IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Synergy in Science:
Partnering for Solutions
2015 Annual Meeting | Nov. 15-18 | Minneapolis, MN
with the Entomological Society of America
American Society of Agronomy | Crop Science Society of America | Soil Science Society of America

Impact Metrics for Crop Nutrition Sustainability in North America

4 nutrient stewardship

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International Plant Nutrition Institute

Agrium Inc.

Arab Potash Company

BHP Billiton

CF Industries Holdings, Inc.

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International Raw Materials LTD

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LUXI Fertilizer Industry Group

The Mosaic Company

OCP S.A.

PhosAgro

PotashCorp

Qatar Fertiliser Company (QAFCO)

Shell Sulphur Solutions

Simplot

Sinofert Holdings Limited

SQM

Toros Tarım

Uralchem, JSC

Uralkali

The **International Plant Nutrition Institute** is supported by leading fertilizer manufacturers.

Formed in 2007 from the Potash & Phosphate Institute, its mission is to develop and promote science for responsible management of crop nutrition

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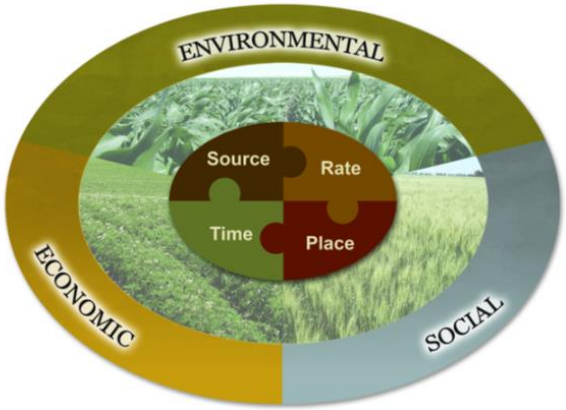
[DRAFT] Nutrient Stewardship Metrics for Sustainable Crop Nutrition



Enablers (process metrics)

- Extension & professionals
- Infrastructure
- Research & innovation
- Stakeholder engagement

Actions (adoption metrics)

[Require regional definition of 4R]

- Cropland area under 4R (at various levels)
- Participation in programs
- Equity of adoption (gender, scale, etc.)

Outcomes (impact metrics)

1. **Farmland productivity**
2. **Soil health**
3. **Nutrient use efficiency**
4. Water quality
5. Air quality
6. Greenhouse gases
7. Food & nutrition security
8. Biodiversity
9. Economic value

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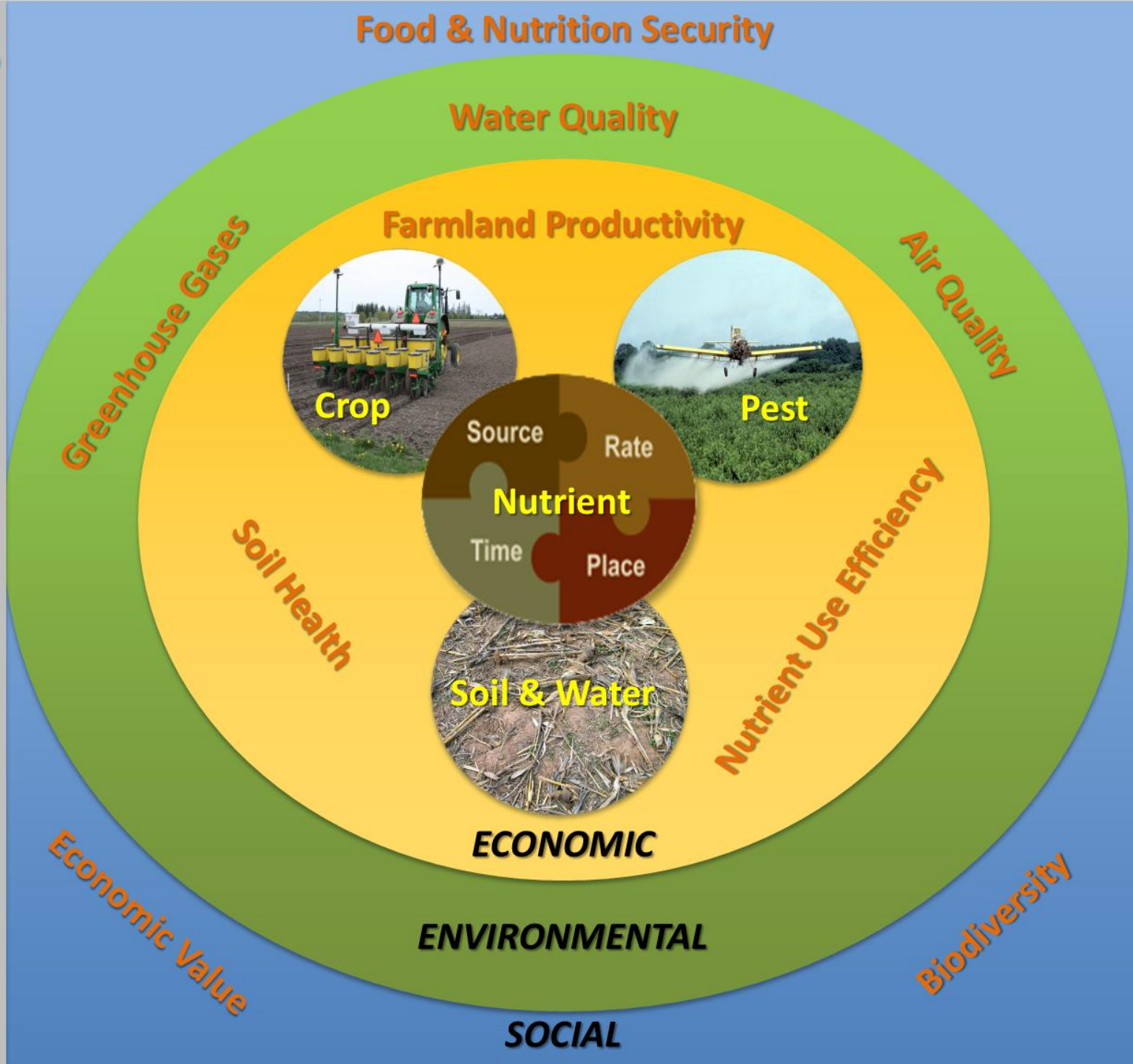
OUTCOMES

