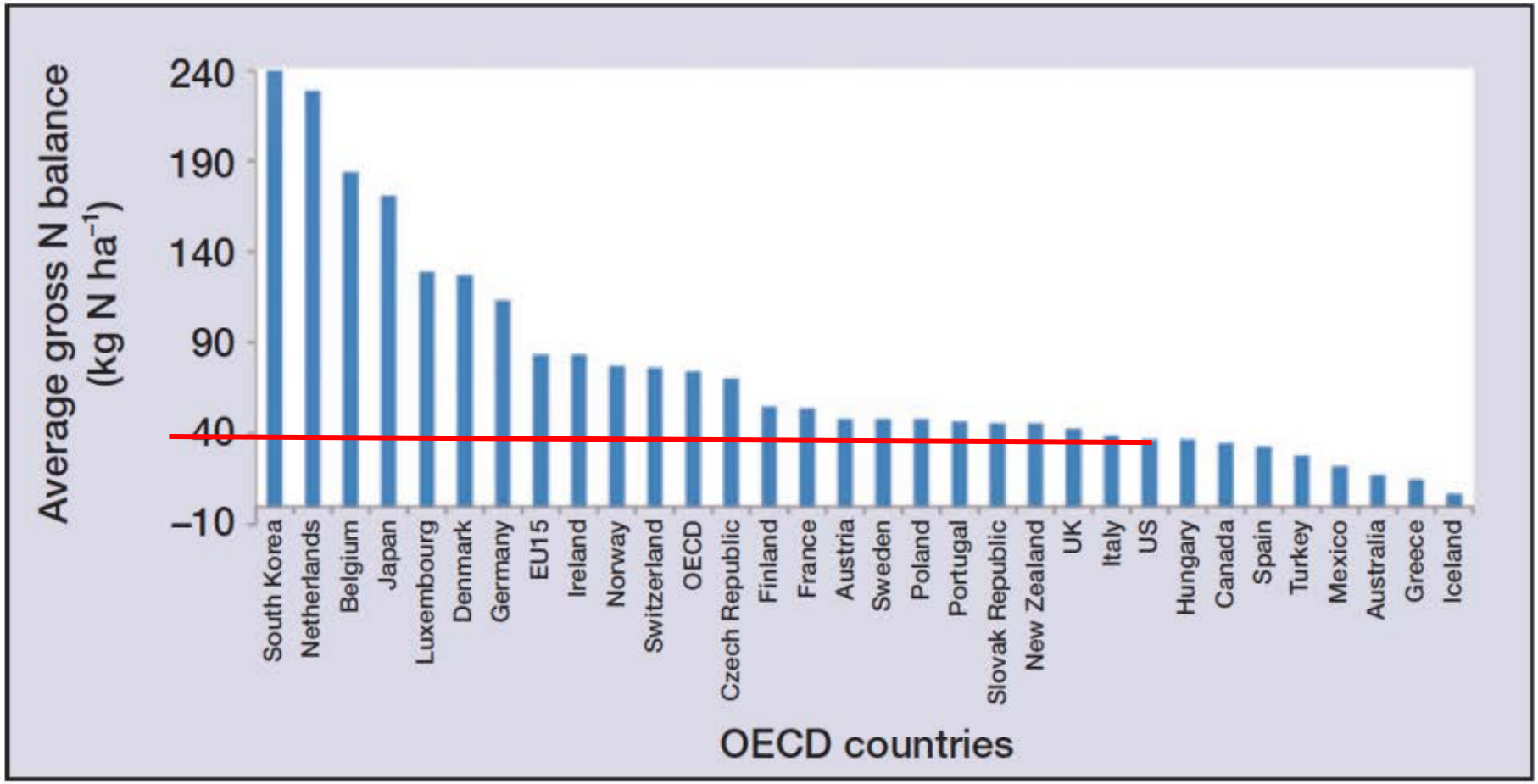
Cropland N Balance – Selected Watersheds





