Seminar in Plant Agriculture
University of Guelph
13 February 2013

IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

4R Plant Nutrition: linking science to practice

Tom Bruulsema, PhD, CCA
Director, Northeast Region, North America Program

Agrium Inc.

Arab Potash Company

Belarusian Potash Company

CF Industries Holdings, Inc.

Compass Minerals Specialty Fertilizers

Incitec Pivot

International Raw Materials LTD.

Intrepid Potash, Inc.

K+S KALI GmbH

The Mosaic Company

OCP S.A.

PotashCorp

Qatar Fertiliser Company (QAFCO)

Simplot

Sinofert Holdings Limited

SQM

Uralkali

Formed in 2007 from the Potash & Phosphate Institute, the **International Plant Nutrition Institute** is supported by leading fertilizer manufacturers.

Outline

1. **Sustainable agriculture**
2. **Nitrogen-climate interactions**
3. **Phosphorus issues**
4. **Soil potassium fertility**
5. **Fertilizing to improve human health**

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

4R nutrient stewardship

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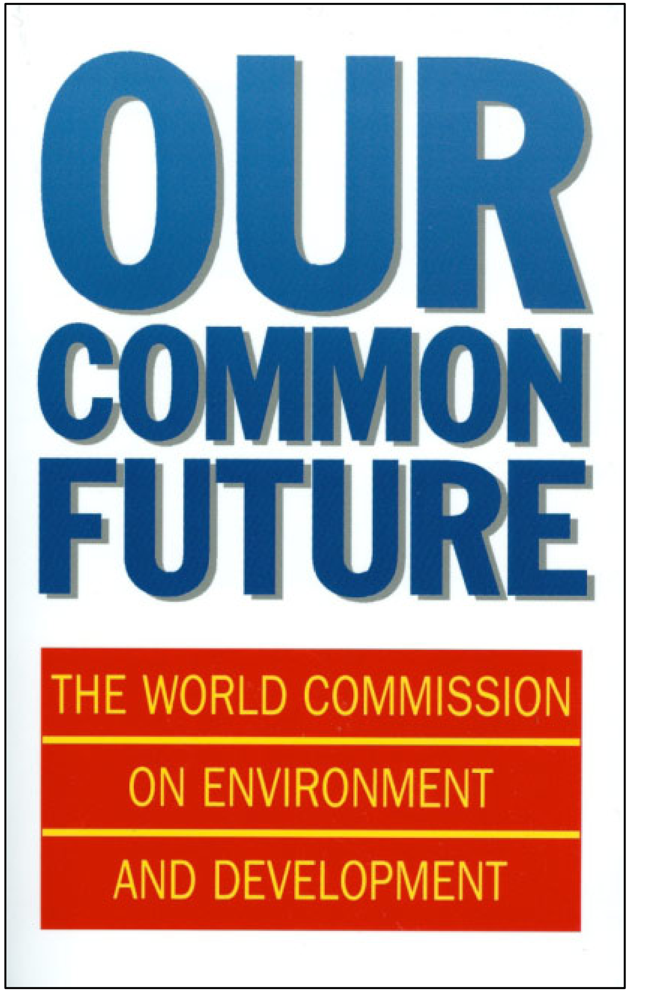
Sustainable Agriculture

4R PLANT NUTRITION

Brundtland report

- *Our Common Future* (1987) addressed concerns "about the accelerating deterioration of the **human environment** and **natural resources** and the consequences of that deterioration for **economic** and **social development**."
- This report provided the basis for sustainable agriculture.



Source: Advisory Panel on Food Security, Agriculture, Forestry, and Environment. World Commission on Environment and Development. 1987.

Sustainability Initiatives Abound in 2013

PEPSICO

Home | Company | Purpose | Brands | Inves…

Performance with Purpose

Home » Purpose » Environmental Sustainability » Agriculture

PURPOSE

Agriculture

THE SUSTAINABILITY CONSORTIUM

4R PLANT NUTRITION

Field to Market

Field To Market: The Keystone Alliance for Sustainable Agriculture

Field To Market is a diverse alliance working to create opportunities across the agricultural s… productivity, environmen… group provides collabor… wide dialogue, grounde… technology choices.

Fieldprint Calculator

The Fieldprint Calculator is an educational too… designed to help you assess how some of your operational decisions affect overall sustainability performance. The

Environmental Sustainability

Walmart Save money. Live better.

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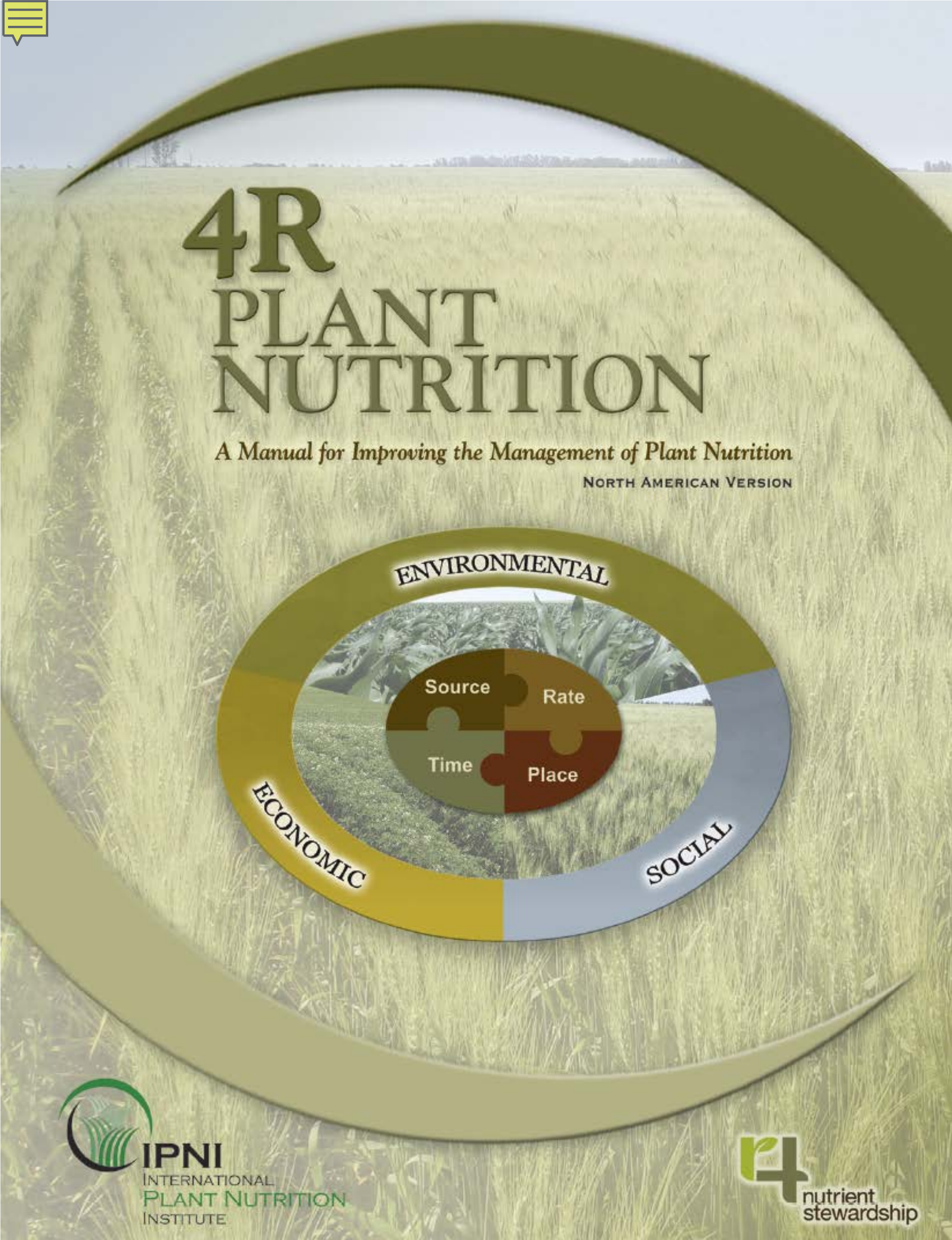
LEARN MORE ▸

THE SUSTAINABILITY CONSORTIUM



http://nane.ipni.net

Source, rate, time, and place describe any nutrient application

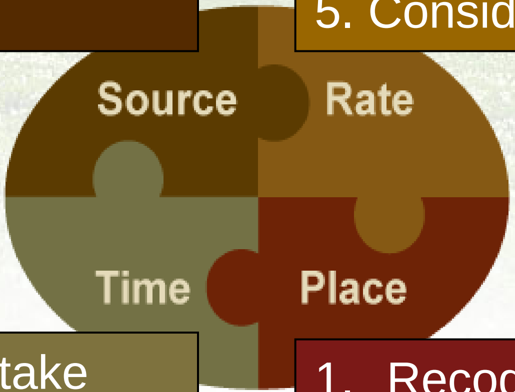
4R PLANT NUTRITION

nutrient stewardship

The basic scientific principles of managing crop nutrients are universal

1. Provide essential elements
2. Supply plant-available forms
3. Suit soil properties
4. Synergisms, blend compatibility
5. Associated elements

1. Assess plant demand
2. Assess soil supply
3. Assess all available sources
4. Predict fertilizer use efficiency
5. Consider resources and economics

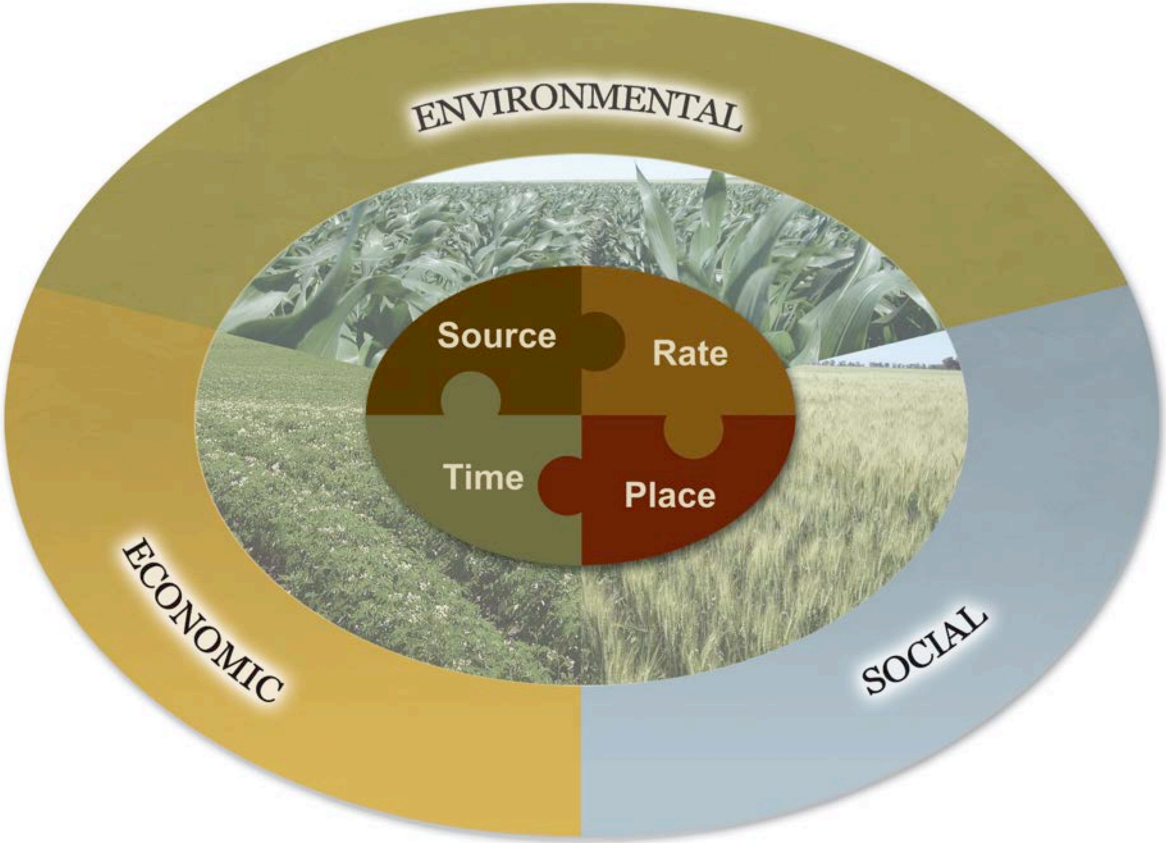


1. Assess timing of crop uptake
2. Assess dynamics of soil supply
3. Assess timing of weather factors
4. Evaluate logistics

1. Recognize root-soil dynamics
2. Consider soil chemical reactions
3. Manage spatial variability
4. Fit needs of tillage system