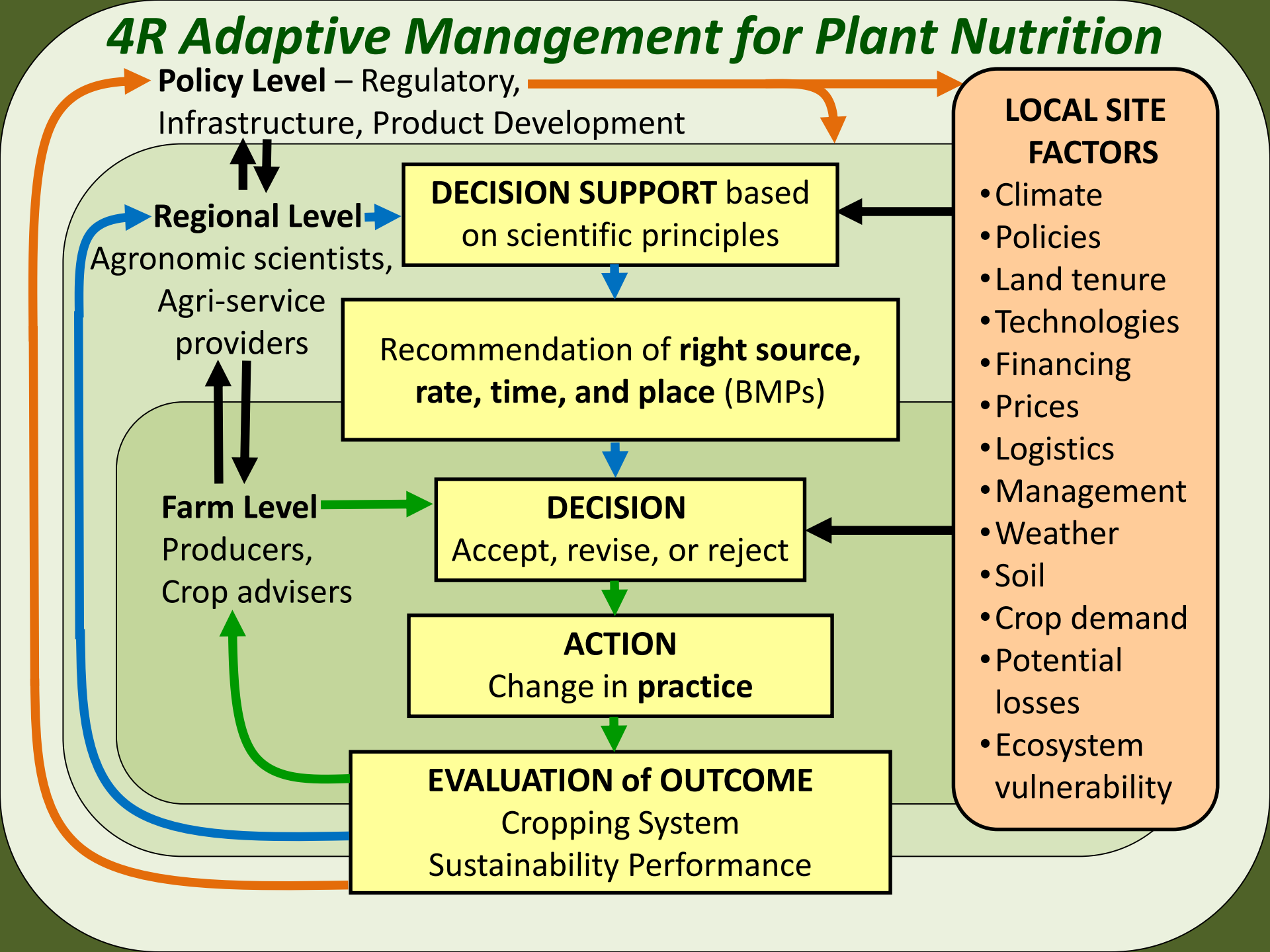
of

4 nutrient stewardship

are influenced by **crop and pest management,** and by **soil and water conservation practices** in the context of changing **weather and climate.**



4R Adaptive Management for Plant Nutrition



GRI guidelines for metrics

- Metric definitions
  - Relevance
  - Linkage
  - Stakeholder interests
  - Compilation
  - Data Sources
  - Quantification
  - Data Interval
  - Geography
  - Targets
  - References
- ‘Materiality’
  - Focus on topics material to the business and to its key stakeholders

The Economic Three

- **Farmland productivity, soil health and NUE**
- Measurable at the farm & field scale
- More closely related to 4R practices than the remaining six
  - But influenced by other agronomic practices as well
- Independent, but inter-related
  - Optimum NUE maintains soil health
  - Soil health essential for productivity

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1. Farmland Productivity

- Directly, but not solely, impacted by nutrient stewardship.
  - Supports food security, fiber & fuel
  - Spares land for nature (biodiversity and GHGs)
  - Plant productivity for soil health and carbon storage
- Yield per unit area of cropland per year
  - Quality included too
- Data sources:
  - USDA-NASS and CANSIM national

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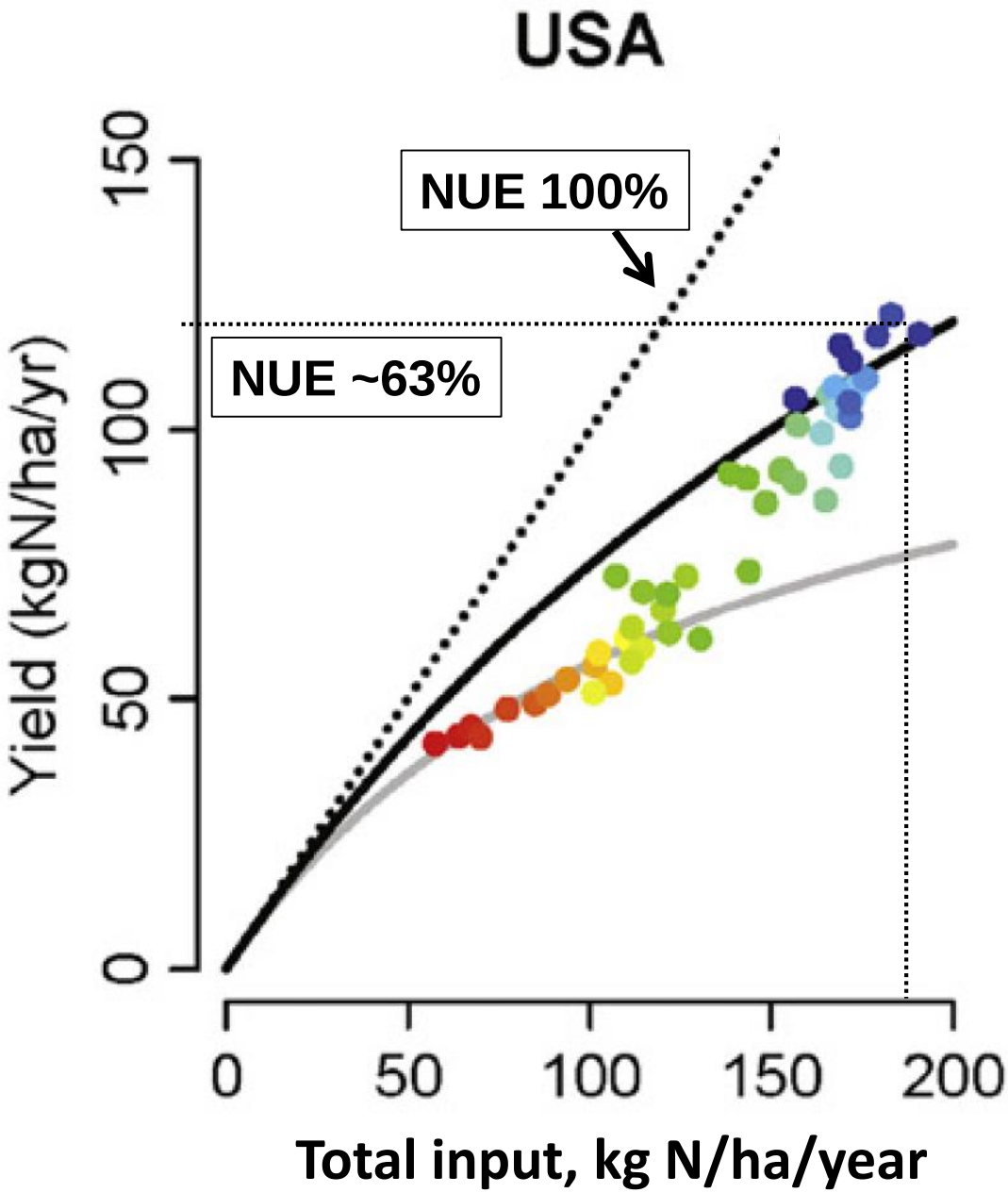
NUE trajectory 1961 to 2009



↑ yield
↑ PNB

Lassaletta et al., 2014, Environ. Res. Lett. 9 (2014) 105011 (9pp)

2. Soil Health

- Physical, chemical and biological condition of the soil
  - "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans" (USDA-NRCS)
  - Nutrient stewardship directly replenishes and maintains soil fertility
  - Nutrient balance (NUE) relates to soil fertility changes
  - Increased soil health increases farmland productivity
- Data sources:
  - Physical – bulk density?
  - Chemical – Soil test levels – IPNI soil test summaries (national)
  - Biological – data from nutrient omission plots, soil respiration?