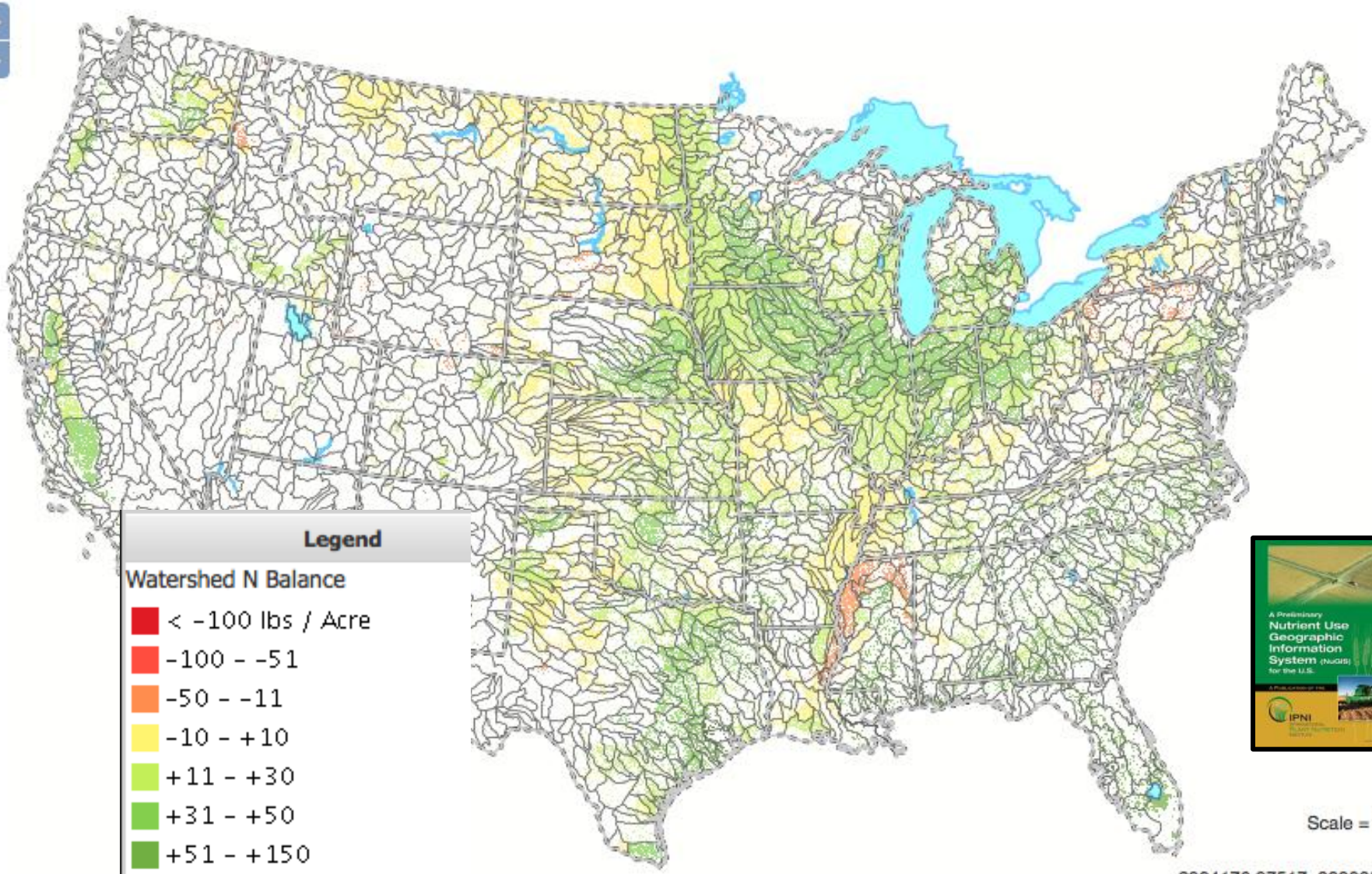
Source: NuGIS, IPNI; using USDA and AAPFCO data

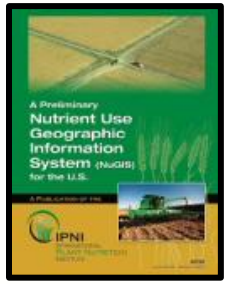
U.S. N Balance: Lower Than in Many Other Countries, 2002-2004 (OECD, 2008)



Average gross N balance estimates for OECD countries, 2002–2004.
Source: Cavigellii et al. Front Ecol Environ 2012; 10(10): 537–546, citing OECD
Gross N balance = ([fertilizer N + manure N + legume N fixation + N deposition] – N removal by crops)

Watershed N Balance,1987





For more information about NuGIS, www.ipni.net/NuGIS

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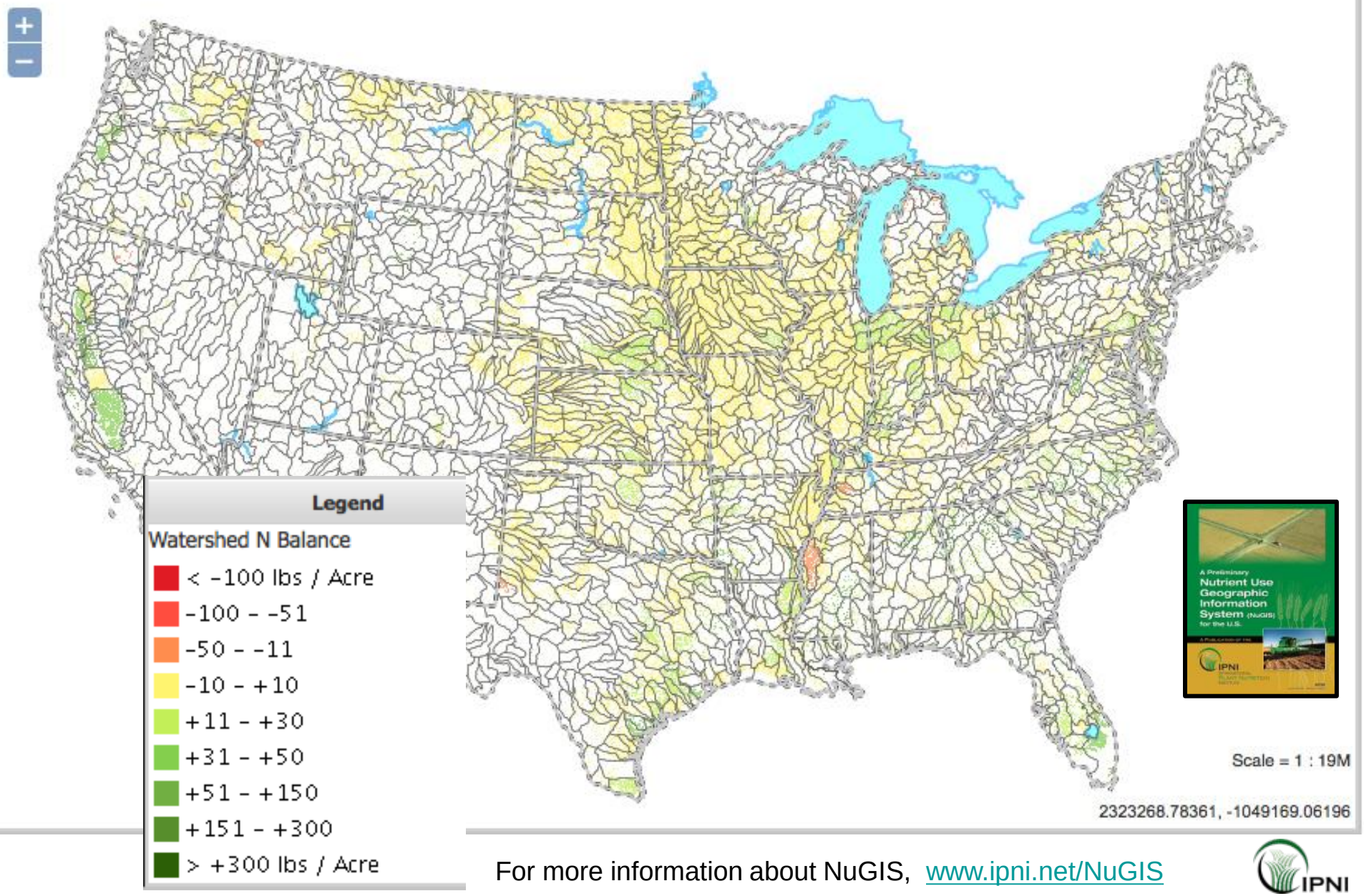
Watershed N Balance, 2010