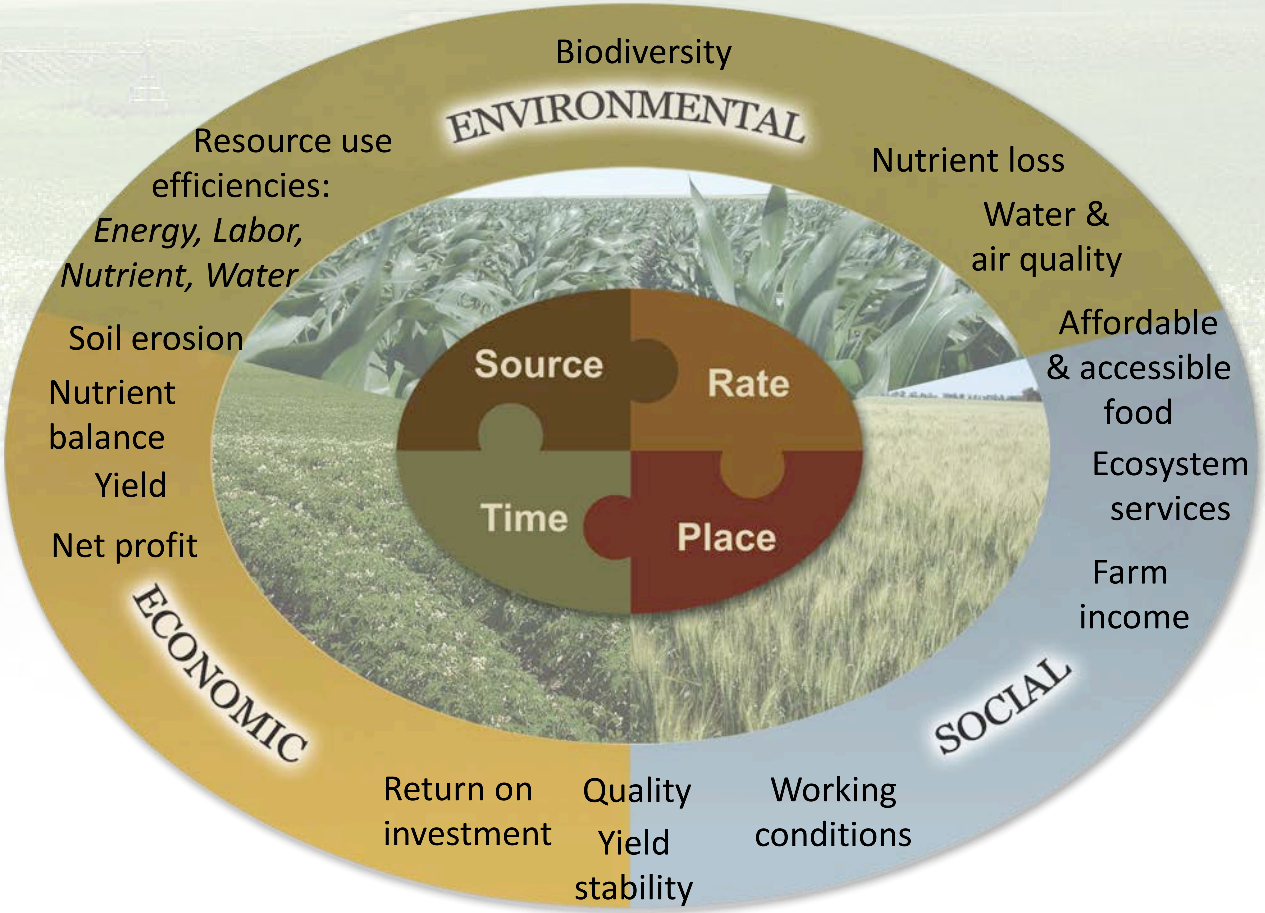
Right means Sustainable

- Right source, rate, time, and place
- Outcomes valued by stakeholders

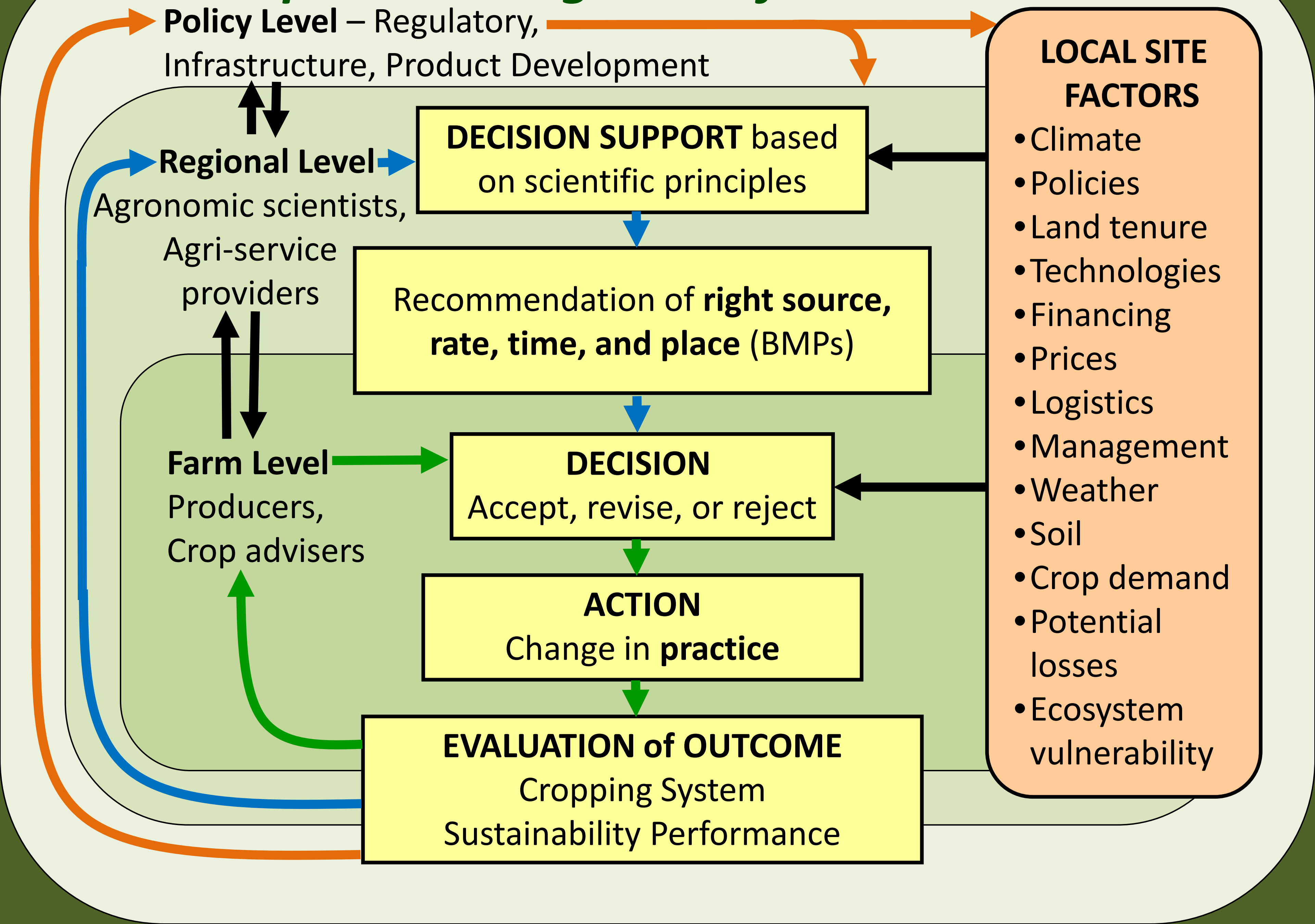


The 4Rs influence many performance indicators

- social, economic and environmental performance
- influenced by crop and soil management as well
- whole system outcomes



4R Adaptive Management for Plant Nutrition



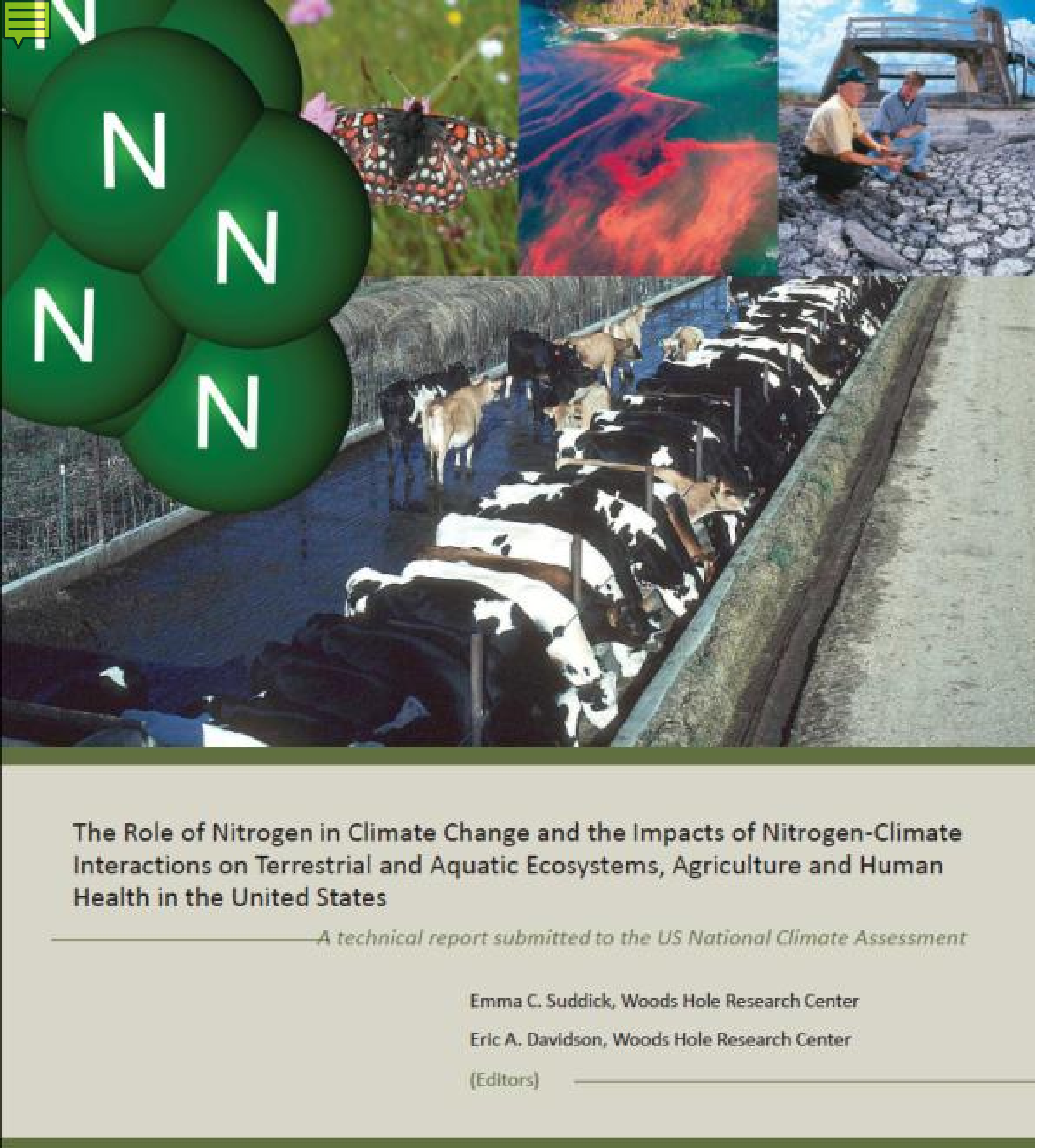
The 4Rs involve adaptive management

- **Balanced assessment of each "R" for contribution toward sustainability goals**
- **Right rate**
  - easily quantified, easily changed
- **Right source, Right time, Right place**
  - require investment to change
  - interaction problem for scientific testing: soil * weather * management * 2^3

Nitrogen-Climate Interactions

4R PLANT NUTRITION

Nitrogen-Climate Interactions



- 7 chapters, 208 pages
- Feeds into U.S. National Climate Assessment
- "improved nutrient management will be increasingly challenging under climate change scenarios of more variable climatic patterns"
- "striving for NUE reduces impact of climate on crop N use, and impact of crop N use on climate"

Woods Hole Research Center | International Nitrogen Initiative | Reactive Nitrogen RCN Research Coordination Network | the David & Lucile Packard Foundation | IPNI

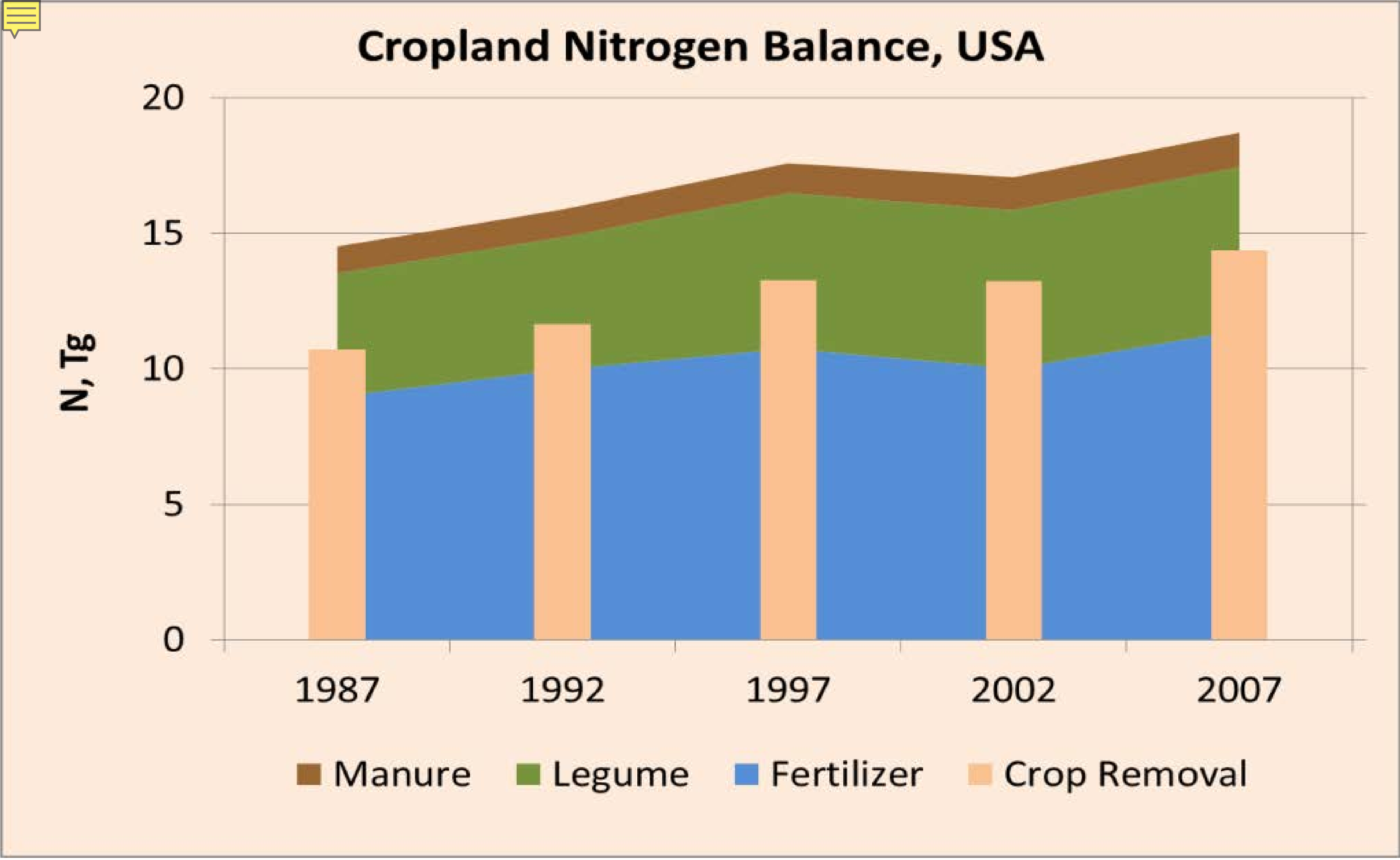


Figure 4.1: Inputs of N to US agricultural land, including recoverable manure, legume fixation, and commercial fertilizers, as compared to removal by crops (adapted from IPNI NuGIS, 2011). *[In Robertson et al., 2012, Biogeochemistry, in press]*