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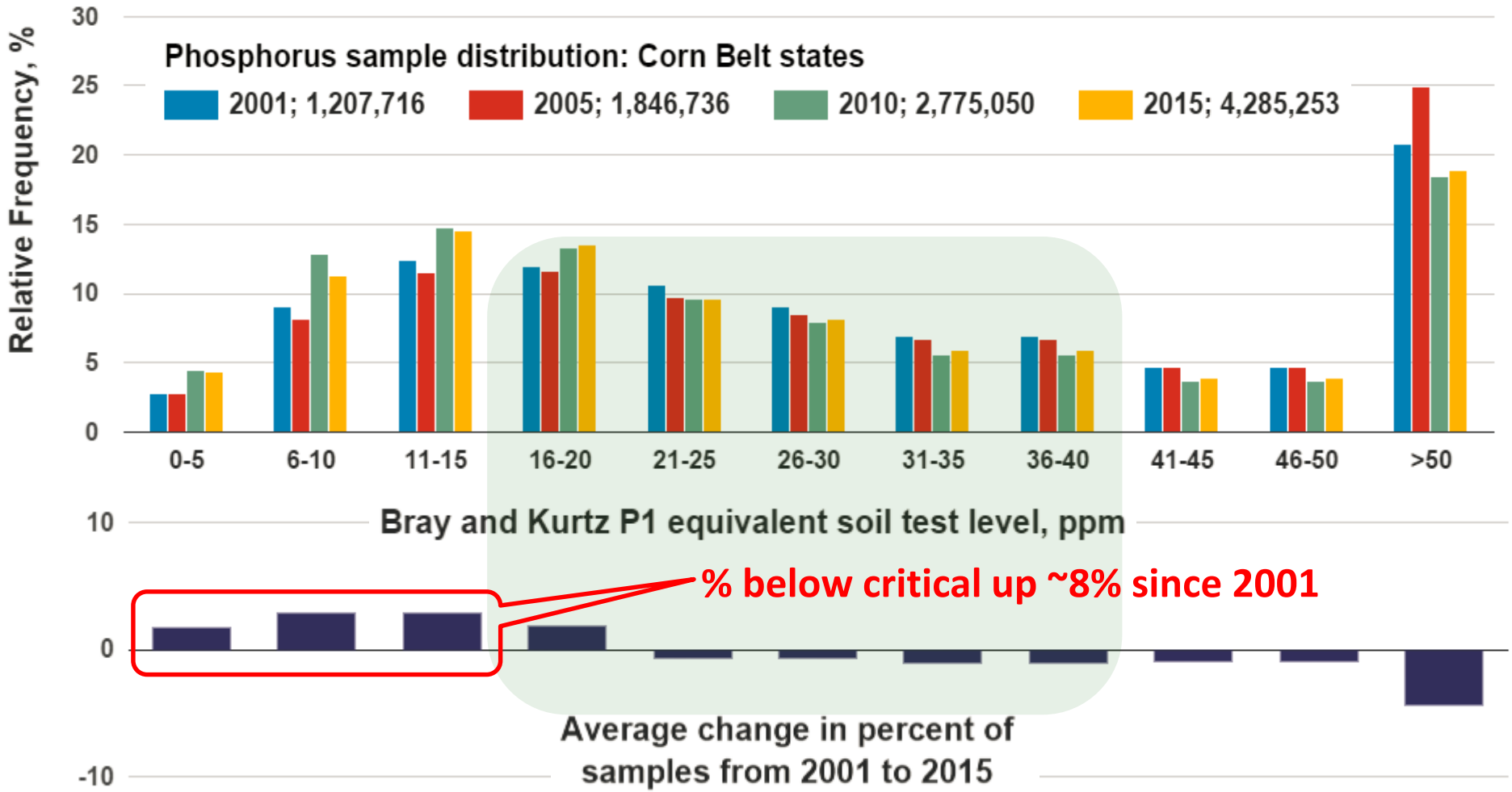
IPNI Soil Test Summary 2015 – preliminary results

Ten Corn Belt states (IL, IN, IA, KS, MI, MN, MO, NE, OH, WI)



ages

#soilyourundies

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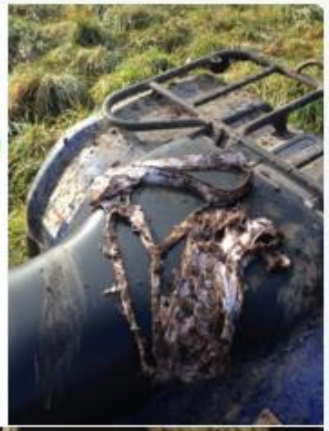

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3. Nutrient Use Efficiency

- Directly, but not solely, impacted by nutrient stewardship
  - Impacted by all factors impacting farmland productivity
  - Ensure crop uses as much of applied nutrient as possible practically
  - Low values indicate waste; high values, depletion of soil fertility
- Nutrient outputs compared to nutrient inputs
- Partial nutrient balance
  - the ratio of nutrient outputs to inputs is the preferred form
- Data sources:
  - USDA-NASS and CANSIM national for yields
  - IPNI for crop removal coefficients
  - Industry & government for crop nutrient use

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NuGIS

Nutrient Use Geographic Information System

Home | Methods | Discussion | Applications | References | Interactive Map | Tabular Data | About IPNI | Login

Select a Year: 2011 | Animation | Seconds to display each map: 5 | Play | Reverse | Stop | Enter a County or Watershed name to search for: | County

navigate | Zoom in to box | identify a feature

Table of Contents

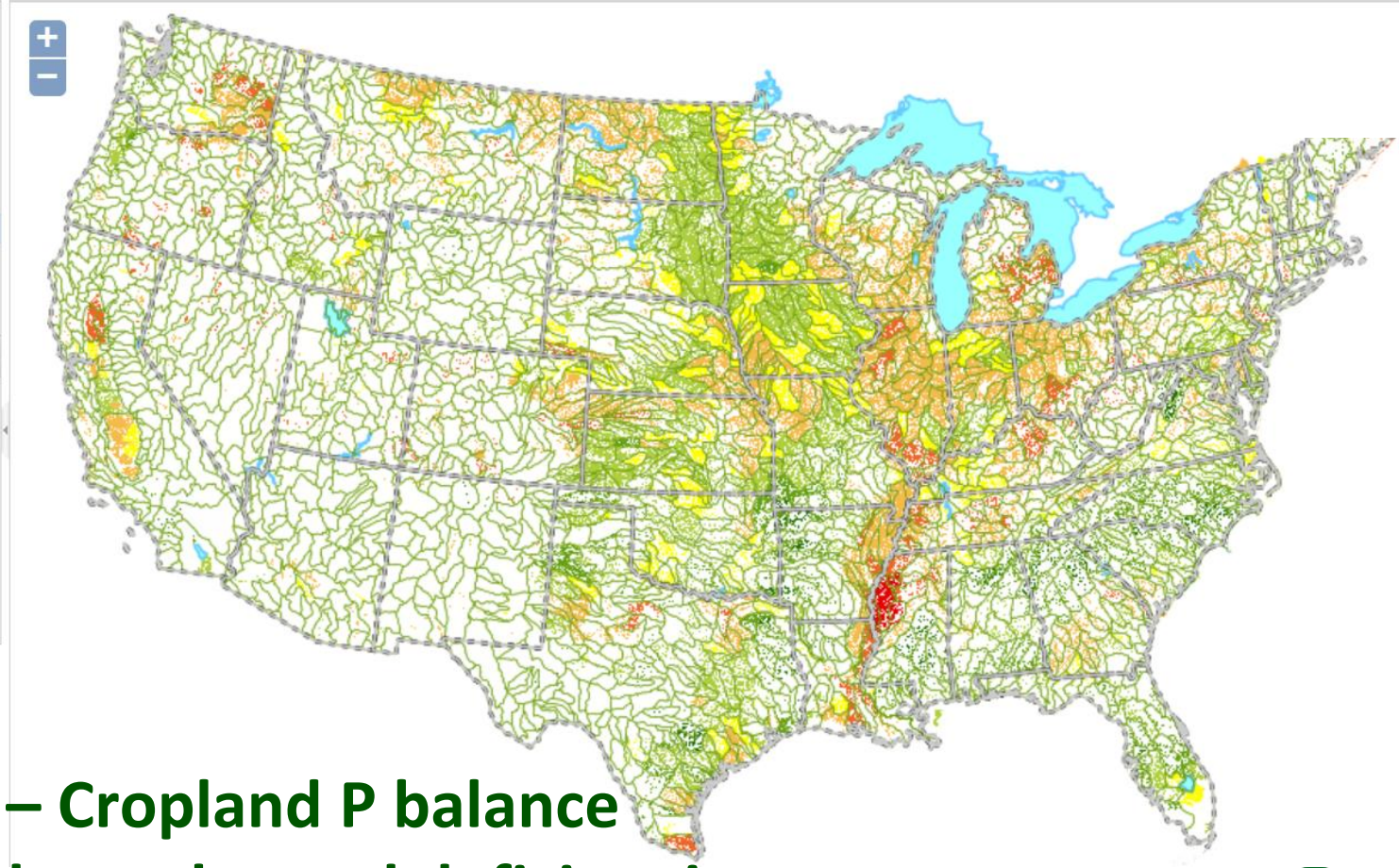
- Layers
  - Overlays
  - Lbs / Cropland Acre Balances
  - Removal to Use Ratios
    - County Ratios
    - Watershed Ratios
      - Watershed N Ratio
      - Watershed P2O5 Ratio
      - Watershed K2O Ratio
    - Hydro Region Ratios
  - Lbs / Acre Inputs

