IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

17th Penn State Plant Biology Symposium
University Park, PA, USA

Fertilizer Biogeochemistry

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IPNI Mission

"to develop and promote scientific information about the responsible management of plant nutrition for the benefit of the human family."

Agrium Inc.

Arab Potash Company

Belarusian Potash Company

Bunge Fertilizantes S.A

CF Industries Holding, Inc.

Incitec Pivot

Intrepid Mining, LLC.

K+S KALI GmbH

The Mosaic Company

Office Chérifien des Phosphates Group

PotashCorp

Simplot

Sinofert Holdings Limited

SQM

Terra Industries, Inc.

Uralkali

Affiliate Members

Arab Fertilizer Association (AFA)

Canadian Fertilizer Institute (CFI)

Foundation for Agronomic Research (FAR)

International Fertilizer Industry Association (IFA)

International Potash Institute

The Fertilizer Institute (TFI)

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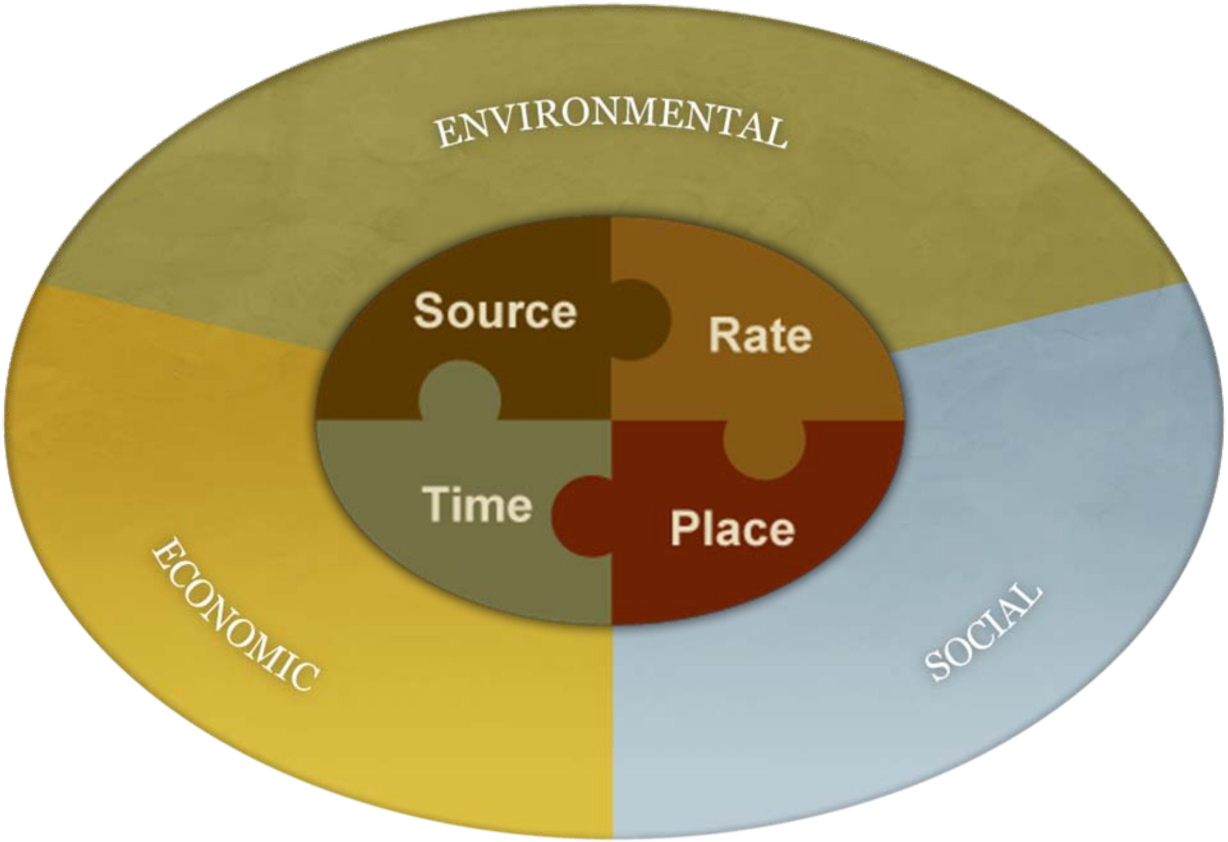
4R Nutrient Stewardship

- Right Source, Rate, Time & Place:
  - A means of linking practices to science to sustainability performance
  - A means of focusing research in support of practical management