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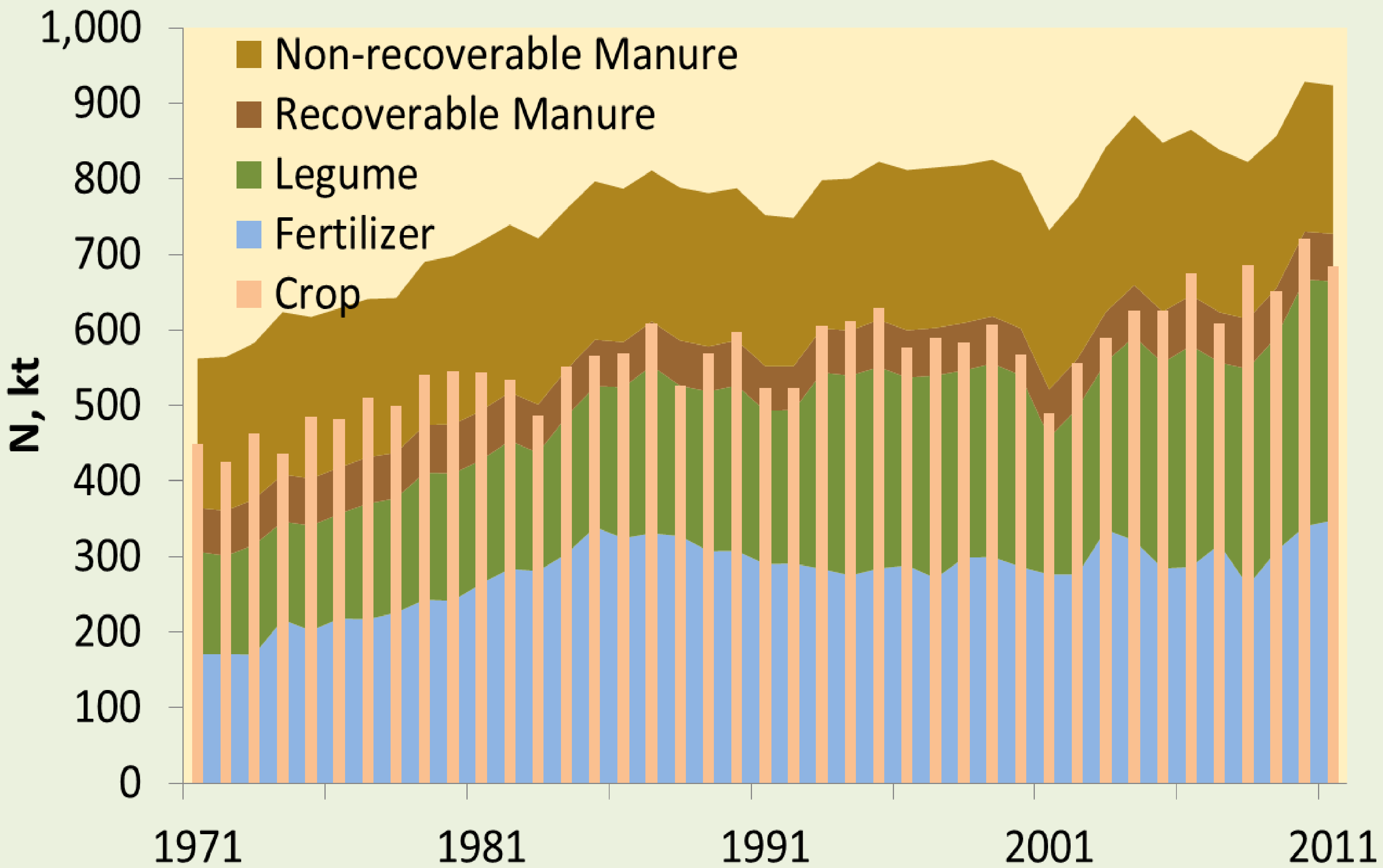
Eastern Canada Cropland Nitrogen Balance



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Climate and soil organic N

- **Soil N mineralization** increased by temperature but reduced by higher C/N ratios (Brevik, 2012, Soil Horizons)
- **Nutrients:** "Soil C sequestration under elevated CO_2 is constrained both directly by N availability and indirectly by nutrients [P, K, Mo] needed to support N_2 fixation" (van Groenigen et al, 2006, PNAS)
- **Progressive N limitation:** "Soil N supply is probably an important constraint on global terrestrial responses to elevated CO_2" (Reich et al, 2006, Nature)

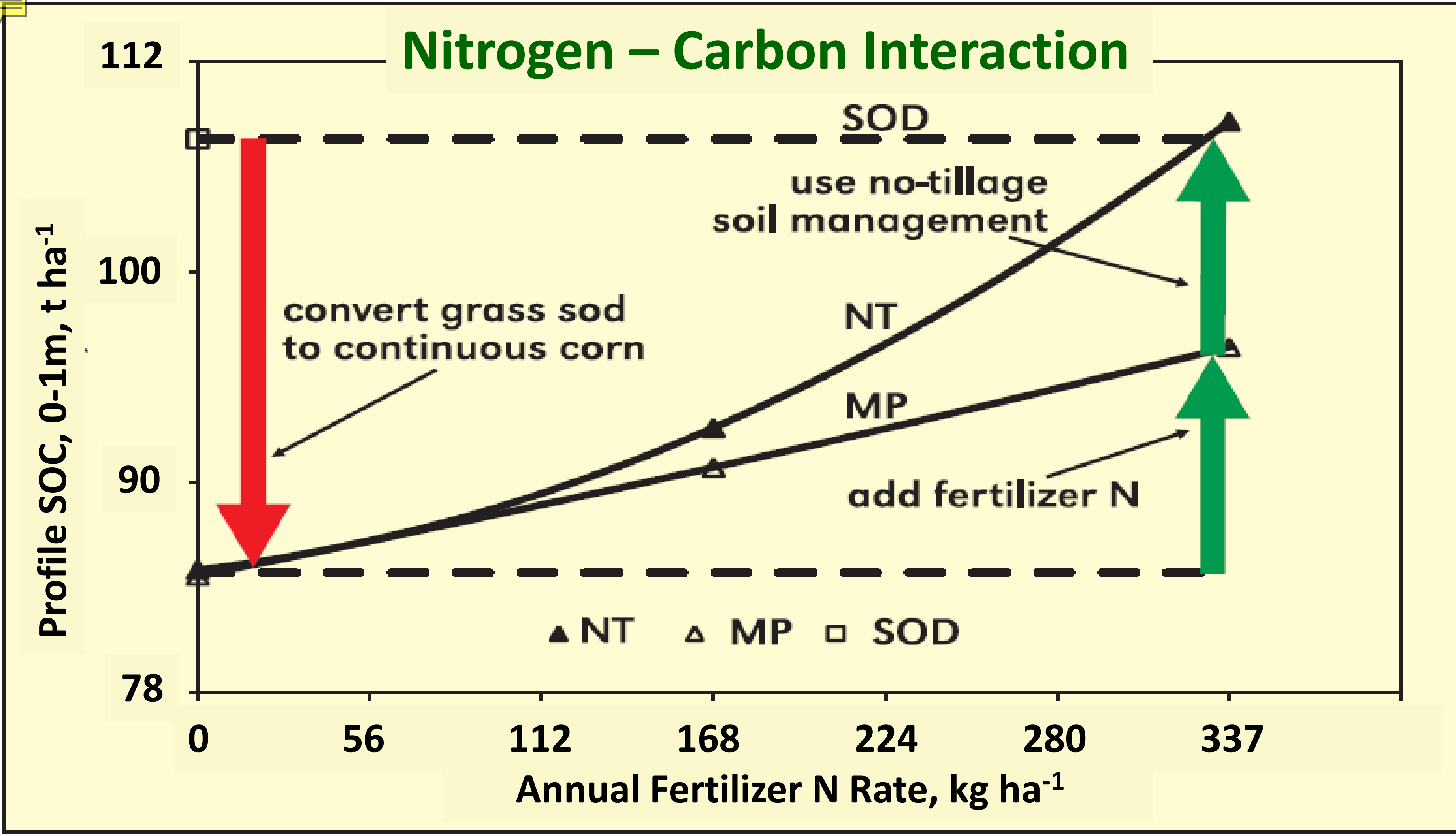
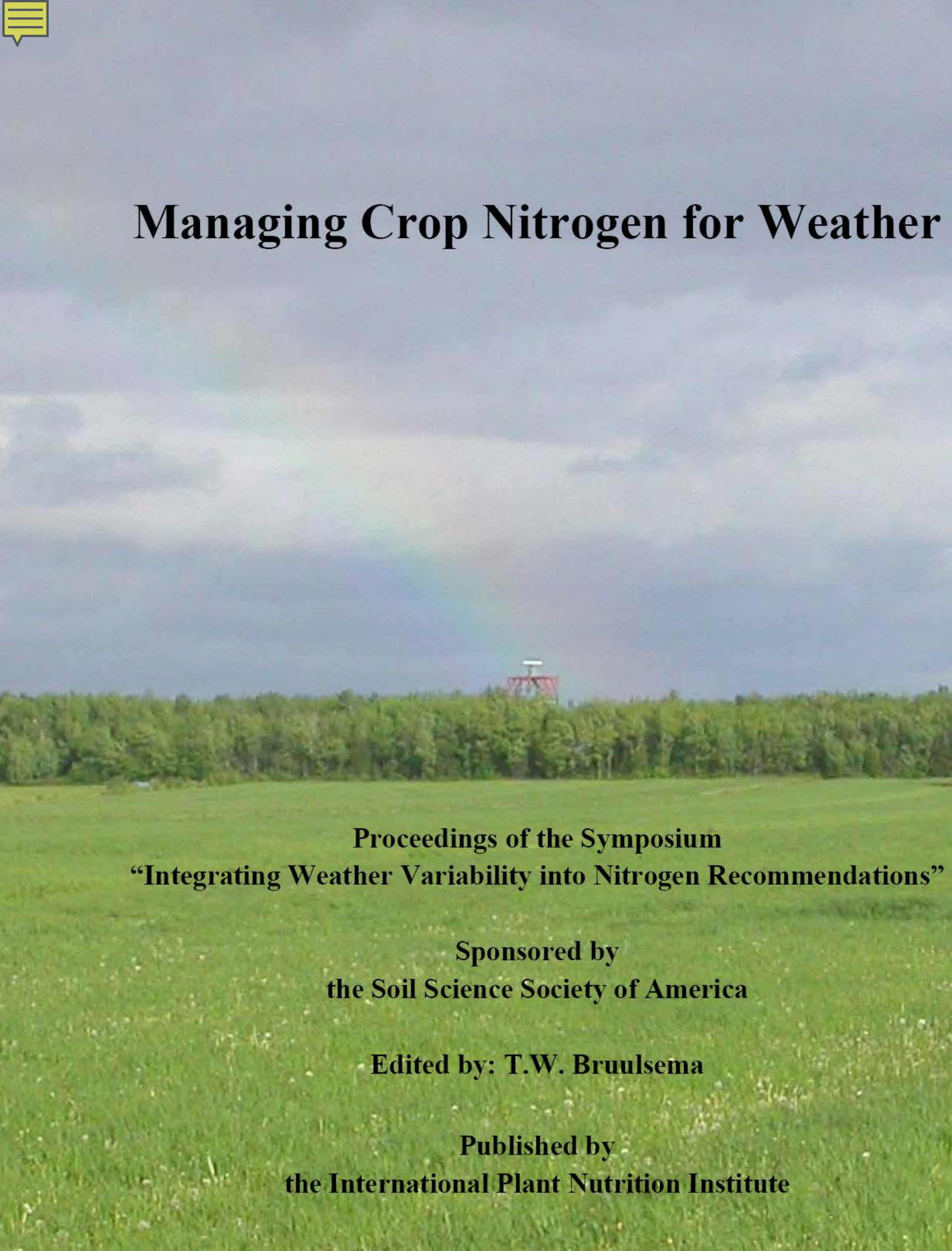
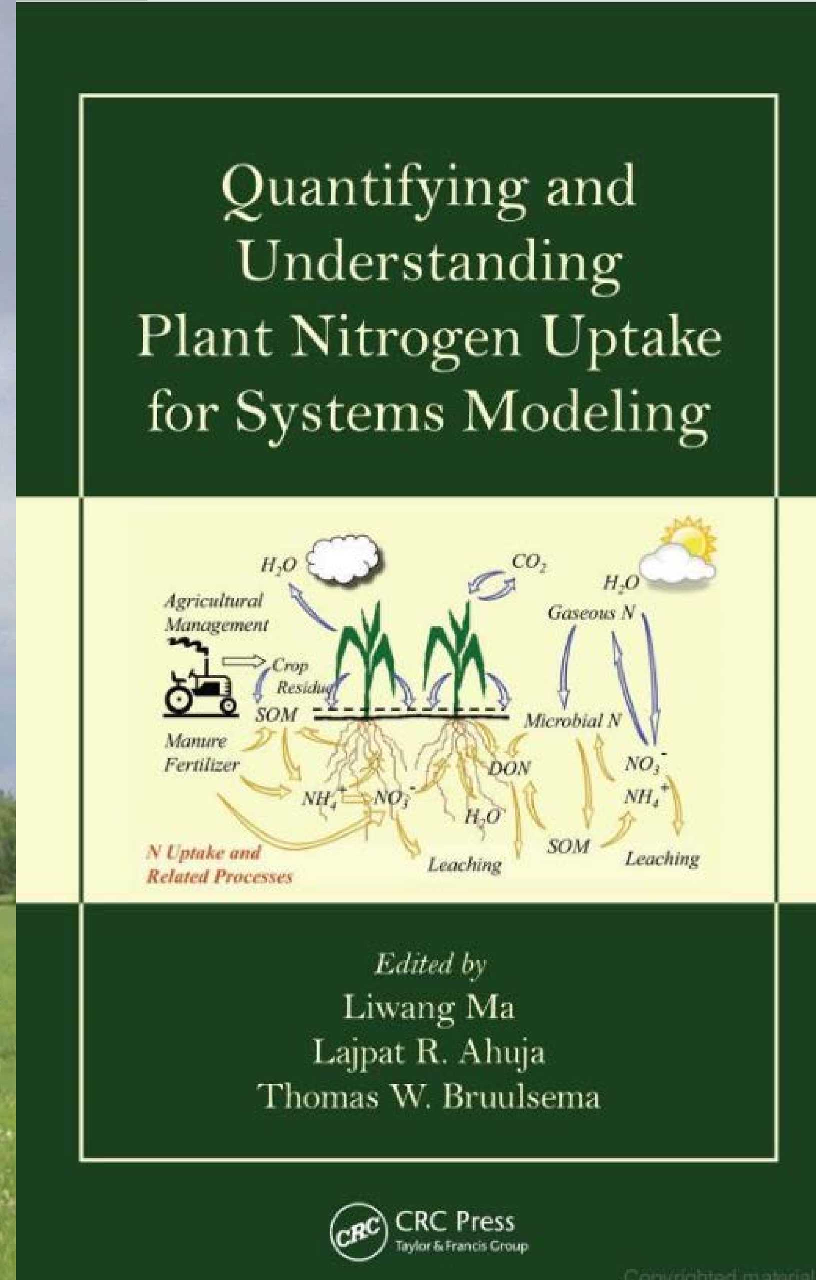