Legend

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

2011 NuGIS Data



NuGIS 2011 – Cropland P balance

Areas of both surplus and deficit exist

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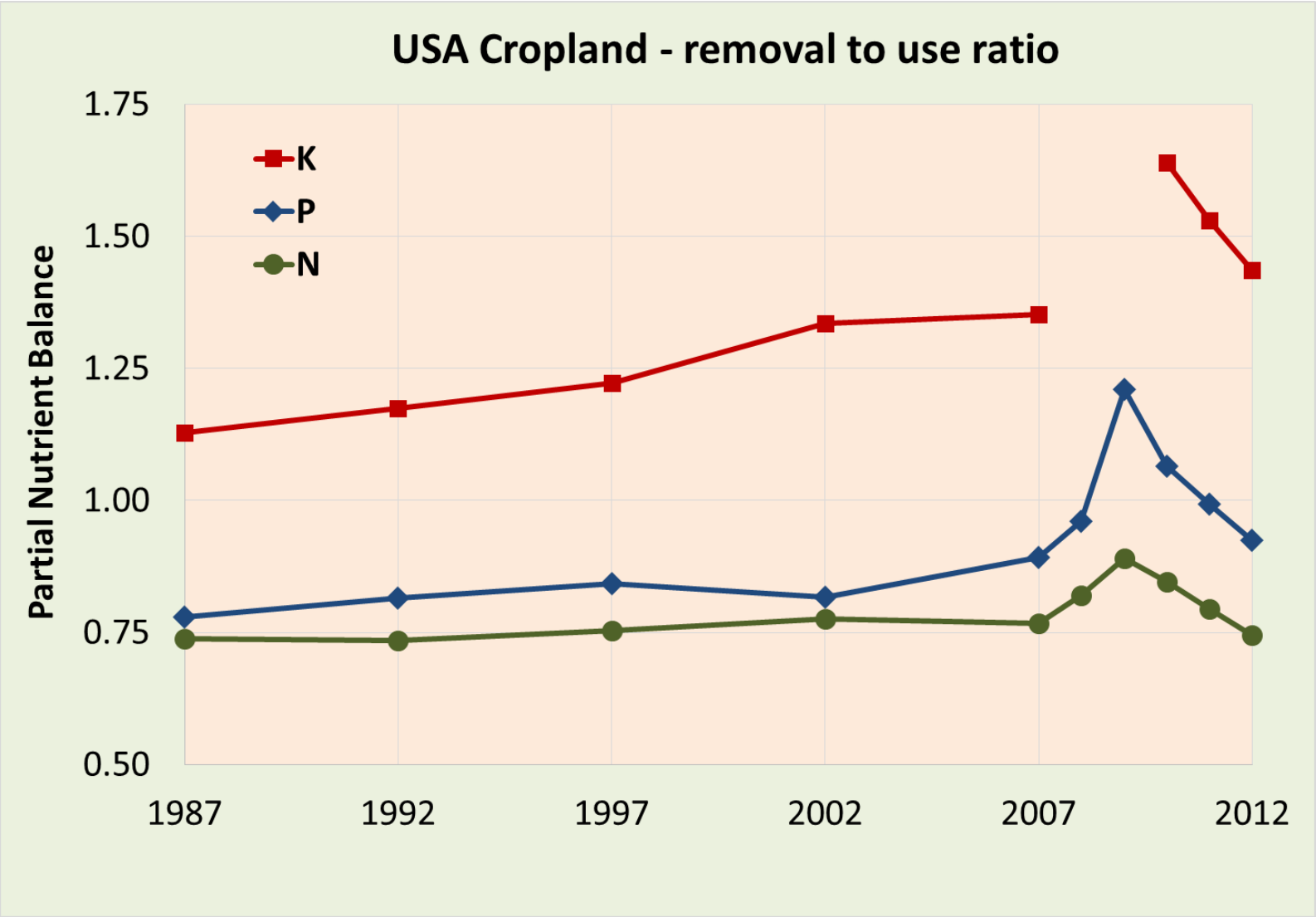
NUE varies by year – prices and weather



Use = fertilizer + manure applied

NuGIS, 2014

The Environmental Three

- **Water Quality, Air Quality and Greenhouse Gases**
- Difficult or impossible to measure at farm scale
- Influenced by 4R, agronomic, and conservation practices
- Other human activities also contribute
- Need models or metrics based on science to relate site-specific 4R practices to losses and emissions

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Water Quality

- Nutrient losses from farming combine with other sources to impact water quality (HABs, hypoxia, toxicities).
  - Nutrient stewardship minimizes EOF losses.
  - Risks ↓ with ↑ NUE, **but source, time & place may affect WQ > NUE**.
- Direct and indirect.
  - Conservation practices minimize losses from erosion.
- Data sources:
  - Concentration and loading of N and P, total and dissolved, in drainage water.
  - Impact of nutrient stewardship estimated by models requiring 4R data.
  - What additional roles can industry take on to provide 4R data?
  - Industry input into modeling.