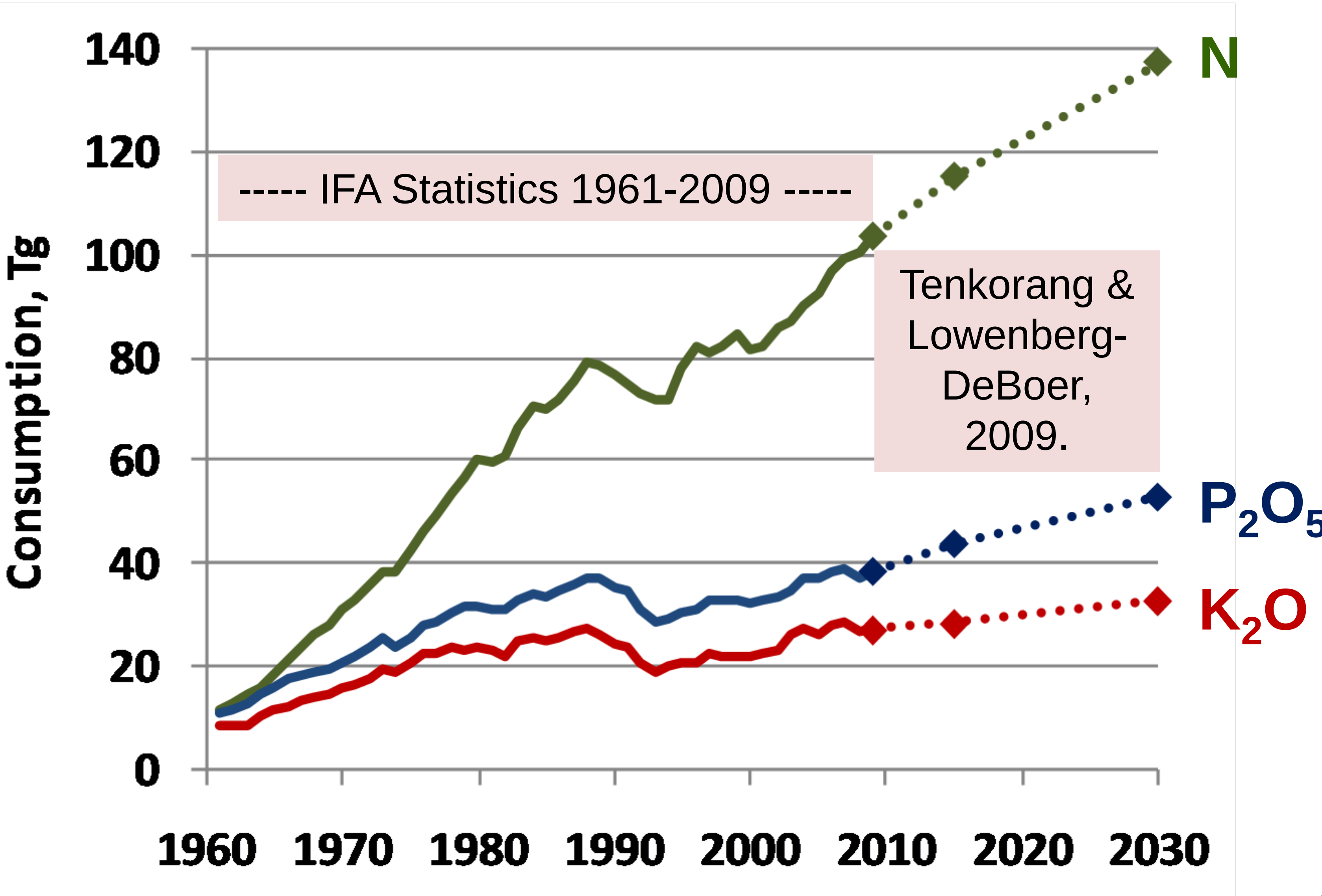
Biogeochemistry - Definitions

- Cornell University: *"…study of biological controls on the chemistry of the environment and geochemical regulation of ecological structure and function…"* (similar to the journal Biogeochemistry, published since 1984)
- *"…study of the cycles of matter and energy that transport the Earth's chemical components..."*
- History – Vladimir Vernadsky – *The Biosphere* (1926)
  - **Abiotic sphere** - all the non-living energy and material processes
  - **Biosphere** - the life processes that live within the abiotic sphere
  - **Nösphere** - the sphere of the cognitive process of man