Figure 5. The impact of fertilizer N on total profile SOC levels found after 39 years of cropping to continuous corn with a winter cereal cover crop.

Grove et al. 2009. Better Crops with Plant Food 93(4):6-8 – Kentucky, USA


Managing Crop Nitrogen for Weather
Proceedings of the Symposium
"Integrating Weather Variability into Nitrogen Recommendations"
Sponsored by
the Soil Science Society of America
Edited by: T.W. Bruulsema
Published by
the International Plant Nutrition Institute


Quantifying and Understanding Plant Nitrogen Uptake for Systems Modeling
H_2O
CO_2
H_2O
Agricultural Management
Gaseous N
Crop Residue
SOM
Microbial N
Manure Fertilizer
DON
NO_3^-
NH_4^+
NO_3^-
NH_4^+
H_2O
N Uptake and Related Processes
Leaching
SOM
Leaching
Edited by
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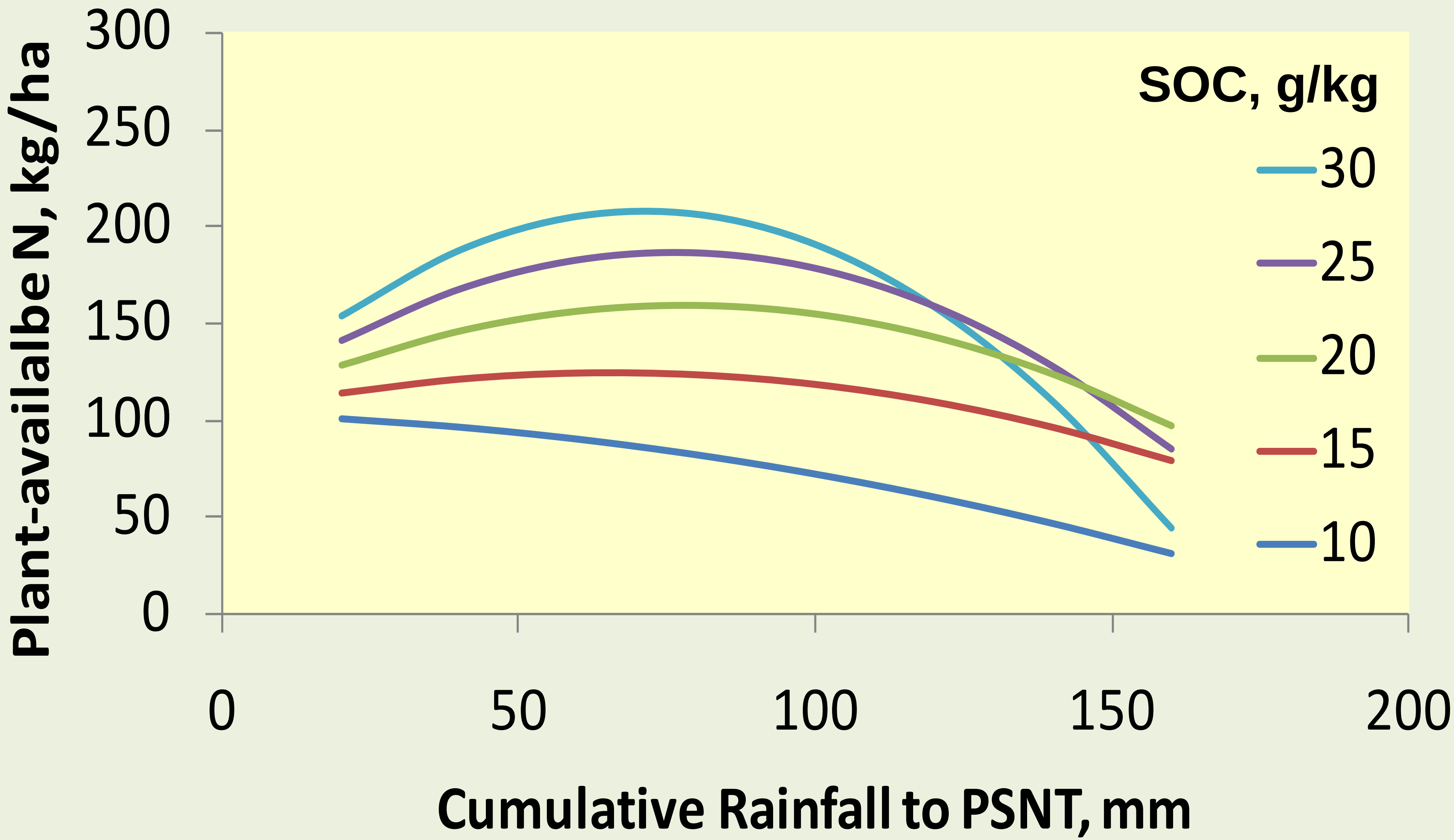
Soil Organic C, Rain and Plant-available N



B.D. Kay, A.A. Mahboubi, E.G. Beauchamp, and R.S. Dharmakeerthi. 2006. Soil Sci. Soc. Am. J. 70:1210–1221. (adapted)

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Right Source

- **Form:** rising [CO_2] and implications for NH_4^+ versus NO_3^-
- Plant dependence on NH_4^+ versus NO_3^- changes with [CO_2] (Bloom et al, 2002; Epstein and Bloom, 2005)
- If preference for NH_4^+ increases, greater crop response may be expected from:
  - nitrification inhibitors (nitrapyrin, dicyandiamide)
  - urease inhibitors, polymer coated urea, later time of application
- Adapting to higher [CO_2] could lead to less nitrate leaching

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Right Rate

- A function of crop demand, soil supply, and soil losses
  - All 3 affected by weather
- Soil-crop system models using real-time data (e.g. Cornell University's Adapt-N), or crop sensors, can help adapt to weather
- Adapting N rates to weather:
  - More variable crop yield and rainfall-related N losses may make it more important.
  - Cover crop response to surplus N may make it less important.

Right Time

- If winter rains increase in amount and intensity, fall application may be even less effective.
- Split applications allow more decision points to help deal with variability in crop yield potential and loss mechanisms.

Right Place

- Greater benefits to subsurface placement with conservation tillage?
- If winter rains are more frequent and intense, more need for varying N rate by landscape position?
- Crop sensors for variable rate?

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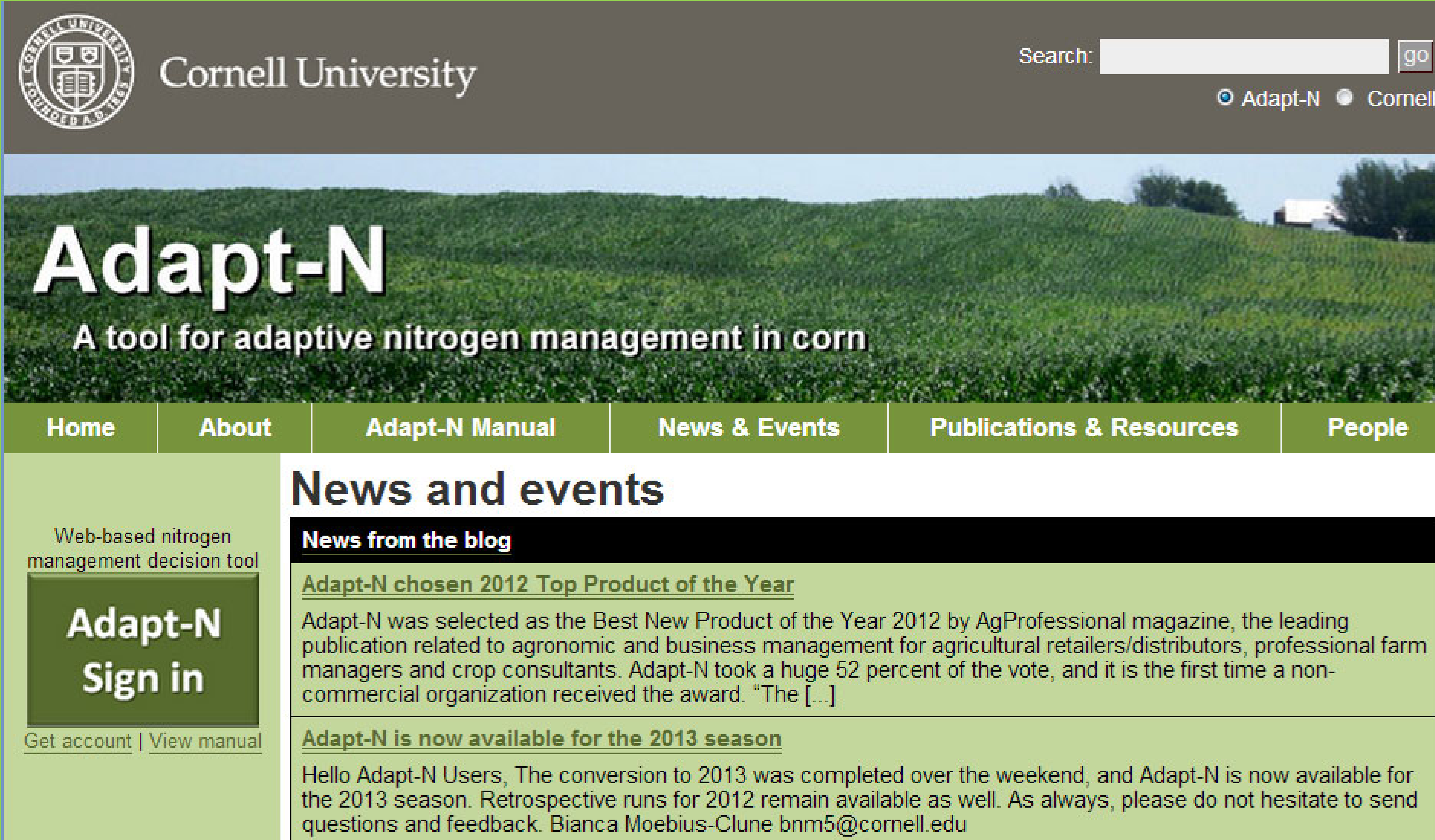

Top Product of the Year, 2012 – Ag Professional Magazine

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Summary – Nitrogen Technologies

1. 4R technologies and practices are available.
2. Agri-service providers are making improvements through voluntary measures by adopting 4R.
3. 4R research needs to focus on validating sustainability performance of specific 4R practices