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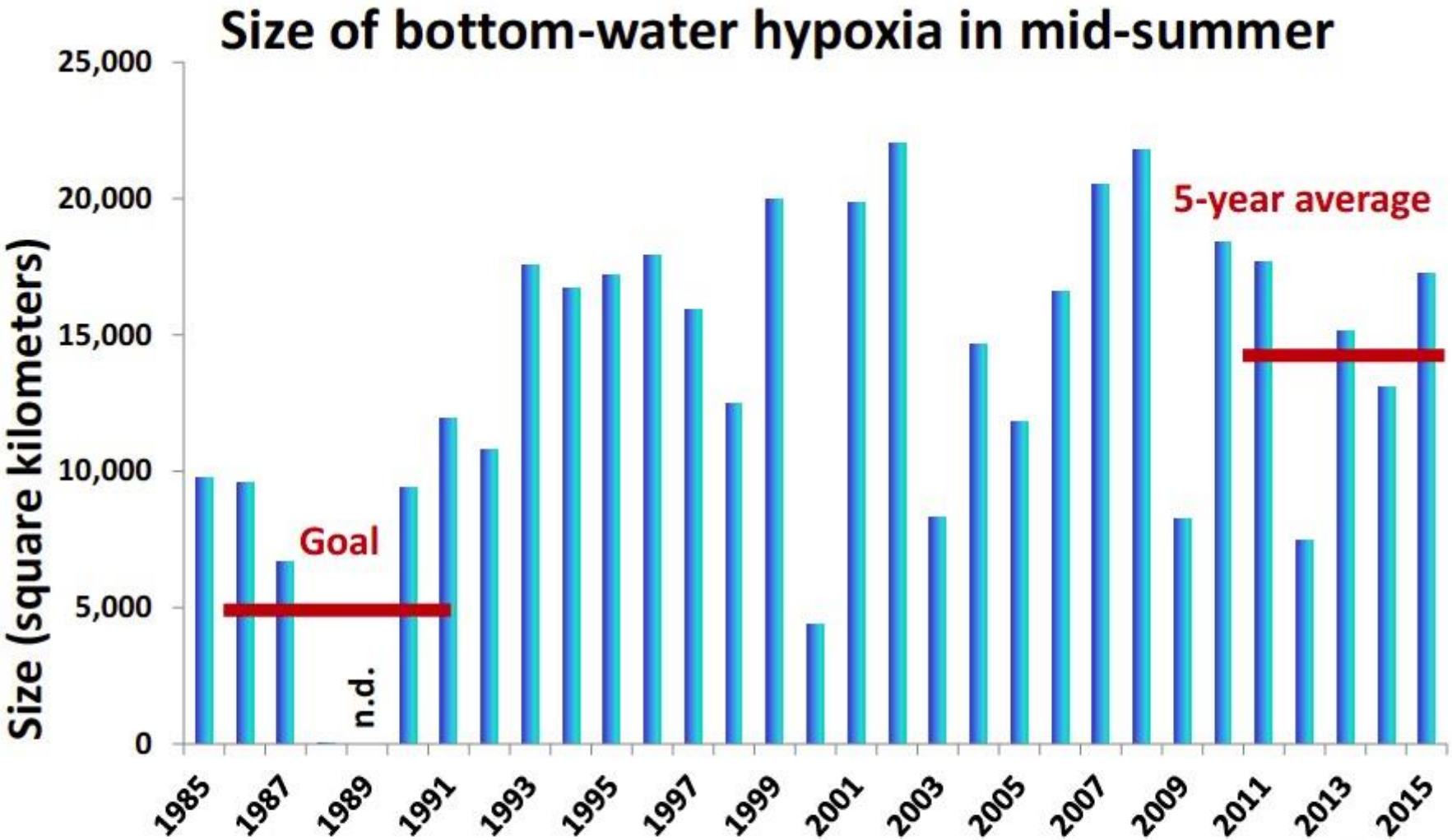
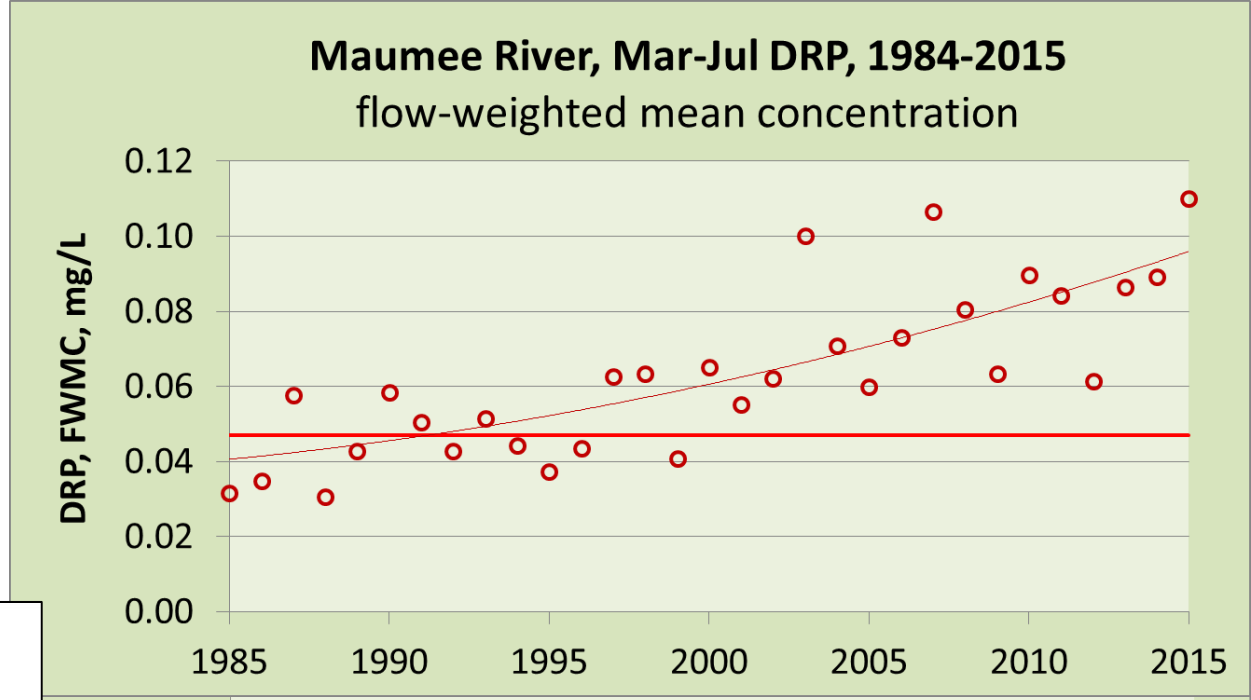
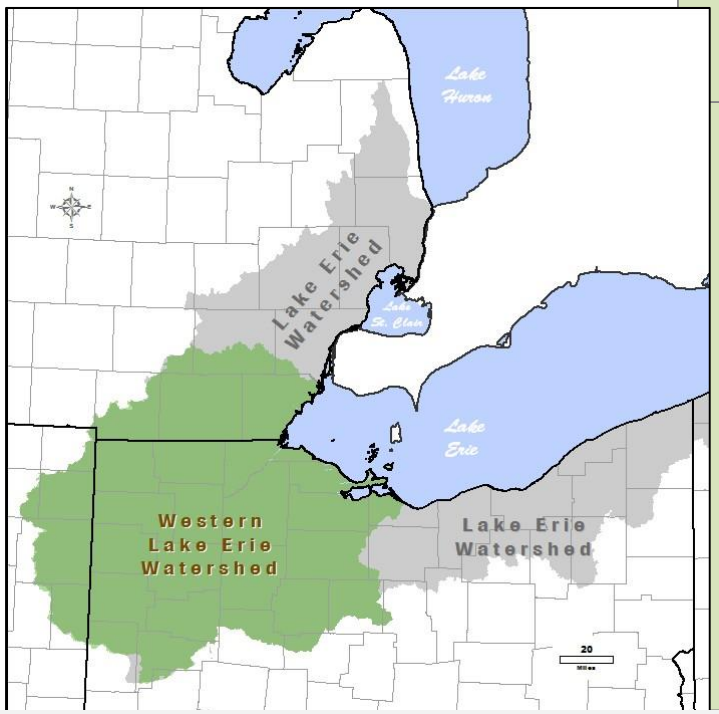