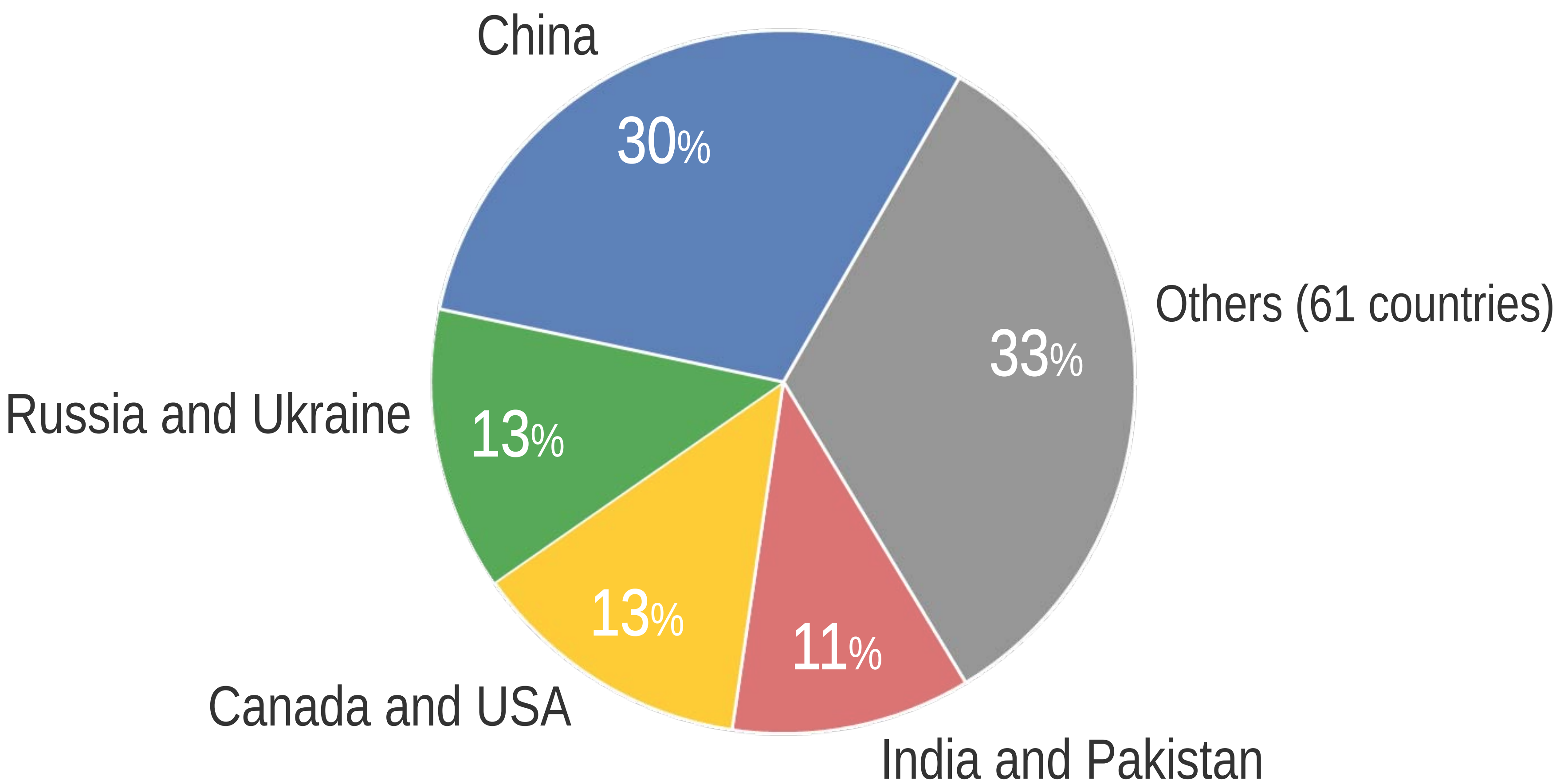
Abiotic Sphere

World Fertilizer Consumption

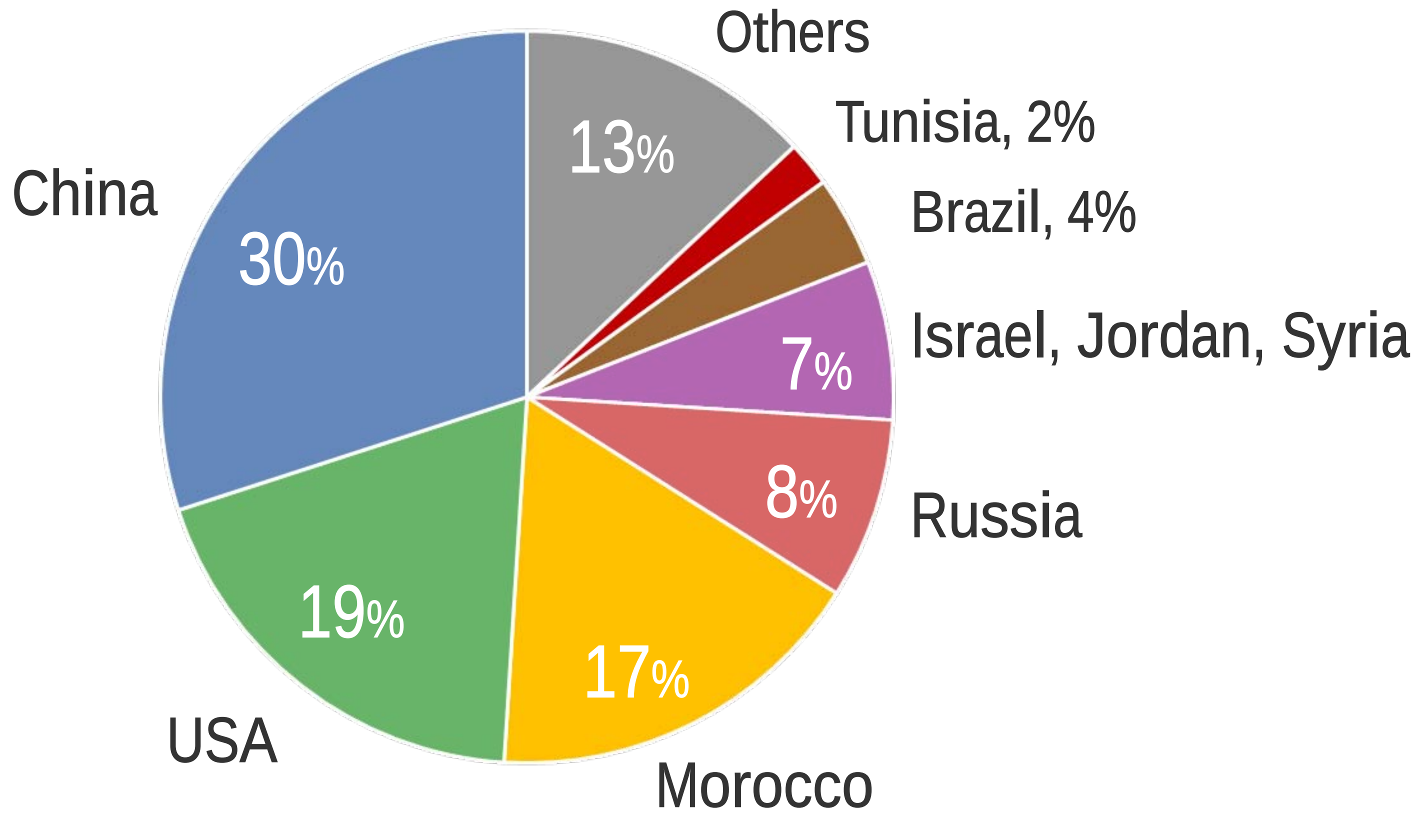
Historical and Projected



Ammonia producing countries (2004 to 2006)



Phosphate rock producing countries (2004 to 2006)



World Phosphate Rock Reserves

Country	2007 Production	Reserves	Reserve Life	Reserve Base
	Tg		Years	Tg
China	45	4,100	90	10,000
USA	30	1,200	40	3,400
Morocco	27	5,700	210	21,000
Russia	11	200	18	1,000
World Total	156	15,000	96	47,000