4R nutrient stewardship

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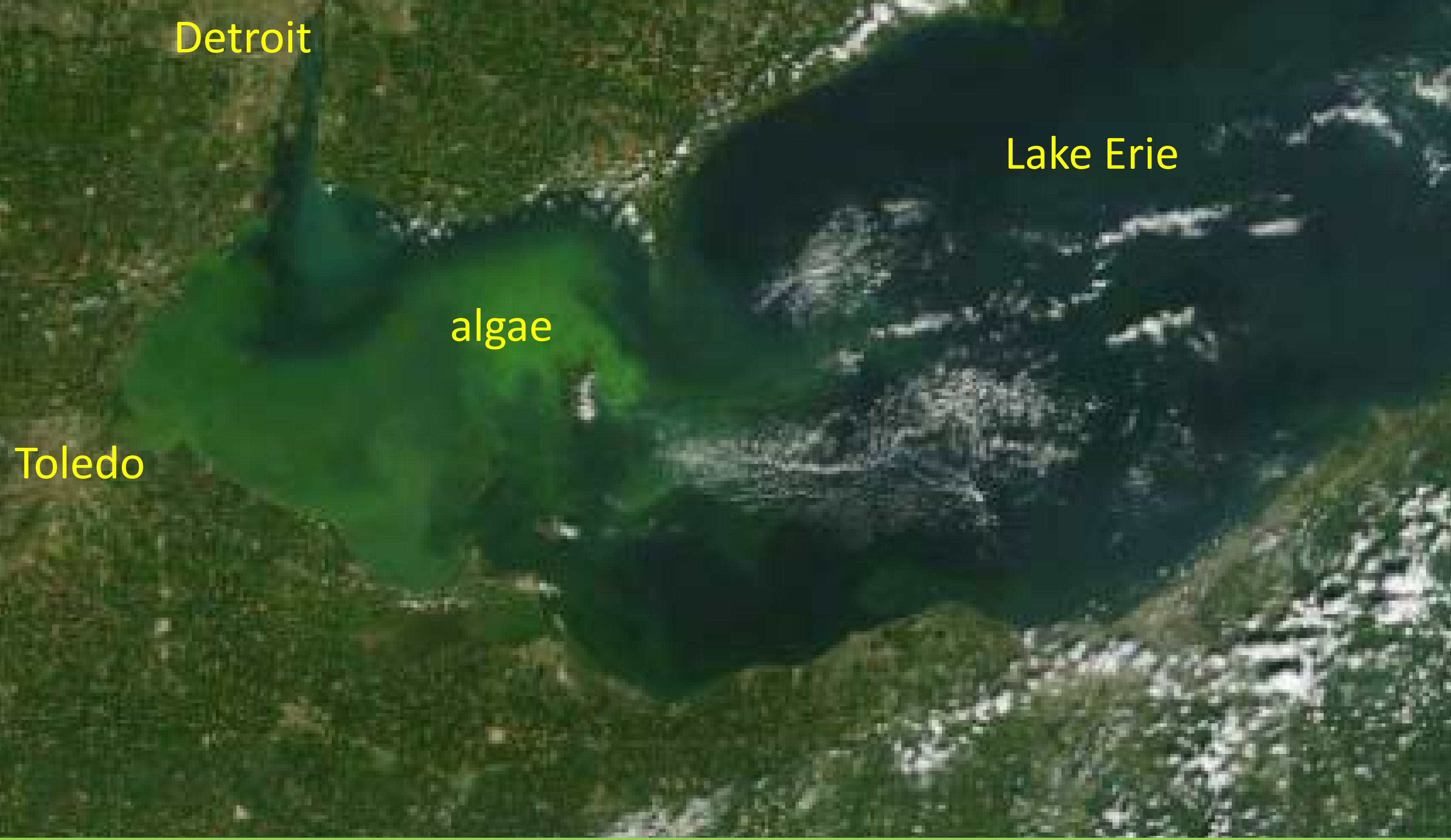
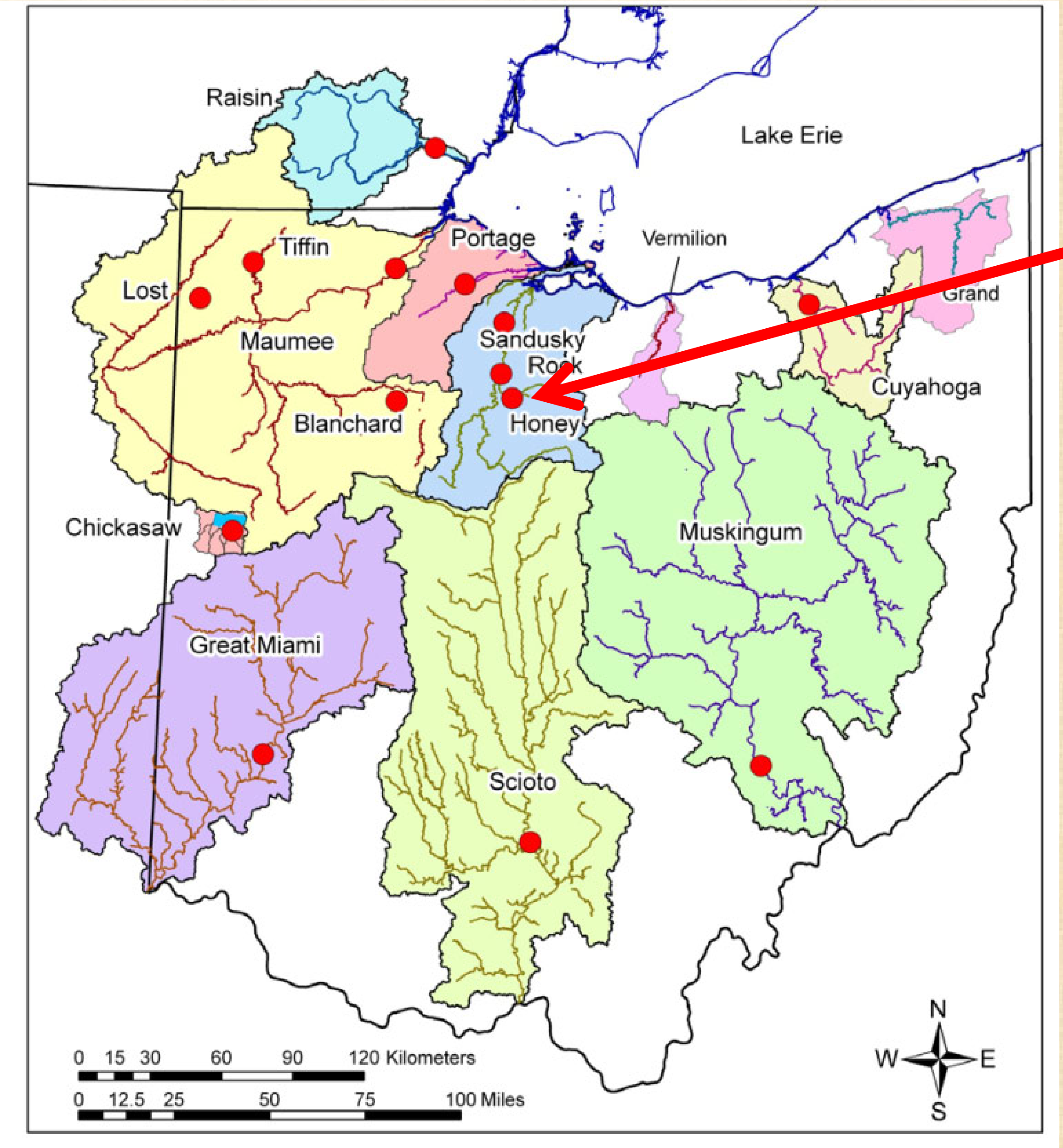
Phosphorus Issues



An aerial photo of a Lake Erie algal bloom on August 19, 2011.

Source: www.glerl.noaa.gov/res/Centers/HABS/western_lake_erie

The Heidelberg University Tributary Loading Program



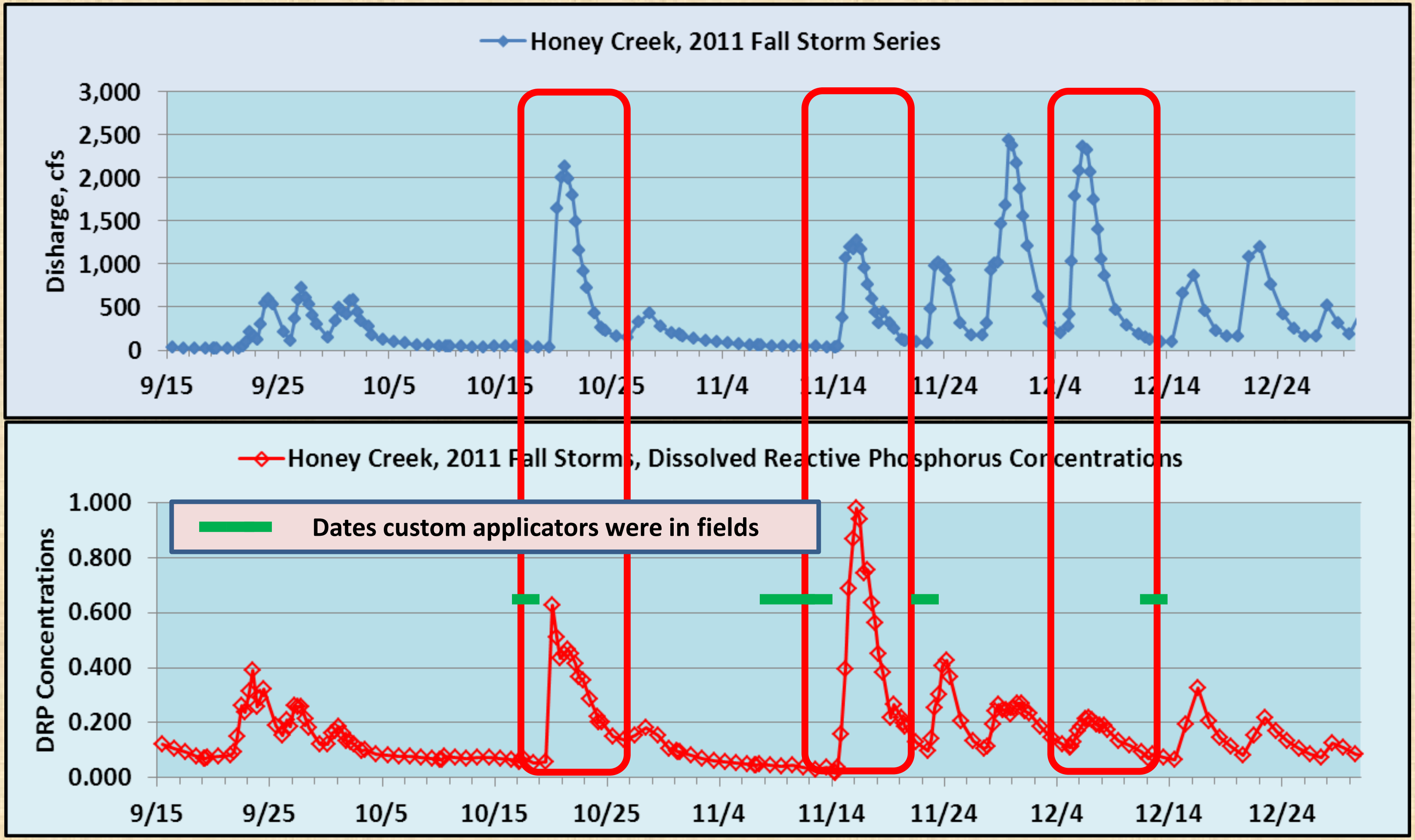
Focus on the Honey Creek Watershed that drains into the Sandusky River.

95,000 acres

~80% row crops

Dr. David Baker

Fall 2011 storms, Honey Creek, Ohio



IPNI INSIGHTS
INTERNATIONAL PLANT NUTRITION INSTITUTE

December 2012

Reducing Loss of Fertilizer Phosphorus to Lake Erie with the 4Rs

Algal blooms in Lake Erie have been getting worse in the past few years. Phosphorus (P) has often been considered the nutrient controlling such blooms. The loads of dissolved P in the rivers draining into Lake Erie vary greatly year-to-year, but higher loads have become more frequent in recent years than in the mid-1990s. Agriculture is one of several sources of dissolved P.

This article outlines how crop producers in the Lake Erie watershed can reduce losses of P by adopting a 4R Nutrient Stewardship approach to guide their fertilizer application practices.

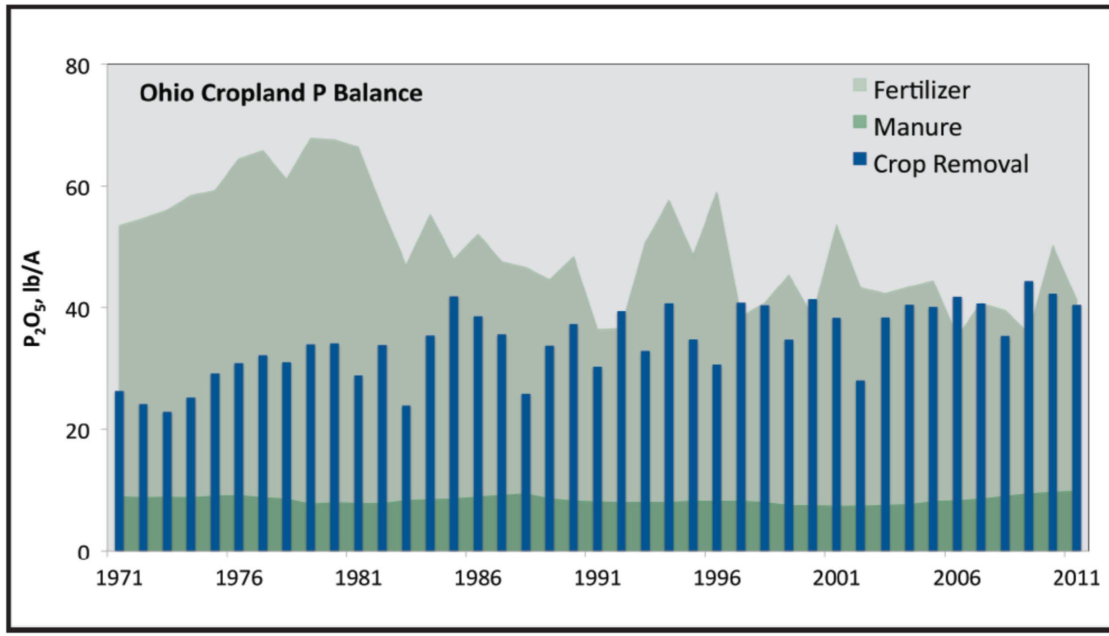


Figure 2. Phosphorus balance trend over time for Ohio cropland. *2011 fertilizer estimated.

Background

Much of the cropland of the Lake Erie watershed is found in Ohio, with smaller areas in Indiana, Michigan and Ontario

Practice	Advantages	Limitations
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 some 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

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Ohio

Industry Partnerships

- Outreach at expos and meetings – TFI, TNC, OH ABA
- October 2011 – adoption of 4Rs by OH Dept. of Ag, OH EPA, OH DNR
- March 2012 – final report naming 4Rs Foundation of Nutrient Management
- June 2012 – Healthy Lake Erie Fund, $3M – to help implement 4Rs
- Developing 4R service provider recognition program

4R nutrient stewardship

Learn more about 4R nutrient stewardship at www.nutrientstewardship.com.