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Grain per Unit of N Applied is Increasing

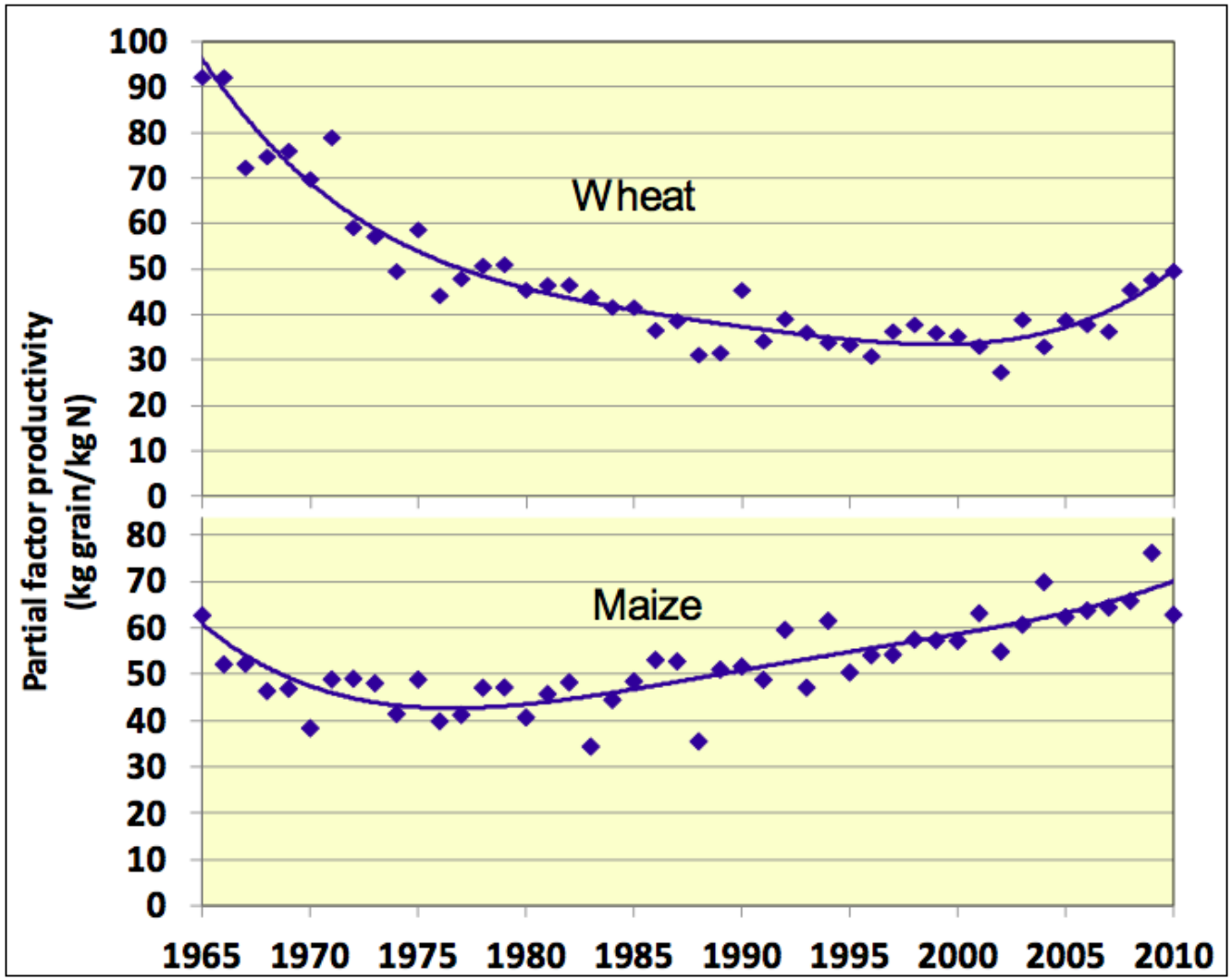


Figure 4. Partial factor productivity in the U.S. for fertilizer N used on maize and wheat from 1965 to 2010 (Adapted from USDA-ERS and USDA-NASS, 2011).