Source: USGS Mineral Commodities Summaries, 2009

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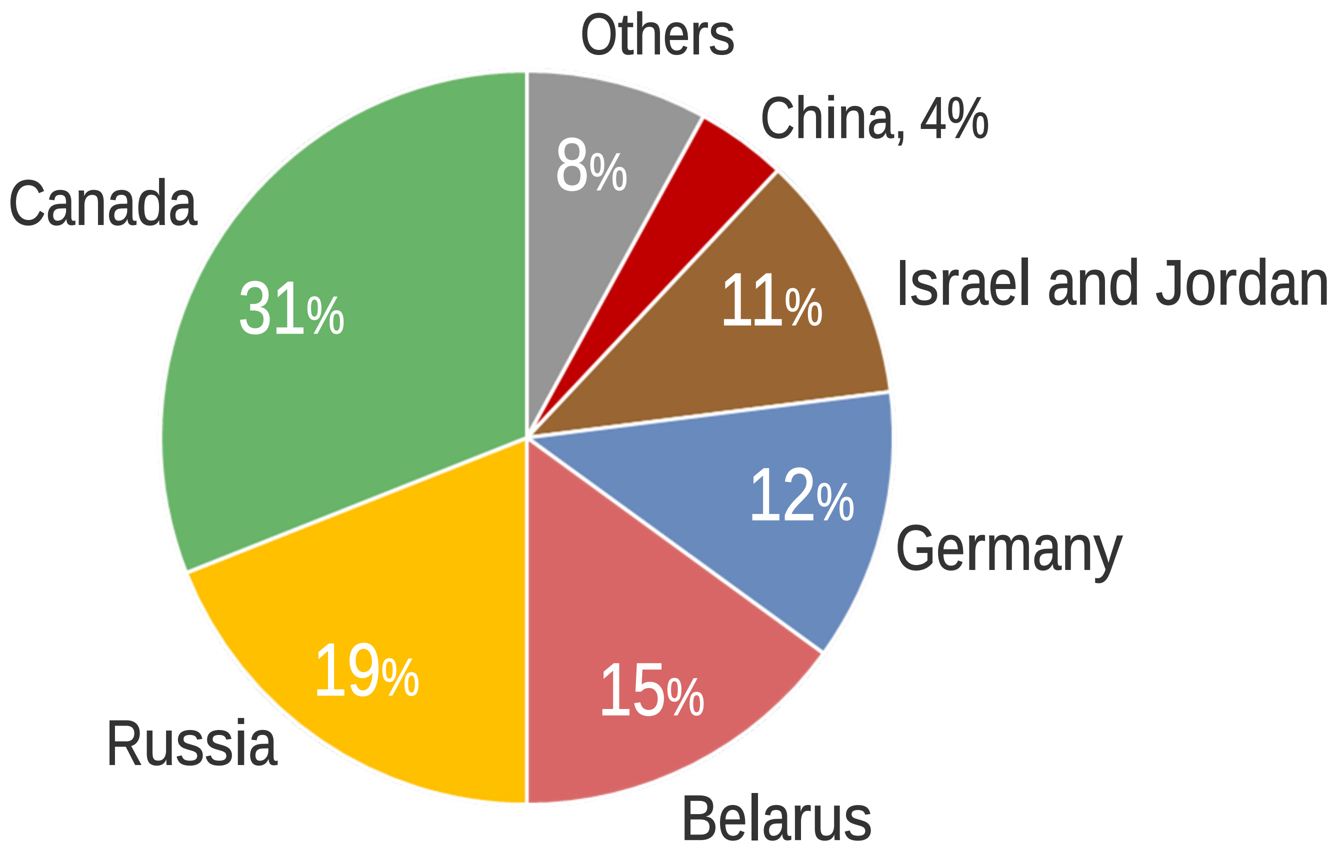
Potash producing countries (2004 to 2006)