KEEP PHOSPHORUS IN YOUR FIELD

THE ISSUE

An aerial photo of a Lake Erie algal bloom on August 19, 2011.
Source: www.glerl.noaa.gov/res/Centers/HABS/western_lake_erie

Historically, commercial fertilizer phosphorus was considered immobile on or in the soil. However, new data suggests fertilizer phosphorus left on the surface when followed by heavy rainfall can also be a major source of phosphorus loading. Research suggests current agricultural practices within the Western Lake Erie Basin contribute to the growing algal crisis, with more than 50 percent of the phosphorus load potentially attributed to agriculture.

THE ACTION

4R nutrient stewardship provides a framework to achieve cropping system goals – increased production, increased farmer profitability, and enhanced environmental protection. To achieve those goals the 4Rs utilize fertilizer best management practices that address the Right Nutrient Source, at the Right Rate, the Right Time, and in the Right Place. The 4R nutrient stewardship principles are the same globally, but how they are used locally varies depending on field and site specific characteristics such as soil, cropping system, management techniques and climate. **The following describes the principles generally, and their specific application to lake-friendly P management.**

RIGHT SOURCE: Ensure a balanced supply of each of the essential nutrients in plant available forms, utilizing all available sources. **Specifically, choose sources of P that can be placed in the soil.**

RIGHT RATE: Assess and make decisions based on soil nutrient supply and plant demand. **Specifically, soil test and determine the P rate appropriate to the crop.**

RIGHT TIME: Assess and make decisions based on the dynamics of crop uptake, soil supply, loss risks, and field operation logistics. **Specifically, avoid applying over snow or frozen soil during mid-winter, and consider replacing fall applications with spring applications where possible.**

RIGHT PLACE: Place nutrients where they are accessible to crops, addressing root-soil dynamics, and managing spatial variability within the field. **Specifically, place P in the soil for each crop, in ways that attain the goals of conservation tillage.**

There is no *single* practice to solve the problem. *Each farm* has different circumstances such as soil type, surface drainage, tile drainage, soil test levels, and tillage programs, which can be modified to make a difference. *Farmers can play a critical role in reducing the algal blooms in Lake Erie and we all need to do our part.*

SUGGESTED PRACTICES TO REDUCE PHOSPHORUS TRANSPORTATION INTO LAKE ERIE

- Inject or incorporate phosphorus when ever possible.
- For low-lying fields that are prone to flooding, delay application to just before planting, and either incorporate, band-place, or inject.
- Avoid spreading phosphorus near tile stand pipes or surface drains.
- Utilize cover crops to improve soil health and increase water holding capacity thereby reducing surface run-off.
- Include starter phosphorus or row fertilizer phosphorus where ever practical.
- Schedule phosphorus broadcast applications when shallow tillage is possible for conventional/reduced tillage programs.
- Schedule phosphorus applications for no-till programs as close to crop utilization as practical.
- Do not schedule phosphorus applications just prior to heavy rainfall.
- Do not schedule phosphorus applications when soils are frozen during mid-winter.
- Do not schedule phosphorus applications when soils are snow covered.
- Soil test to determine nutrient requirements for the next crop.
- Keep fertilizer phosphorus out of ditches, streams and waterways while making application.
- Consider all nutrient sources available to the crop when deciding on how much to apply.

r4 nutrient stewardship

Farming4RWatershed

AgriINNOVATIONS: Supporting farmers and communities with practical tools to implement Beneficial Management Practices that protect water quality and grow agriculture.

FARMING 4R FUTURE
Stewardship Today, to Feed Tomorrow

4R Nutrient Stewardship encompasses:

Right Source | Right Rate | Right Time | Right Place

AgriINNOVATIONS | Canadian Fertilizer Institute / Institut Canadien des Engrais | Ontario Centres of Excellence — Where Next Happens | OFA | Grand River Conservation Authority | the water Institute, University of Waterloo | Region of Waterloo

farming4Rfuture.ca

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World Phosphate Rock Reserves and Resources

Country	Current Production	Reserves	Reserve Life	Resources
	Mt		Years	Mt
USA	29	1,800	62	49,000
China	53	3,700	70	16,800
Morocco	25	51,000	2,040	170,000
World	160	60,000	375	290,000

"No matter how much phosphate rock exists, it is a non-renewable resource"
IFDC, 2010

Summary – P issues

- 4R Nutrient Stewardship provides a framework to communicate sustainable management
- 4R management of P requires a focus on Right Place
  - In the soil, not on the soil
  - Right Time?
- Phosphate rock depletion not imminent
  - Recycling processes need to consider principles of "right source"

nutrient stewardship

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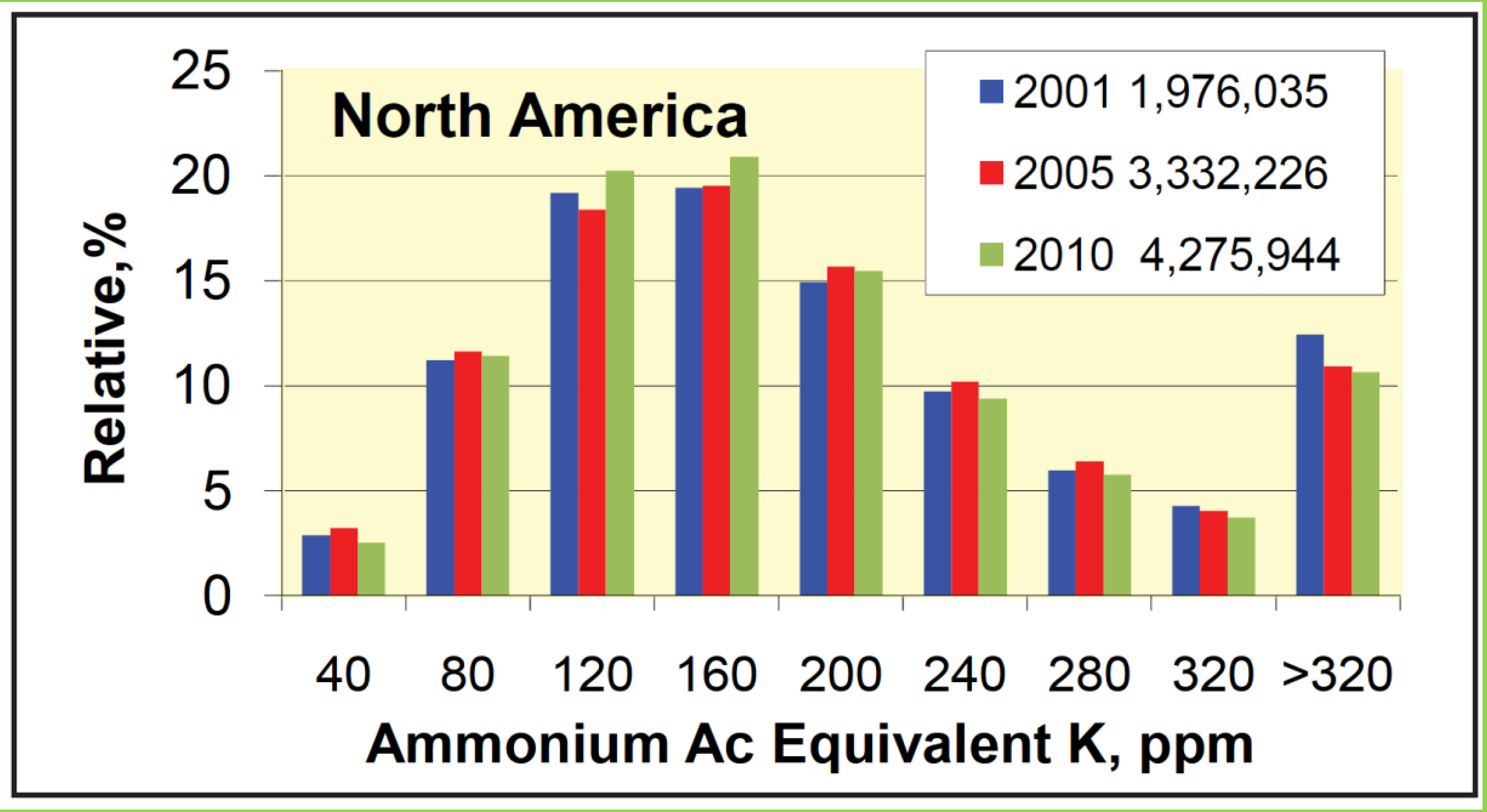
Soil Potassium Fertility

4R PLANT NUTRITION

Soil test K frequency distribution, 2001-2010



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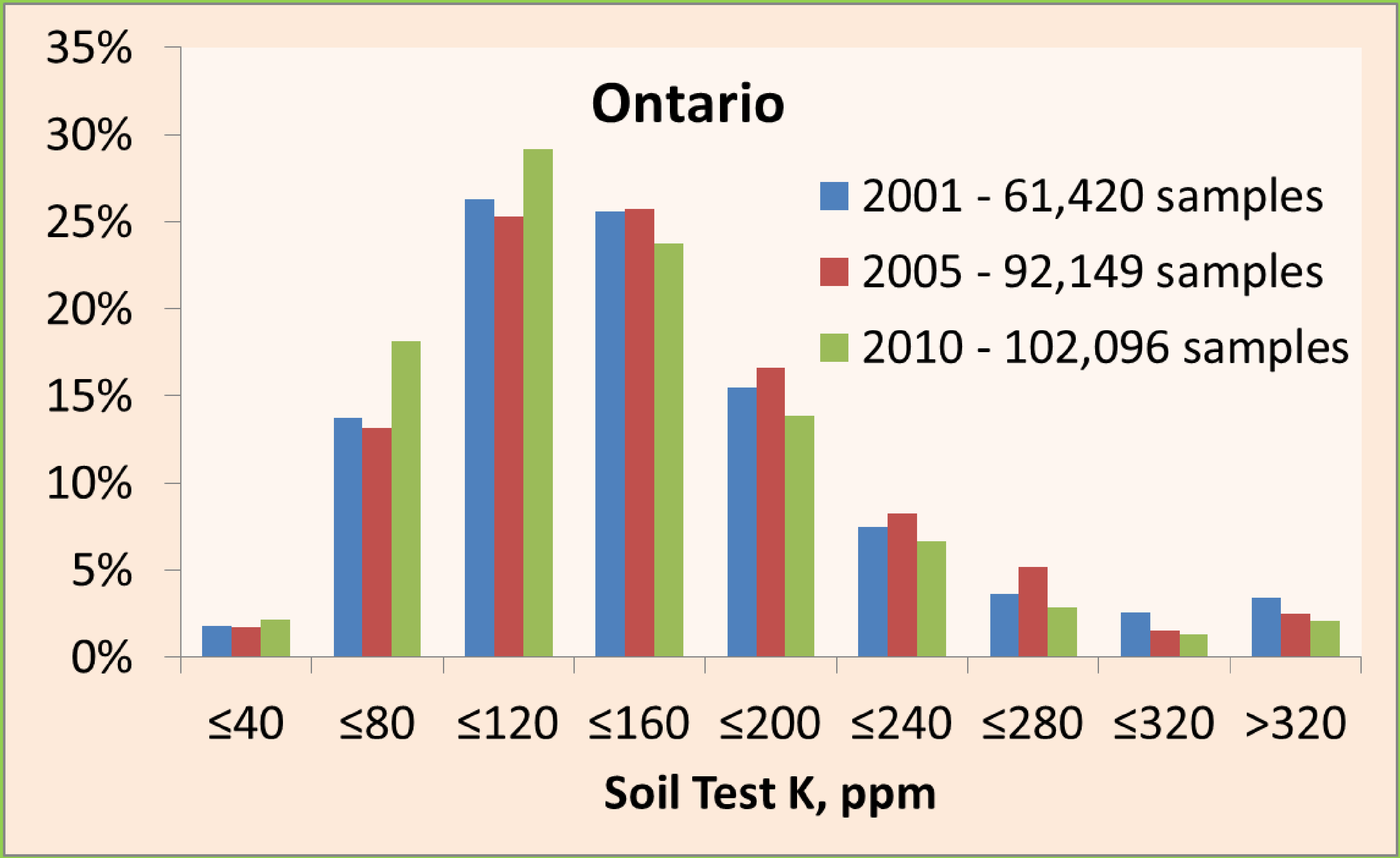
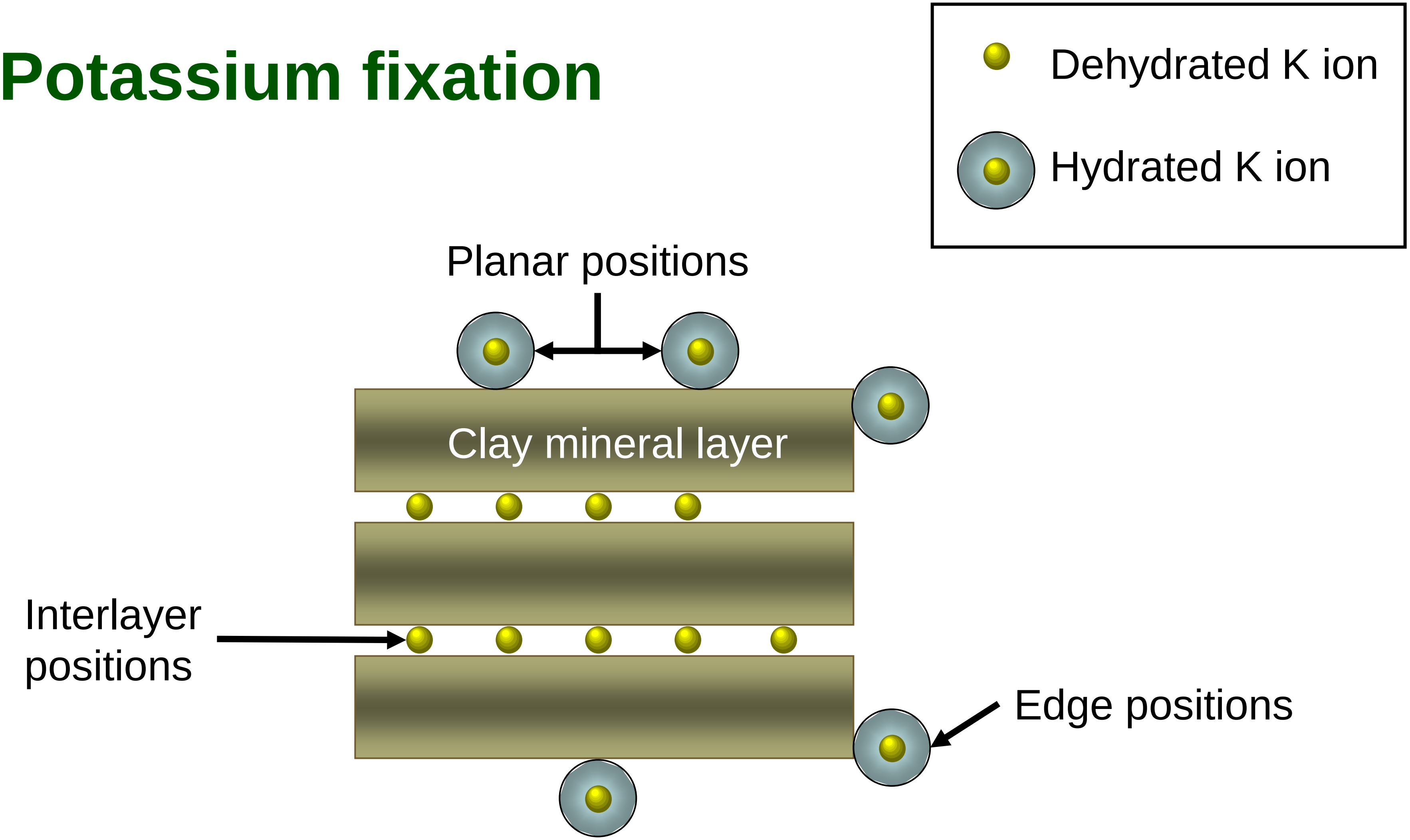
Soil test K frequency distribution, 2001-2010