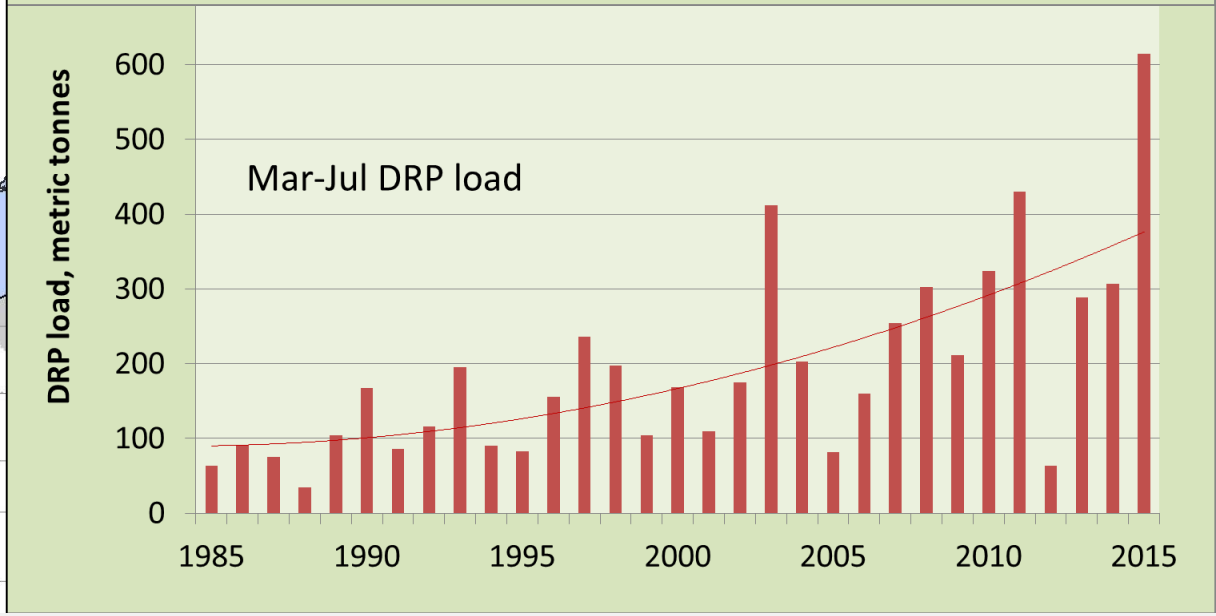
Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU
Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program

Historic size of hypoxia from 1985 to 2015. The complete area was not mapped in 1989(n.d.) The value for 1988 is 42 square kilometers and not visible on the scale.

Western Lake Erie: dissolved P trends increasing since early 1990s







GLWQA Annex Nutrients Committee, May 2015

David Baker & Laura Johnson, National Center for Water Quality Research, Tiffin, OH

Air Quality

- Ammonia emissions from crops, soils, animals, manures and fertilizers can contribute to formation of $PM_{2.5}$
  - Aerial transport can eutrophy nitrogen-limited natural ecosystems.
  - Nutrient stewardship has potential to reduce losses.
- Direct and indirect.
  - Non-ag sources also exist.
  - Practices reducing ammonia emissions generally improve NUE as well.
- Data sources:
  - Monitoring. The fraction attributable to agriculture and to nutrient stewardship can often only be estimated by models requiring 4R data.

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Better data on source, rate, time and place of N application needed to estimate ammonia impact on air quality

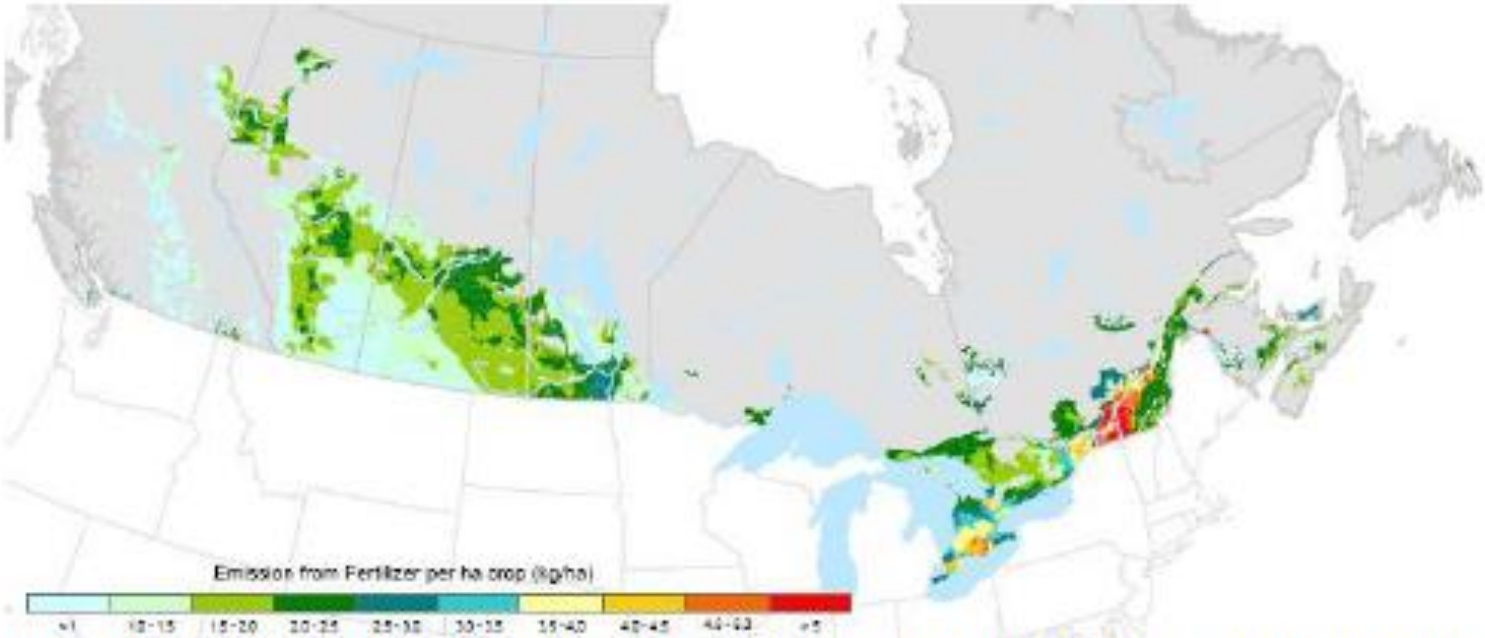

Fig. 12.3 Annual NH_3 emissions (kg NH_3 ha^{-1} crop land) from fertilizer in 2006 in Canada. (from Sheppard et al., 2010a, with permission from Canadian Journal Soil Science).

Greenhouse Gases

- Nutrient use can increase GHG emission.
  - Nutrient stewardship ↓ losses, ↑ productivity thus ↓ emission per unit of production.
- Direct and indirect.
  - Non-agricultural sources dominate.
  - Can be influenced by all 4Rs.
  - Emissions ↓ when NUE ↑, but source can impact nitrous oxide emissions more strongly than NUE.
- Data sources:
  - Global atmospheric concentrations of nitrous oxide, carbon dioxide and methane.
  - The fraction attributable to agriculture and to nutrient stewardship can often only be estimated by models requiring 4R data.