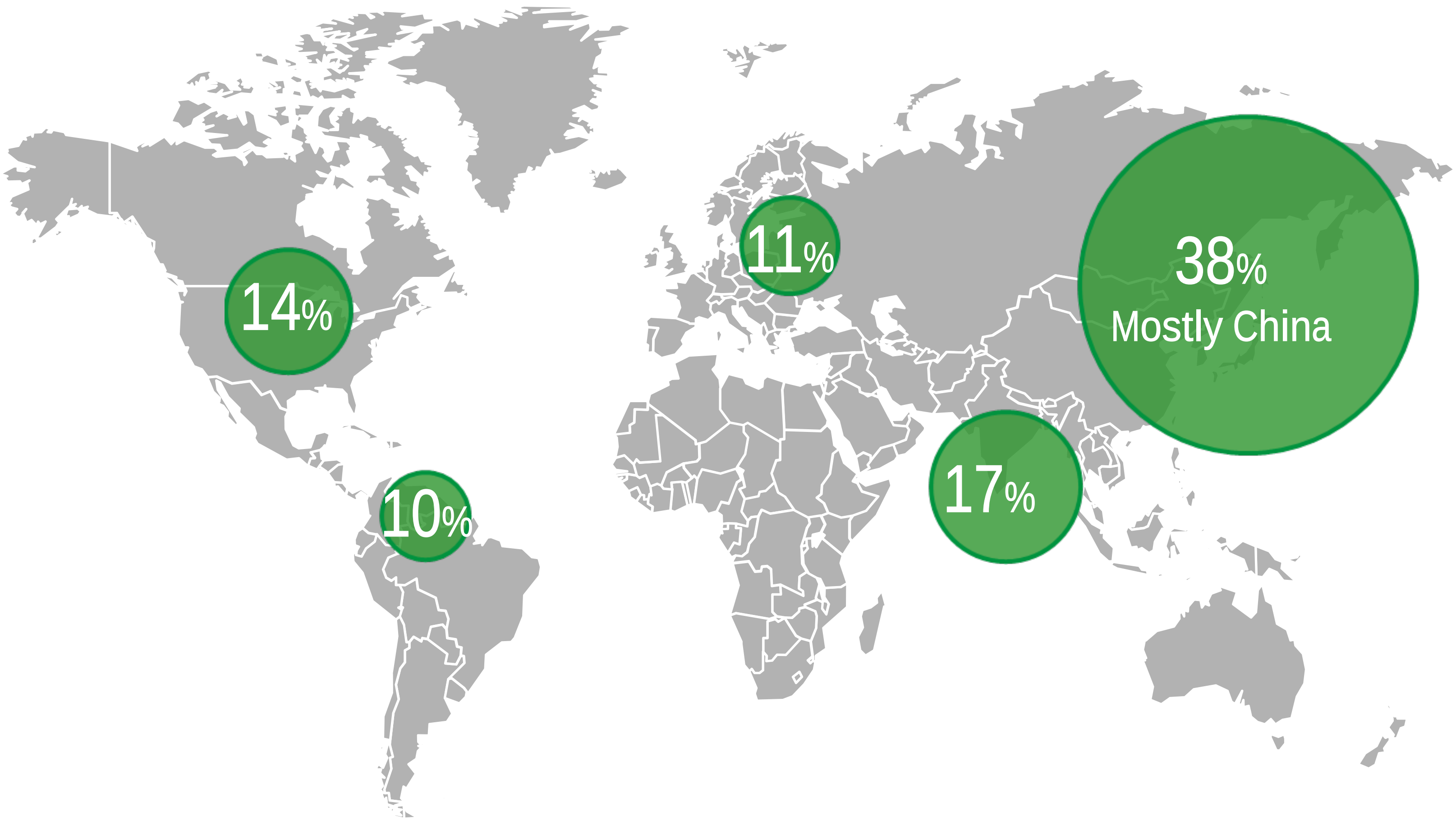


World Potash Reserves

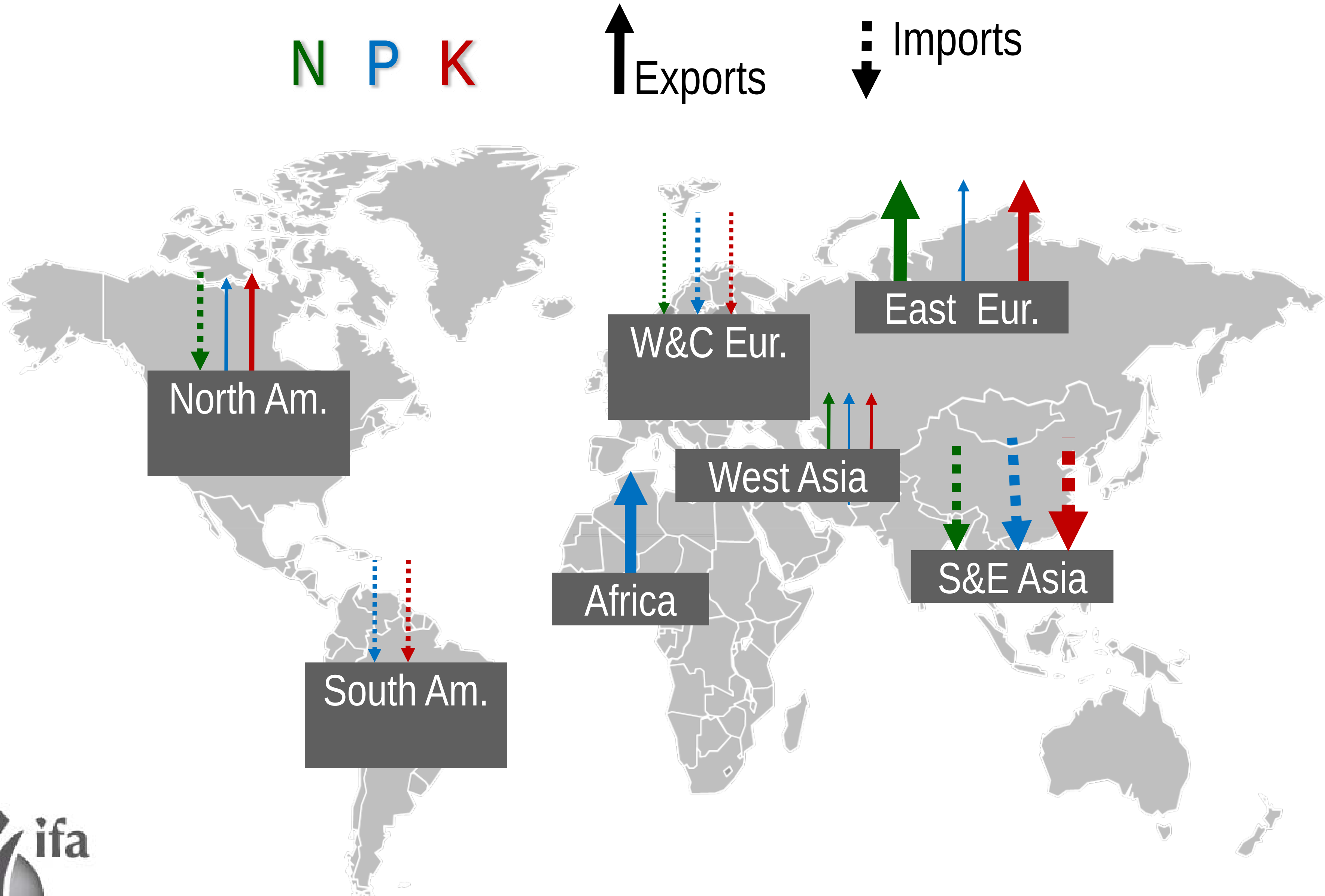
Country	2007 Production	Reserves	Reserve Life	Reserve Base
	Tg K_2O		Years	Tg K_2O
Canada	11	4,400	400	11,000
Russia	7	1,800	270	2,200
Belarus	5	750	150	1,000
Germany	4	710	200	850
USA	1	90	80	300
World Total	35	8,300	240	18,000