Fixen et al. 2014. Accepted for publication, IFA

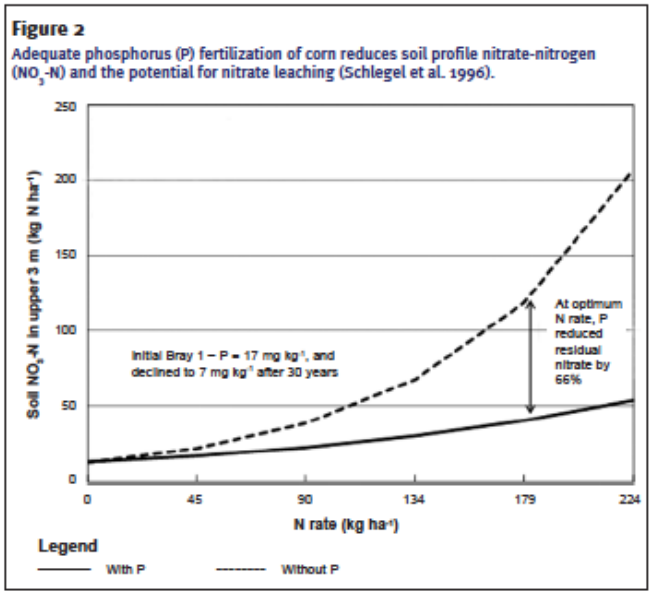
N Use Efficiency ≠ N Performance

- **Crop nutrients are applied to increase overall cropping system performance**
- **NUE is only one aspect of that system performance**
- **NUE offers no insights into soil fertility, soil organic matter, or other soil quality characteristics**
- **Each NUE term provides unique indication of potential for improved fertilizer management, but none alone provide a full representation of the impact on overall performance**

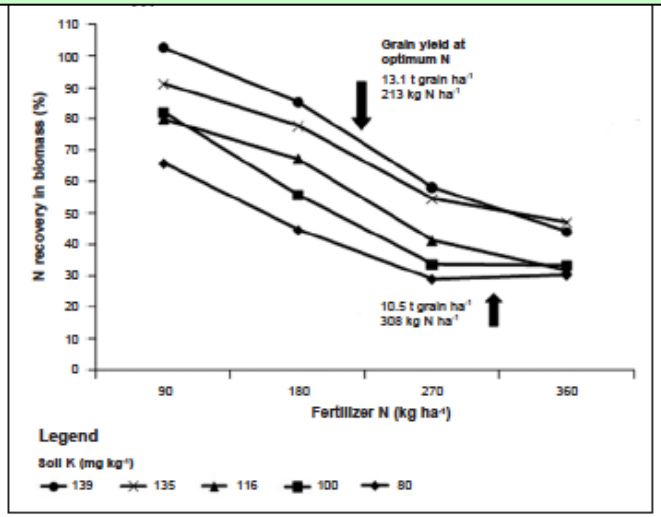
Source: P. Fixen, with adaptation, 2014

N Management and Balanced Nutrition

- **P and K soil fertility levels are below optimum and need improved (IPNI, 2010)**
  - 2010 median **soil P**=25 ppm: a 6 ppm <u>decline</u> since 2005; approximately 42% of samples <20 ppm agronomic optimum
  - 2010 median **soil K** =150 ppm: a 4 ppm <u>decline</u> since 2005; approximately 34% of samples <120 ppm agronomic optimum



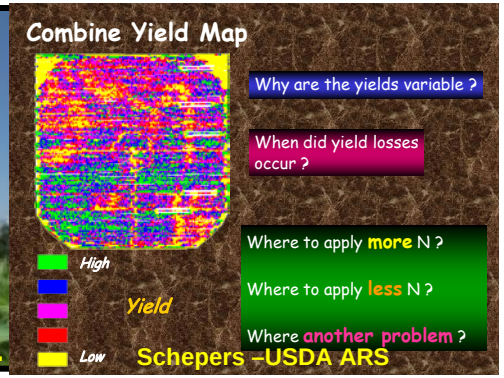
Optimum P and K enhance crop N recovery



Snyder & Fixen. 2012. J. Soil Water Conserv.

Many Factors Are Contributing to Changes in Nutrient Management and Educational Needs

Raun, Oklahoma State U.