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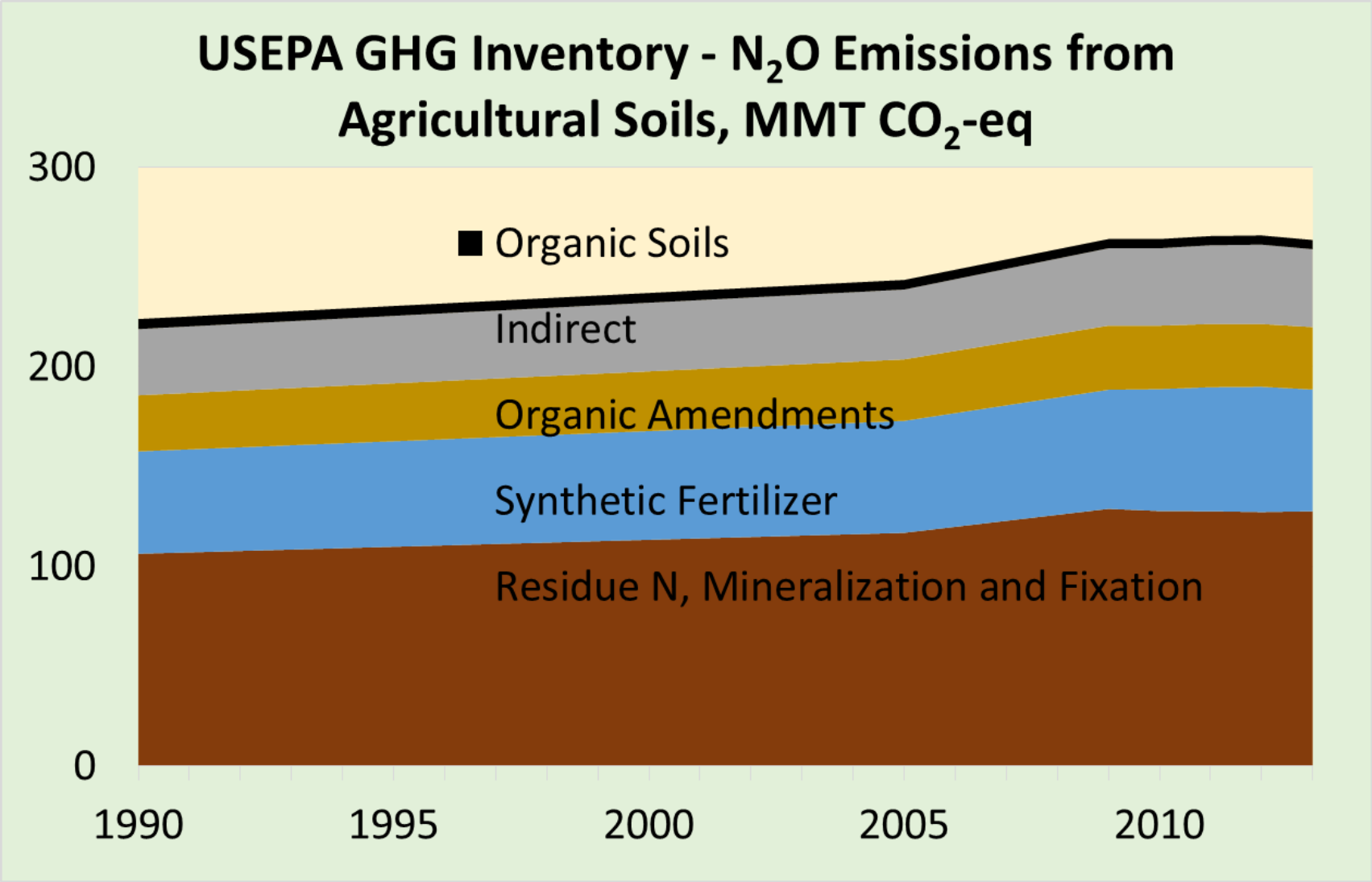
Ag soils N_2O – 4% of US GHG emissions



USEPA, 2015. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013

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Food and Nutrition Security

- Nutrient stewardship is one of the factors impacting the amount and quality of food produced.
  - In the context of the need to spare land for nature to preserve biodiversity, the use of fertilizers is fundamental to feeding and nourishing the growing global population.
  - Currently, around half of global food production depends on the use of crop nutrients.
  - Many other socio-economic factors, however, impact access to food and therefore food and nutrition security.
- Indirect
- Data sources
  - Major measure is FAO data on percentage of total population undernourished (which is calculated from per capita food supply). Other measures include surveys of individual perceptions of food security, or of health indicators like stunting

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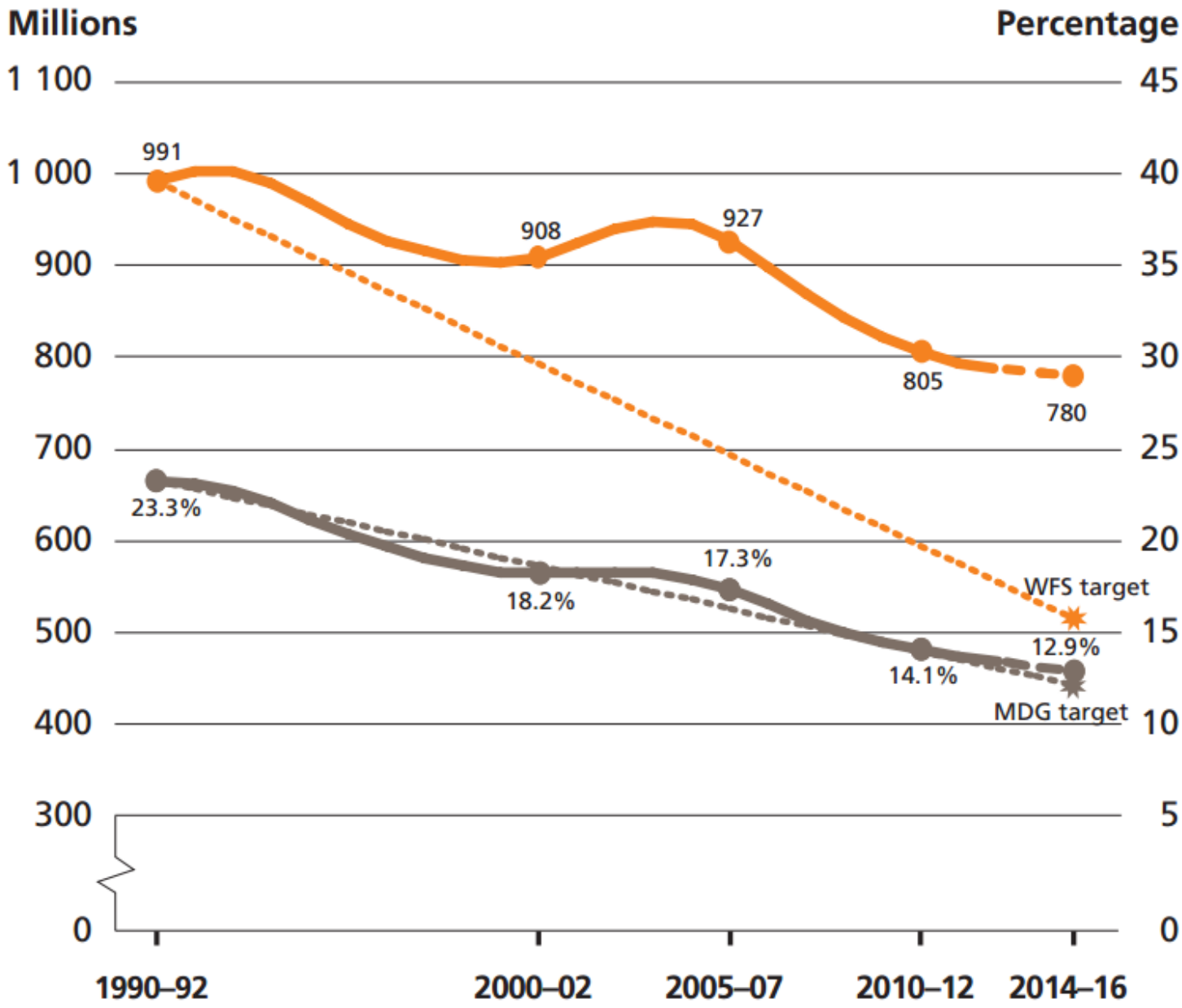