USGS Mineral Commodities Summaries, 2009

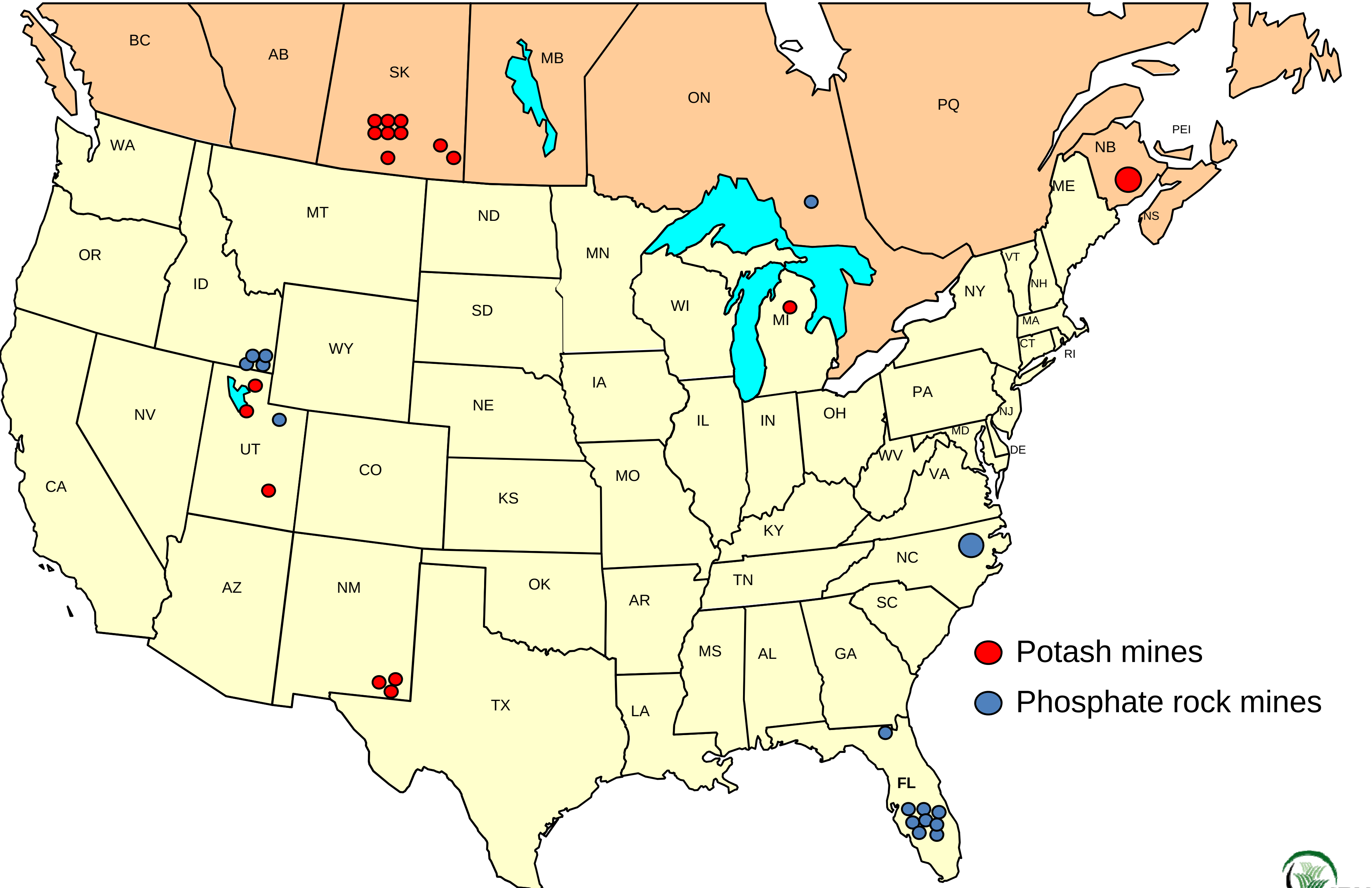
Fertilizer consumption (2005/06 – 2007/08)