Schepers –USDA ARS

Scharf, U. of Missouri

Wiebers, Ruffo, Fairchild –FFF,

Scharf, U. of Missouri

Major changes in fertilizer costs or crop prices

Climate change induced shifts in cropping patterns, yields, soil processes

Genetic changes that alter crop yields and NUE

Changes in crop species due to bioenergy

Changes in plant parts harvested due to bioenergy

Manure composition changes due to distillers grains

Application of bioash

Government policy

Fertilizer and equipment technology & tools

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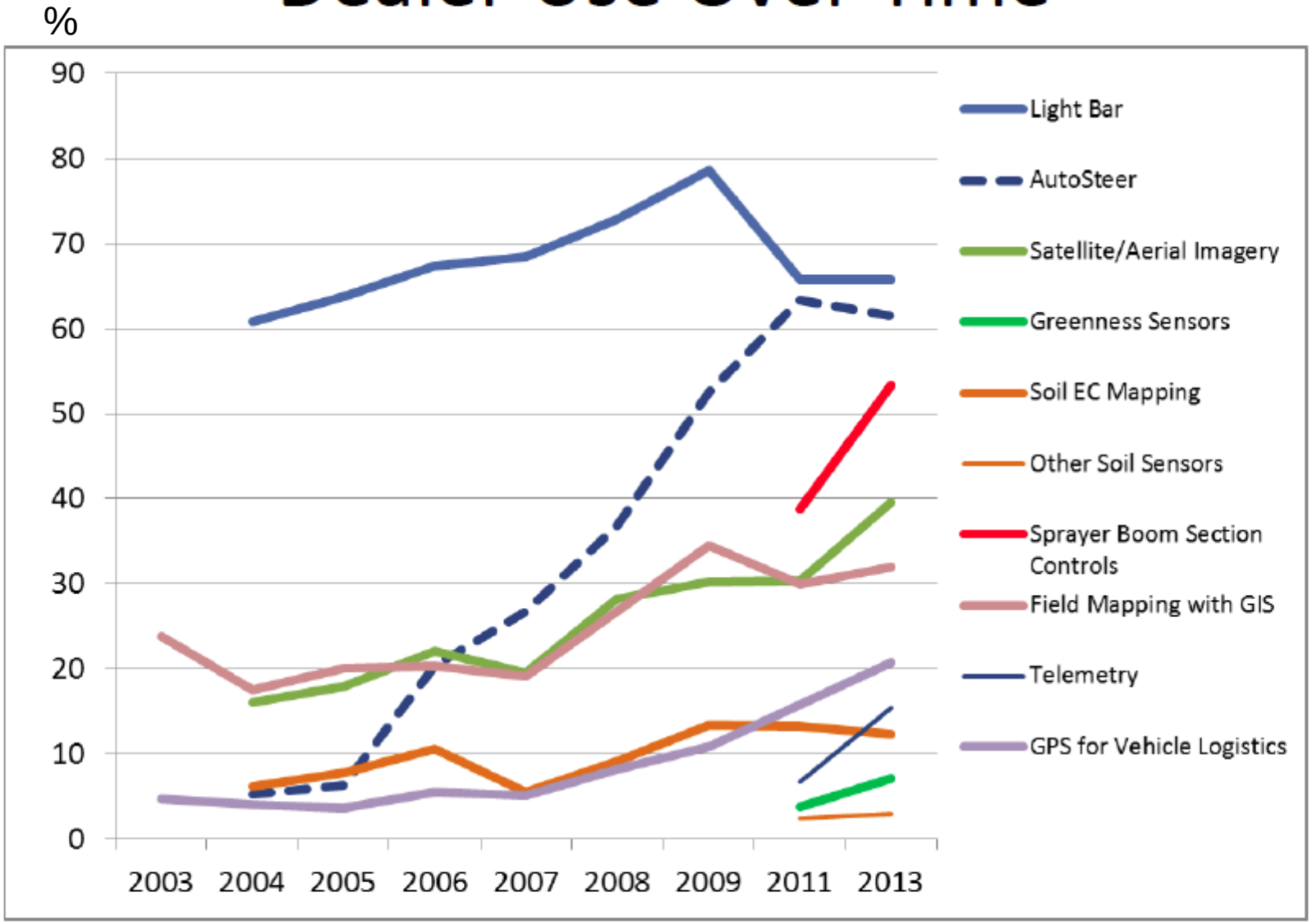
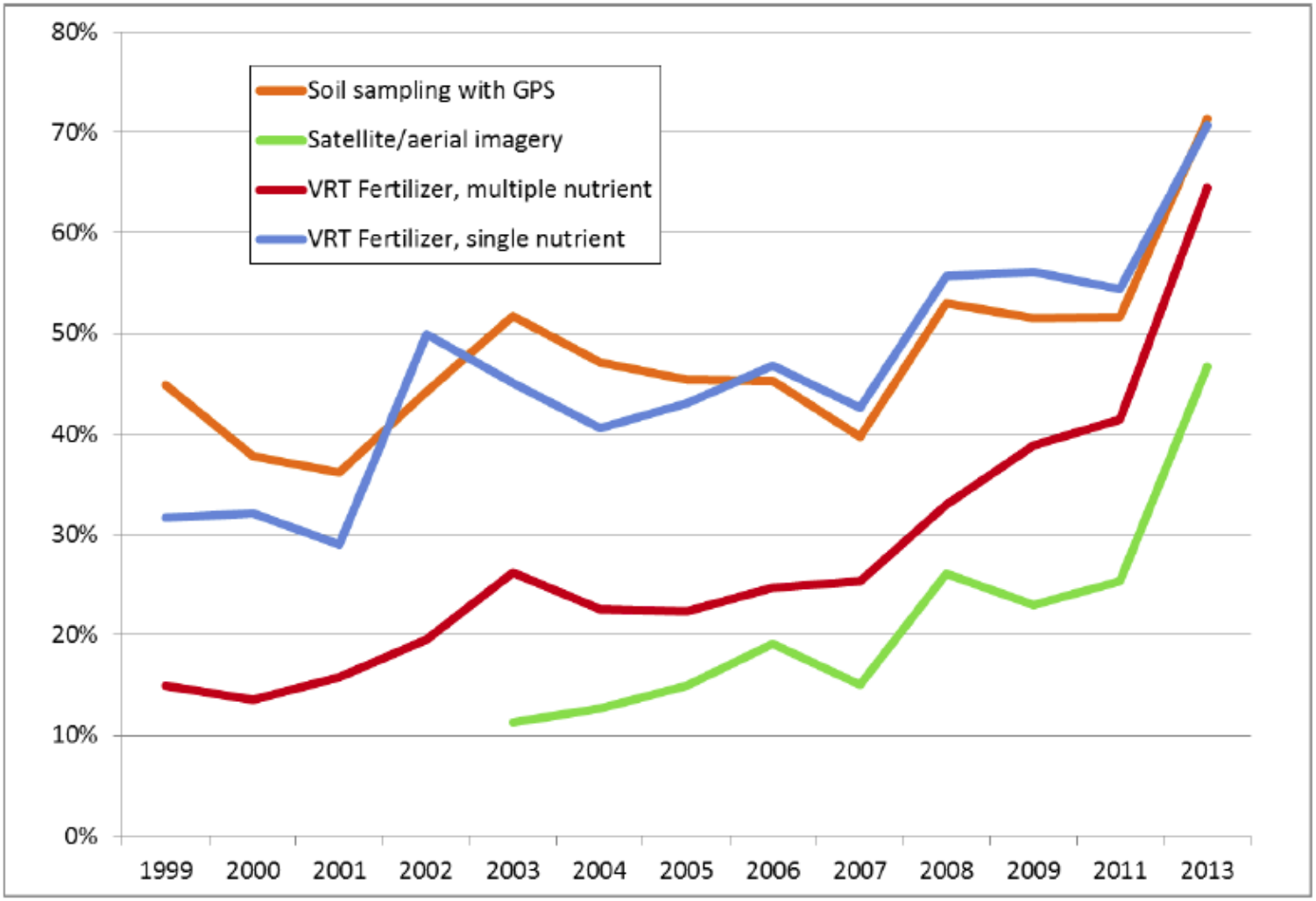
Dealer Use Over Time