Food and Nutrition Security

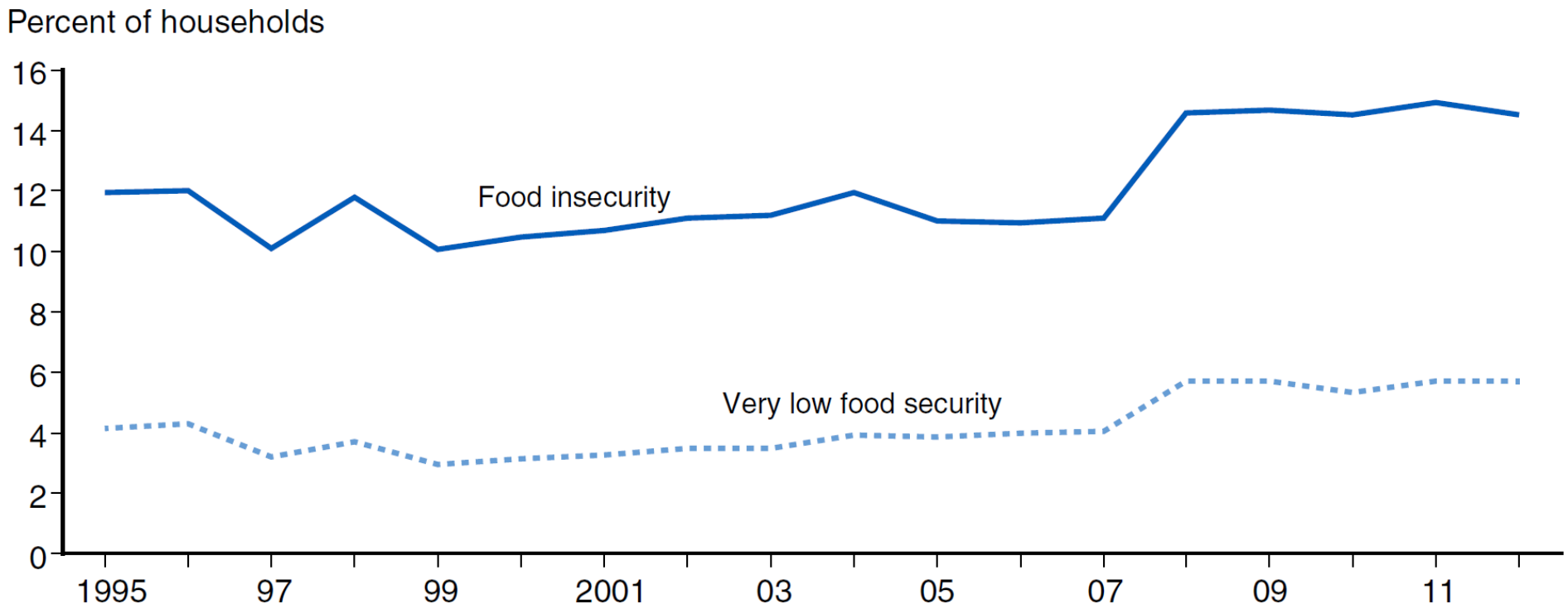
Under-nourishment in developing regions is declining, but remains substantial

FAO, IFAD and WFP. 2015. The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Rome, FAO.

Food insecurity in USA

- defined differently, measured, less related to food supply

Trends in the prevalence of food insecurity and very low food security in U.S. households, 1995-2012[1]



[1]Prevalence rates for 1996 and 1997 were adjusted for the estimated effects of differences in data collection screening protocols used in those years.

Source: Calculated by USDA, Economic Research Service based on Current Population Survey Food Security Supplement data.

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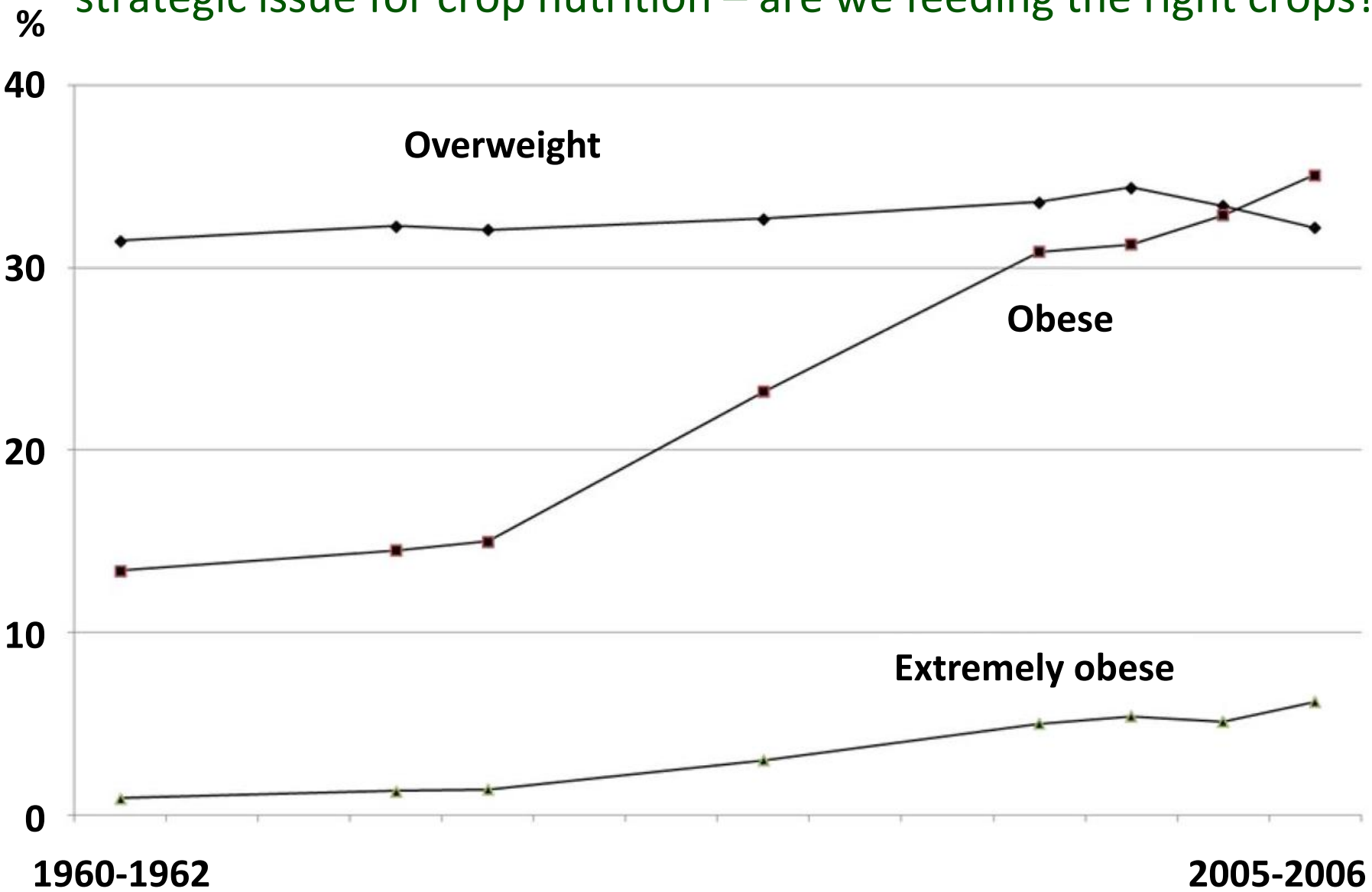
Obesity – another form of malnutrition

strategic issue for crop nutrition – are we feeding the right crops?



Mitchell et al., 2011, Psychiatr Clin North Am 34(4):717-732 – US Bureau of the Census

Biodiversity

- Biodiversity depends on conserving land for natural habitat.
  - By impacting farmland productivity, nutrient stewardship is linked to society's ability to spare land for nature. Such land sparing occurs when increasing demands for agricultural products are met through yield improvement instead of cropland expansion.
  - Losses of nutrients by air or water, however, can cause both aquatic and terrestrial ecosystems external to agriculture to become eutrophic, resulting in loss of species diversity. Such nutrient losses are minimized when nutrient use efficiency (NUE) is optimized.
- Data sources:
  - Cropland area
  - Monitoring by governments and conservation organizations. The proportion of the threat of reductions attributable to agriculture and to nutrient stewardship can often only be estimated by models requiring data on the 4Rs.

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Economic Value

- **Relevance:** By increasing farmland productivity and optimizing nutrient use efficiency, nutrient stewardship can increase the profitability of farming. **The economic benefits accrue not only to producers, but to upstream and downstream value chains and rural communities as well**.
- **Linkage:** Indirect, through farmland productivity and nutrient use efficiency. Influenced by market conditions and weather and other agronomic and conservation practices as well as nutrient stewardship.

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Summary

- Outcome metrics: balanced reflection of environmental, economic, and social impacts
- For metrics of crop nutrition, three sets of three is one approach:
  1. Farmland Productivity, Soil Health, NUE
  2. Water Quality, Air Quality, GHG
  3. Food Security, Biodiversity, Economic Value
- Need for stakeholder engagement
  - Consumers and public on priority and relevance
  - Within all of agriculture as goals for adaptive management
  - Crop, pest, soil and water conservation practices as well as nutrient stewardship

4 nutrient stewardship

www.ipni.net/4R

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