Median STK declined from 133 to 121; cumulative K_2O deficit 168 lb/A

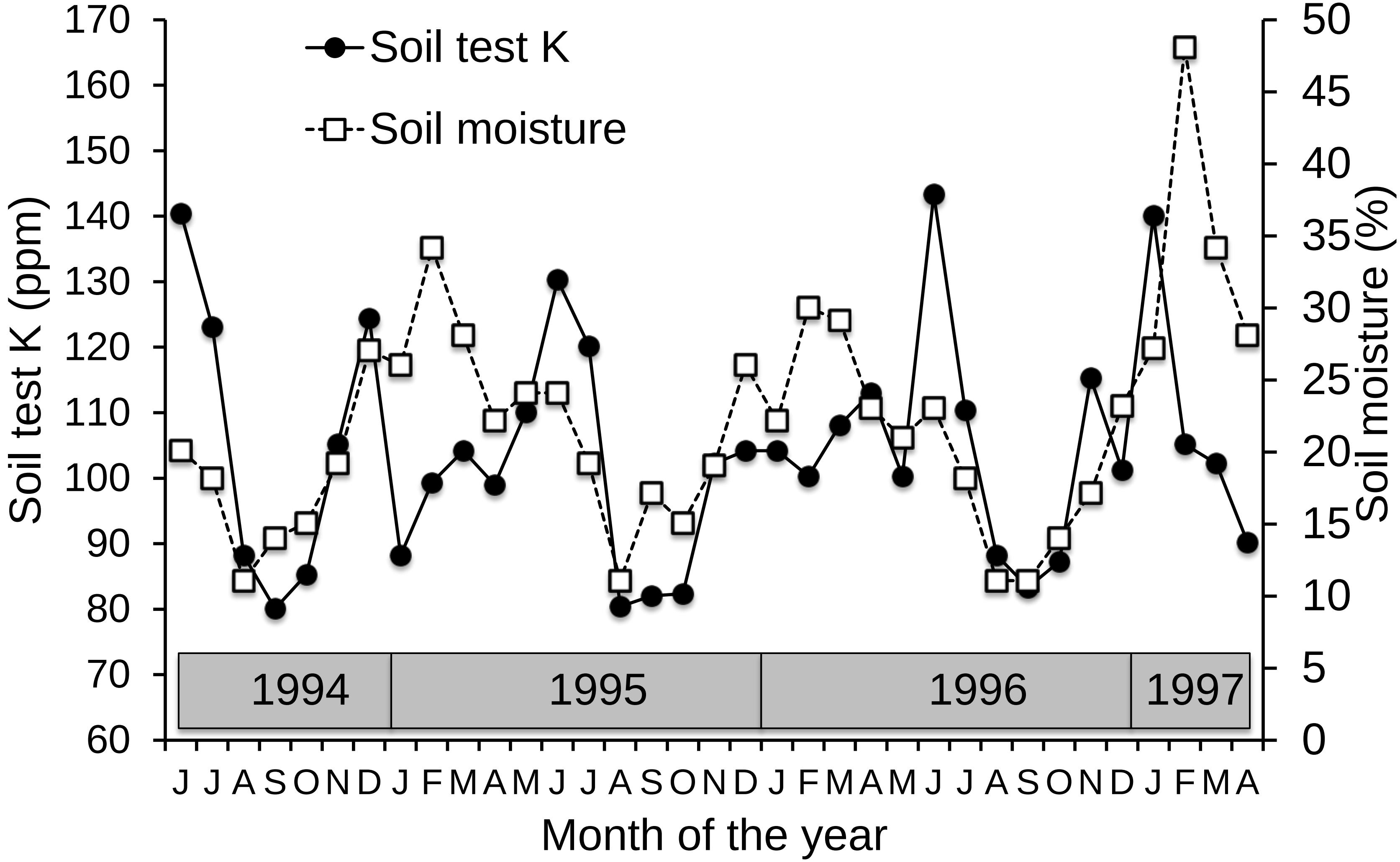
= 14 lb/A of K_2O deficit to lower STK by 1 ppm

Potassium fixation



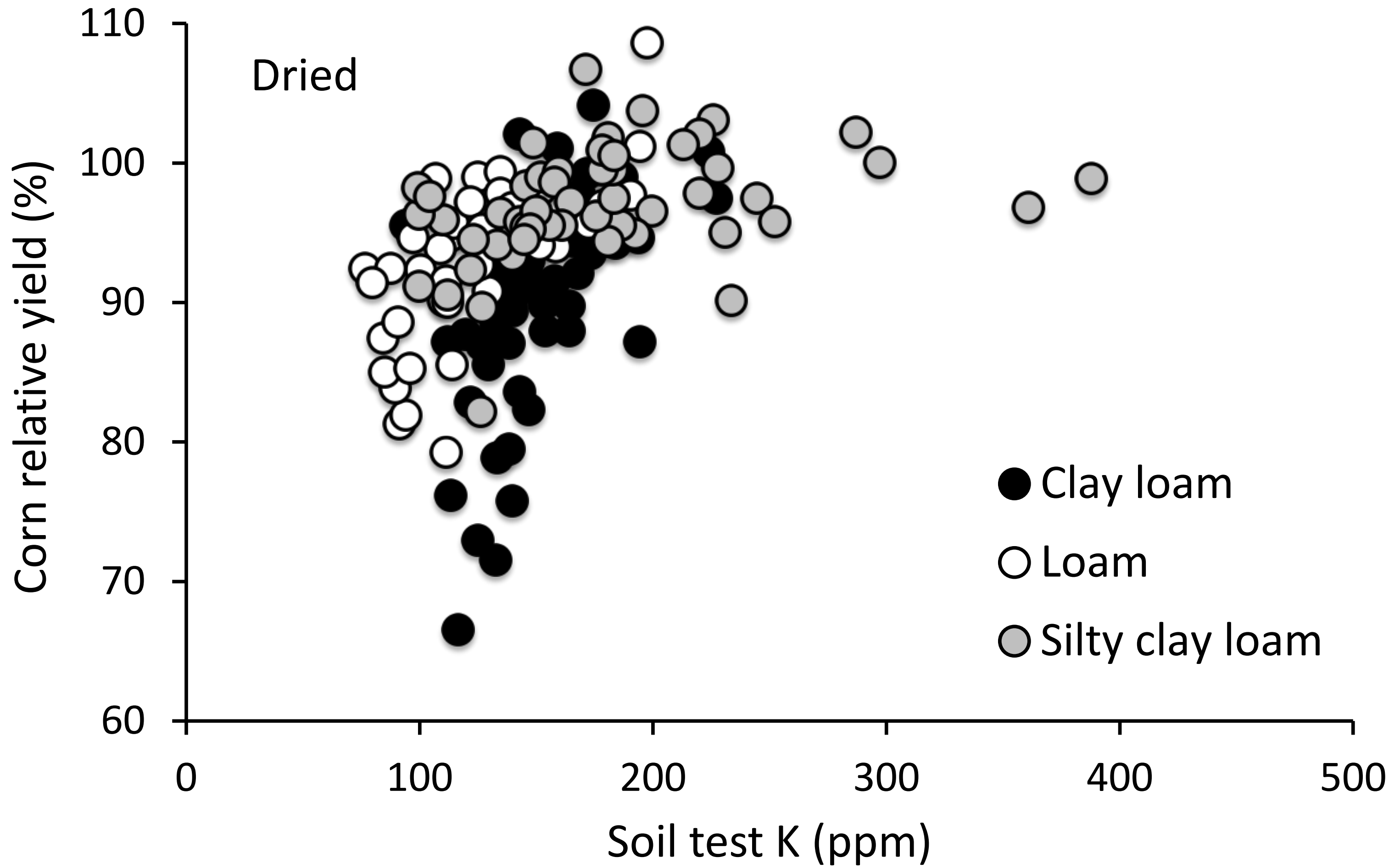
Havlin et al., 1999

Seasonal variation in soil test K



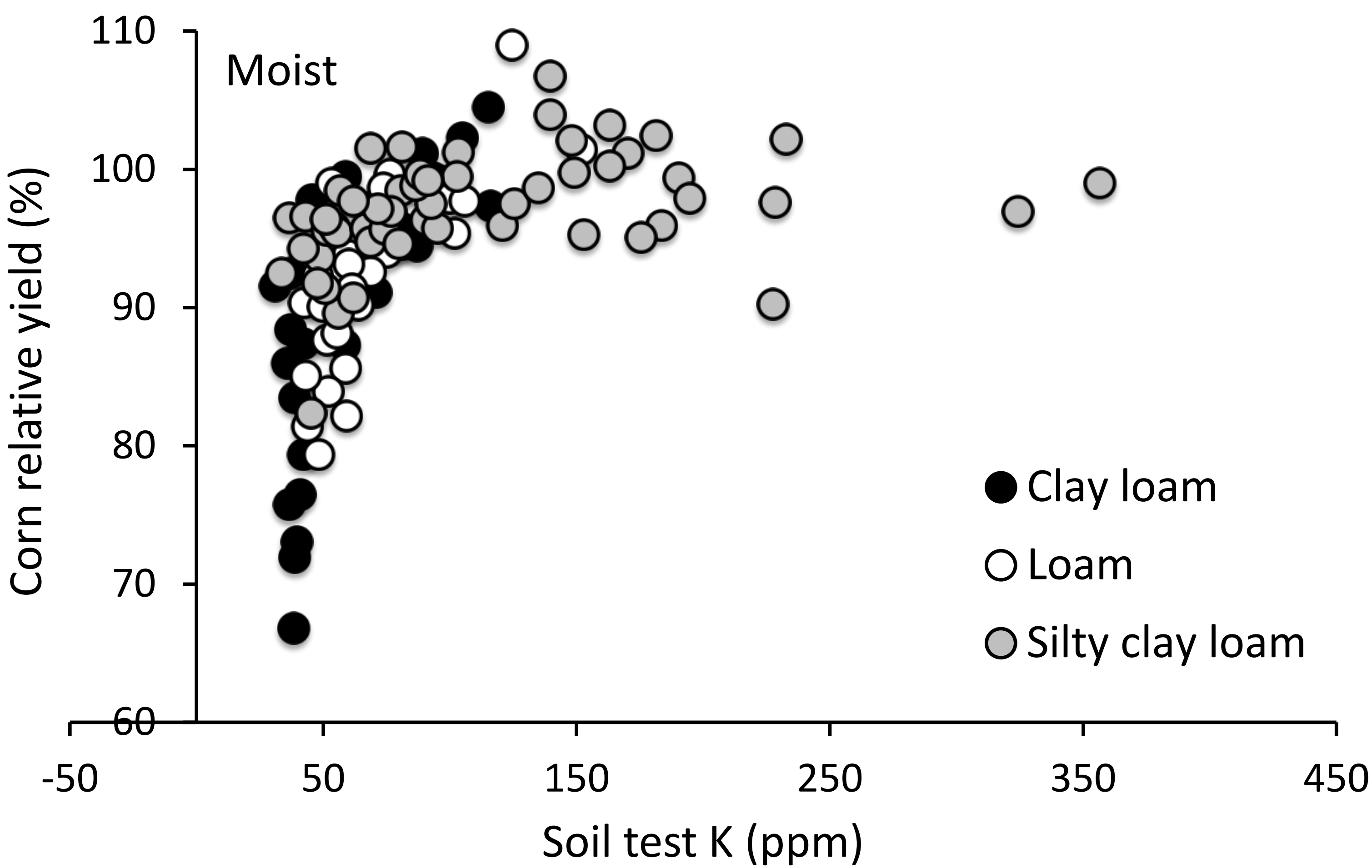
Ebelhar et al. 1997. Personal communication. Soil test values are ammonium acetate extractable.