Purdue/CropLife Precision Dealer Survey

Source: Bruce Erickson, Am. Soc. Agron. – InfoAg 2013

Dealer Offering Over Time



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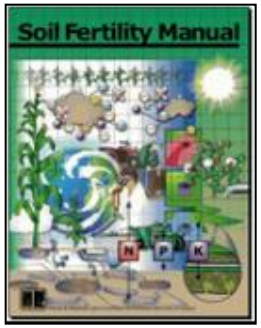

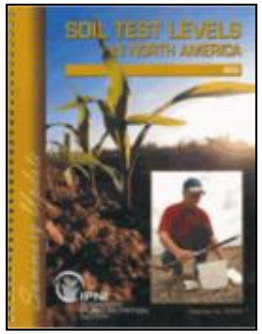

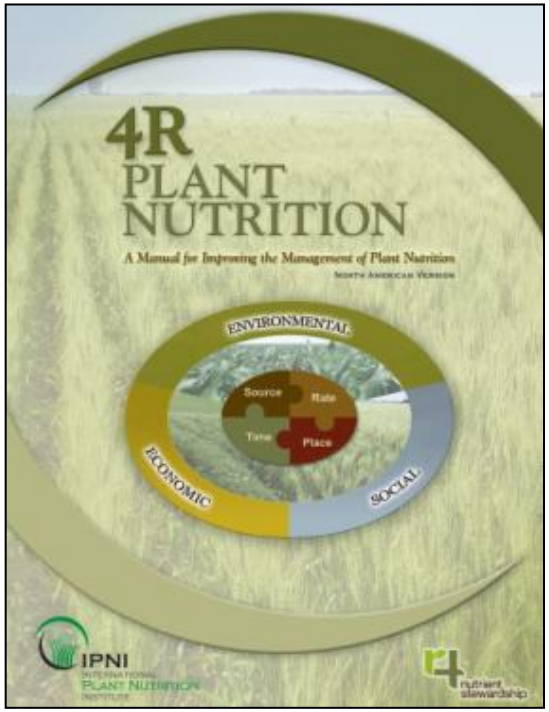

4R Nutrient Stewardship Education & Outreach

- Intensified education: North America and globally
- CCA and ag professional training
- Working with state & provincial fertilizer associations, & water quality agencies in key watersheds
- Involved in:
  - USDA NRCS: CEAP Assessment reviews
  - UNEP & USDA Climate Change Office: N_2O mitigation science committees
  - EPA: annual GHG inventory review
  - U.S. Research Coordination Network for Reactive N in Environment

American Society of Agronomy
Agronomy Feeds the World

2009
42:2-5

ASHS American Society for Horticultural Science

The "4R" Nutrient Stewardship Framework for Horticulture

Robert L. Mikkelsen[1]

5 articles

HortTechnology. 2011. 21(6)

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Soil Science Society of America

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NITROGEN USE EFFICIENCY

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PAST CONFERENCE (AUGUST 2013)

IMPROVING NITROGEN USE EFFICIENCY IN CROP AND LIVESTOCK PRODUCTION SYSTEMS: EXISTING TECHNICAL, ECONOMIC, AND SOCIAL IMPEDIMENTS AND FUTURE OPPORTUNITIES

Kansas City Marriott Country Club Plaza, Kansas City, MO

Sponsored by

IPNI International Plant Nutrition Institute

Reactive Nitrogen RCN Research Coordination Network

CONFERENCE WRAP UP

View the **World Cafe Discussion** results.