Iowa corn yield response vs. soil test K – dried soils



Barbagelata and Mallarino. 2005. Personal communication.

Iowa corn yield response vs. soil test K – moist soils



Barbagelata and Mallarino. 2005. Personal communication.

http://info.ipni.net/KFellow.

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Summary

- Soil test K levels are declining in many states in the Midwest, but declines are not explained by mass balance
- The role of fluctuating soil water as a cause of variability in soil test K—and plant availability of K—needs further investigation
- Scientific research opportunities:
  - New soil test based on field-moist sampling?
  - Exchange resins?
  - Plant analysis?
  - Crop sensing?

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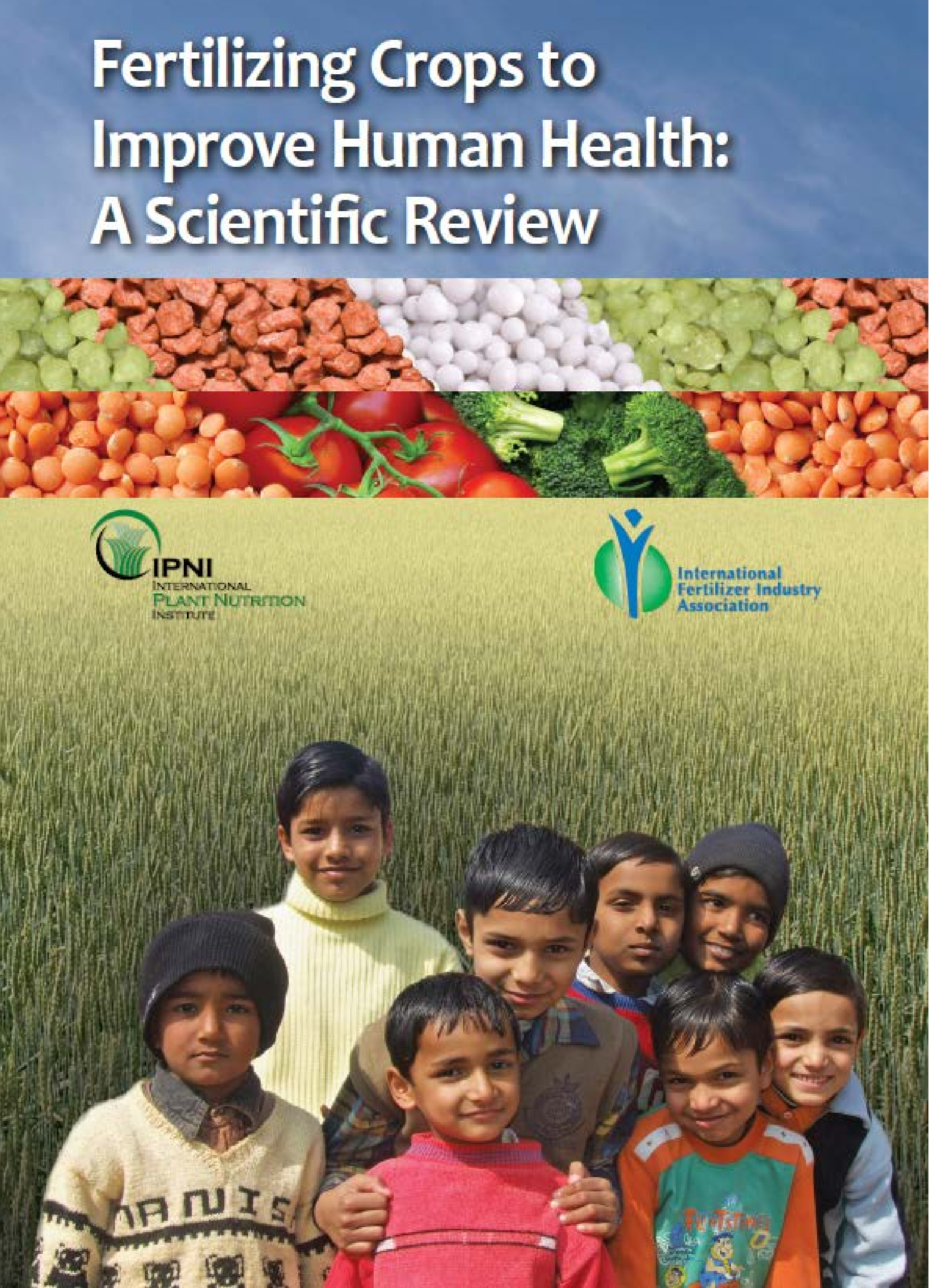
Fertilizing for Human Health



Topics

- Food security
- Micronutrient malnutrition
- Functional foods
- Proteins, oils and carbohydrates
- Plant disease
- Farming systems
- Remediation of soil contaminated with radionuclides
- 11 chapters

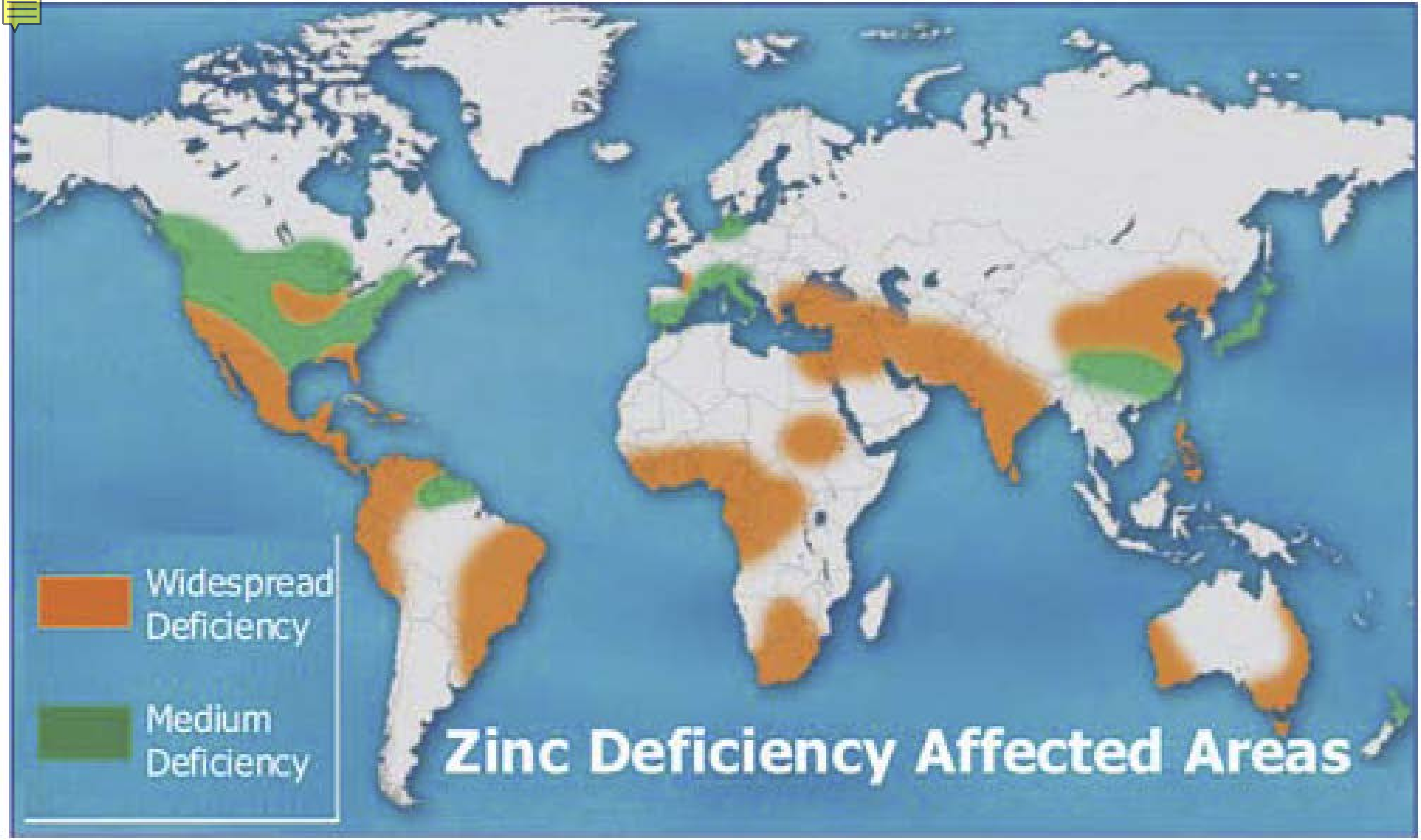


Figure 2: Global distribution of Zn-deficiency affected regions (Alloway, 2007)

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Ontario, Canada, 1989…

A growth-limiting, mild zinc-deficiency syndrome in some Southern Ontario boys with low height percentiles[1–3]

Rosalind S Gibson, Patricia D Smit Vanderkooy, A Carolyn MacDonald, Anne Goldman, Bruce A Ryan, and Margaret Berry

ABSTRACT A double-blind, pair-matched 12-mo study examined the effects of a zinc supplement (10 mg Zn/d as $ZnSO_4$) on linear growth, taste acuity, attention span, biochemical indices, and energy intakes of 60 boys (aged 5–7 y) with height ≤ 15th and midparent height > 25th percentiles. Boys with initial hair Zn < 1.68 μmol/g ($n = 16$) had a lower mean (±SD) weight-for-age Z score (−0.44 ± 0.59 vs −0.08 ± 0.84), and a higher median recognition threshold for salt (15 vs 7.5 mmol; $p = 0.02$) than those with hair Zn > 1.68 μmol/g. Only boys with hair Zn < 1.68 μmol/g responded to the Zn supplement with a higher mean change in height-for-age Z score ($p < 0.05$); taste acuity, energy intakes, and attention span were unaffected. A growth-limiting Zn deficiency syndrome exists in boys with low height percentiles, hair Zn levels < 1.68 μmol/g, and impaired taste acuity. *Am J Clin Nutr* 1989;49:1266–73.

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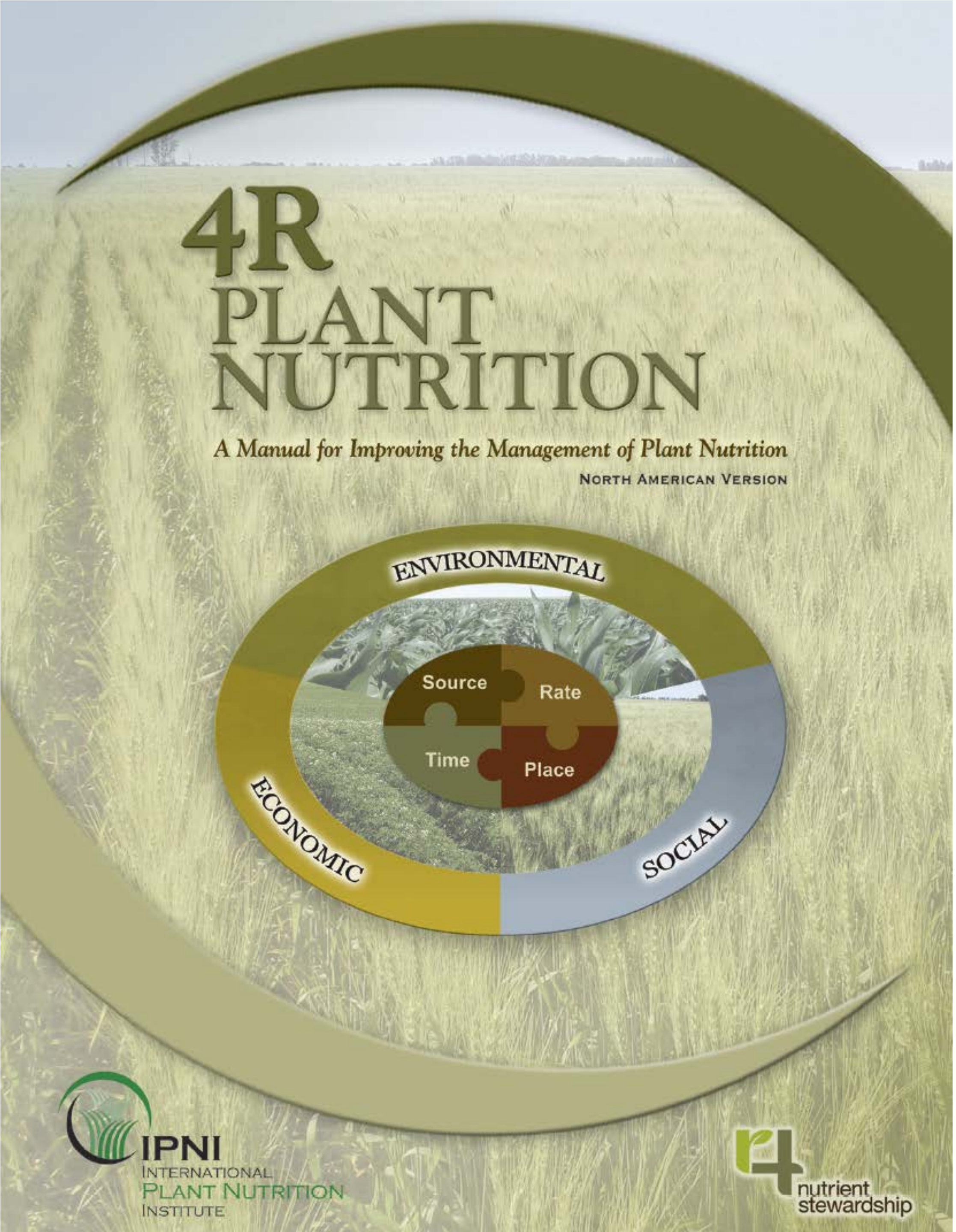
Summary

Research supporting 4R Nutrient Stewardship has great potential to improve sustainability through:

- Addressing nitrogen-climate interactions
  - impact of N losses on climate change
  - impact of changing climate on N management
- Mitigating phosphorus issues
  - impacts on water quality, and resource depletion
- Better assessment of soil potassium fertility
- Fertilizing for crop qualities to improve human health



Thank you

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