View the **poster abstracts** that were presented at the Nitrogen Use Efficiency Conference.

View the **oral presentation slides** that were presented at the conference.

WHO SHOULD ATTEND ?

This conference will bring together agronomists, biogeochemists, farmers, economists, sociologists, extension a private sectors to identify the major impediments to improved nutrient management and to make recommendati

Also sponsored by

Soil Science Society of America | AGU American Geophysical Union | The Woods Hole Research Center | International Nitrogen Initiative | The Fertilizer Institute Nourish, Replenish, Grow

» **View the Program Agenda** (PDF)

» **View the Poster abstracts**

» Print and share the **Nitrogen Use Efficiency Flyer** (PDF)

APPROVED CEUS

Nutrient Management: 5.5

https://www.soils.org/meetings/specialized-conferences/nitrogen-use-efficiency

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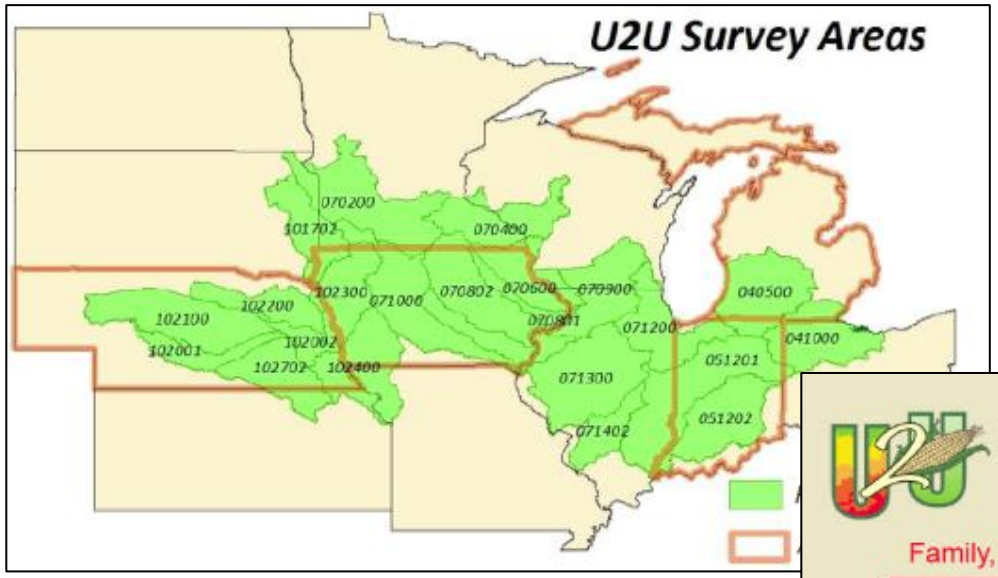
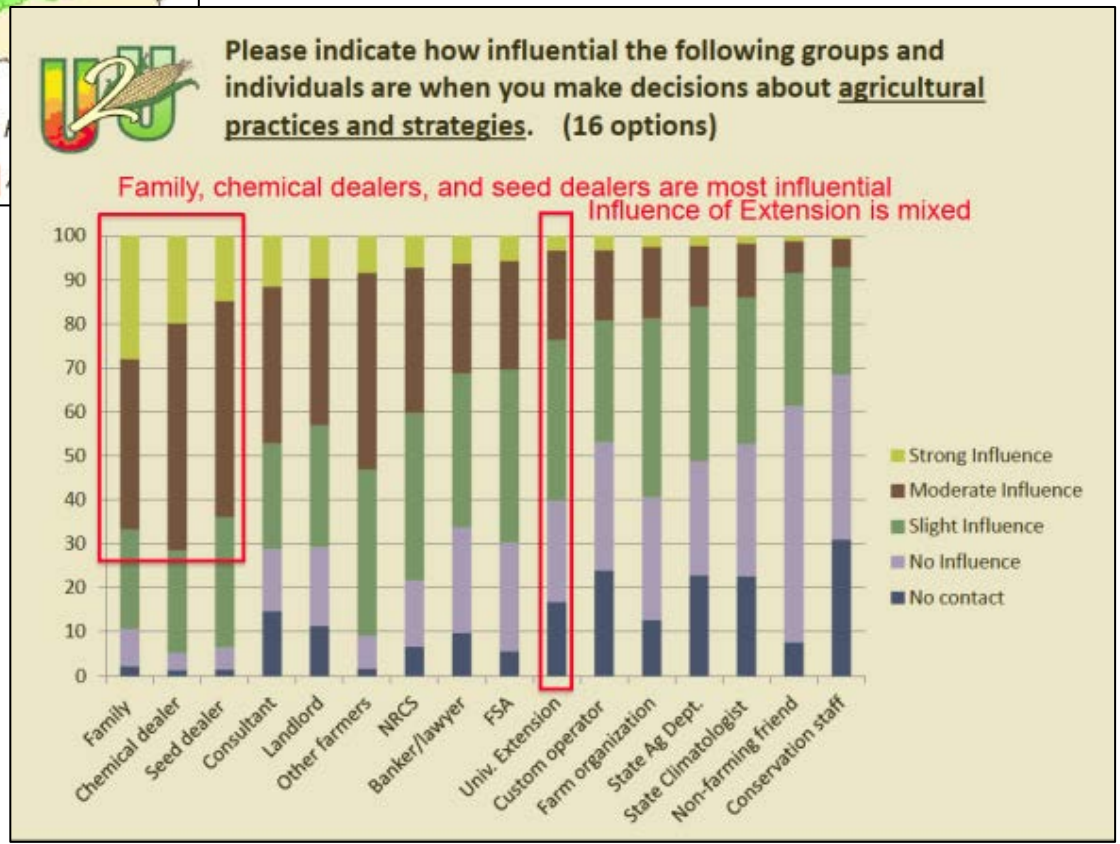
Many Farmers Get Their Nutrient Management Advice from Ag Retailers





Source: Linda Prokopy, Purdue U., Nitrogen Use Efficiency Conference, August 2013

4R Nutrient Stewardship Retailer Certification Program – Western Lake Erie Basin

NUTRIENT STEWARDSHIP CERTIFIED

Private Third Party Auditor

Nutrient Service Providers

Voluntary

Source: Lara Moody, TFI

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Who is working on 4R Certification?

The Andersons
MABA
AGRIbusiness Council of INDIANA
MORRAL COMPANIES
FB OHIO FARM BUREAU
The Fertilizer Institute
Nourish, Replenish, Grow
The Nature Conservancy
Protecting nature. Preserving life.
INDIANA CONSERVATION PARTNERSHIP
IPNI INTERNATIONAL PLANT NUTRITION INSTITUTE
Ohio AgriBusiness Association
NRCS
DESHLER FARMERS ELEVATOR
SOY OHIO
Ohio Soybean Council
FARMERS ELEVATOR
WESTERN LAKE ERIE BASIN PARTNERSHIP
EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work
Nester Ag LLC
MAEAP
MICHIGAN STATE UNIVERSITY
THE OHIO STATE UNIVERSITY
CAP CONSERVATION PROJECT
CERTIFIED CROP ADVISER

Source: Lara Moody, TFI

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Genetic Improvement of N Use Efficiency …….. and N-Fixation in Cereals ??

Farm Industry News - Aug. 21, 2012

Seed companies developing hybrids that use nitrogen more efficiently

Monsanto, DuPont Pioneer, & Syngenta

Science

20 Sep. 2013

Nonlegumes Respond to Rhizobial Nod Factors by Suppressing the Innate Immune Response

U.S. Office of Technology Assessment, 1981

National Science Foundation
WHERE DISCOVERIES BEGIN

21 Aug. 2013

Press Release 13-147

US AND UK SCIENTISTS COLLABORATE TO DESIGN CROPS OF THE FUTURE

Three Ideas Lab projects and a fourth NSF-sponsored project aim to transform future farming while reducing pollution and energy consumption

In Vitro Cellular & Developmental Biology - Plant
January–February 2006, Volume 42, Issue 1, pp 74-82

Intracellular colonization of roots of *Arabidopsis* and crop plants by *Gluconacetobacter diazotrophicus*

Edward C. Cocking, Philip J. Stone, Michael R. Davey

The N-Fix technology licensed by Univ. of Nottingham to Azotic Technologies

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Potential for Further Reductions in Nutrient Loads to Rivers and Streams through Comprehensive Conservation Treatment - USDA CEAP Reports

- Upper Mississippi River Basin: N 44%, P 27%
- Ohio-Tennessee River Basin: N 41%, P 58%
- Great Lakes Basin: N 37%, P 33%
- Missouri River Basin: N 13%, P 12%
- Lower Mississippi Basin: N 48%, P 62%
- **NIFA CEAP Watershed Assessment - Lessons Learned**
  - "Practices based on management changes, such as nutrient management, were less likely to be sustained by farmers than structural practices"
  - " … many conservation practices designed to control nutrients are disliked (nutrient management and buffers)";
  - " farmers cannot readily observe nutrient losses whereas they can observe soil losses." (Osmond et al. 2012)

Fertilizer N BMPs Help Minimize Potential for Residual NO_3-N Accumulation & Losses

- **N source, rate, timing, and place of application …. which may include**
  - **Urease inhibitors**
  - **Nitrification inhibitors**
  - **Slow-release materials**
  - **Controlled-release materials**
- **In combination with appropriate, site-specific cropping system and conservation practices**
  - **(e.g. conservation tillage, cover crops, vegetative buffers, riparian areas, managed drainage, wetlands, bioreactors, etc.)**
- ***What could we accomplish if in-field, edge of field, and above-stream BMPs are coupled?***

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Bottom Line

- Use appropriate fertilizer N & balanced fertilization (P, K, Mg, S, Zn, etc.) to
  - enhance N use efficiency <u>and</u> effectiveness
  - increase crop biomass, help restore/maintain/increase soil carbon (*soil organic matter*) and "soil "health"
- Remember, N (and P) losses can vary among 4R factors …depending on site-specific conditions, weather, cropping, and tillage systems
- Work more pro-actively with state and local partners to advance **4R Nutrient Stewardship**
- **Track and record performance indicators**
  - **<u>for example</u>: trends in harvested nutrients, yield per unit of nutrient applied, soil organic matter increase, etc.**

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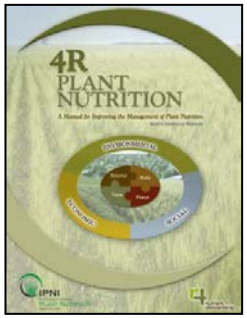
We Can Improve N Use Efficiency and Effectiveness

by implementing nutrient BMPs …

Right source @ Right rate,
Right time, and Right place



In conjunction with other proven conservation practices

4R Nutrient Stewardship

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Thank You

Better Crops, Better Environment … through Science

www.ipni.net