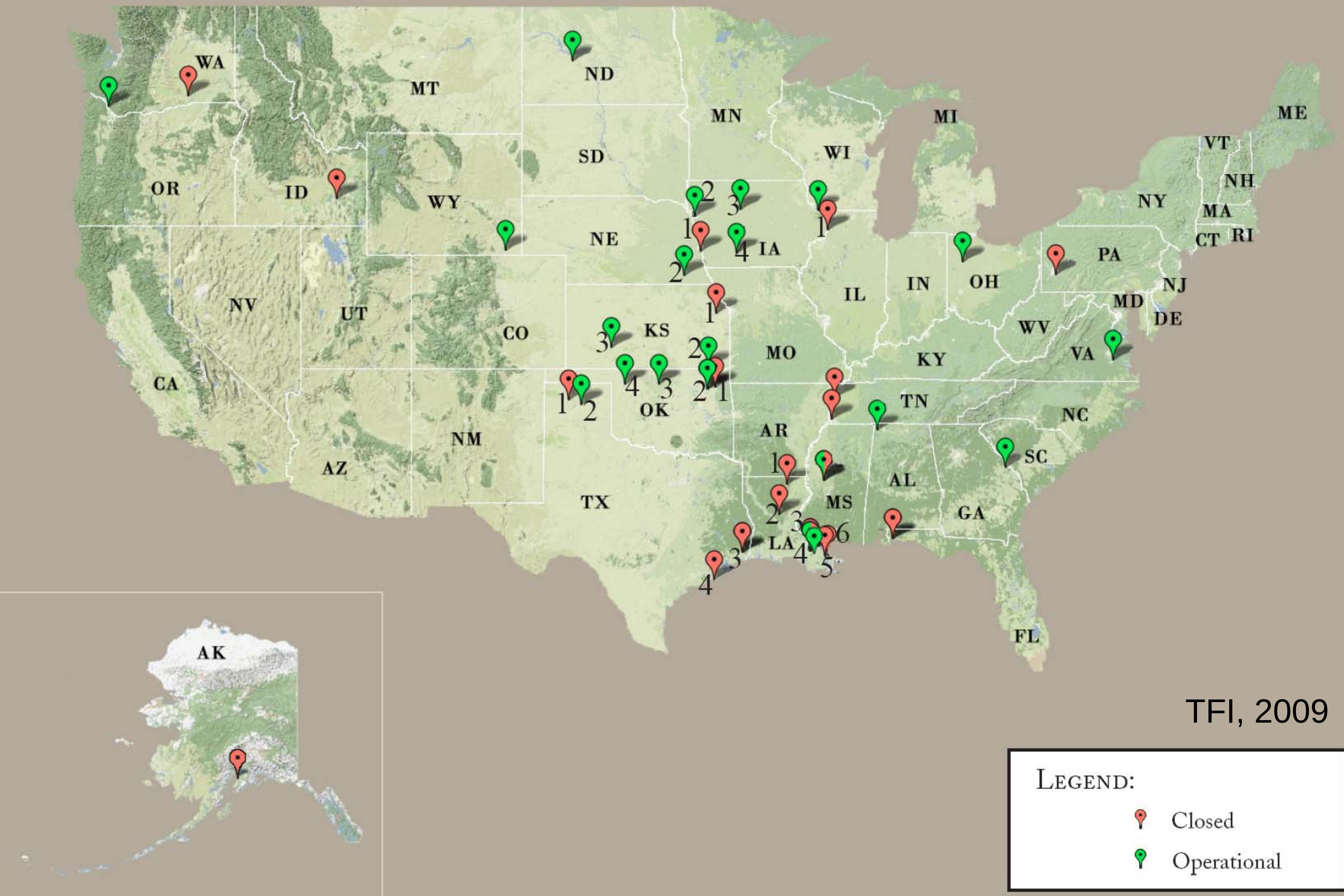
Net import/export of plant nutrients in fertilizers



PHOSPHATE AND POTASH MINES



Operational and Closed Ammonia Plants Since Fiscal Year 1999



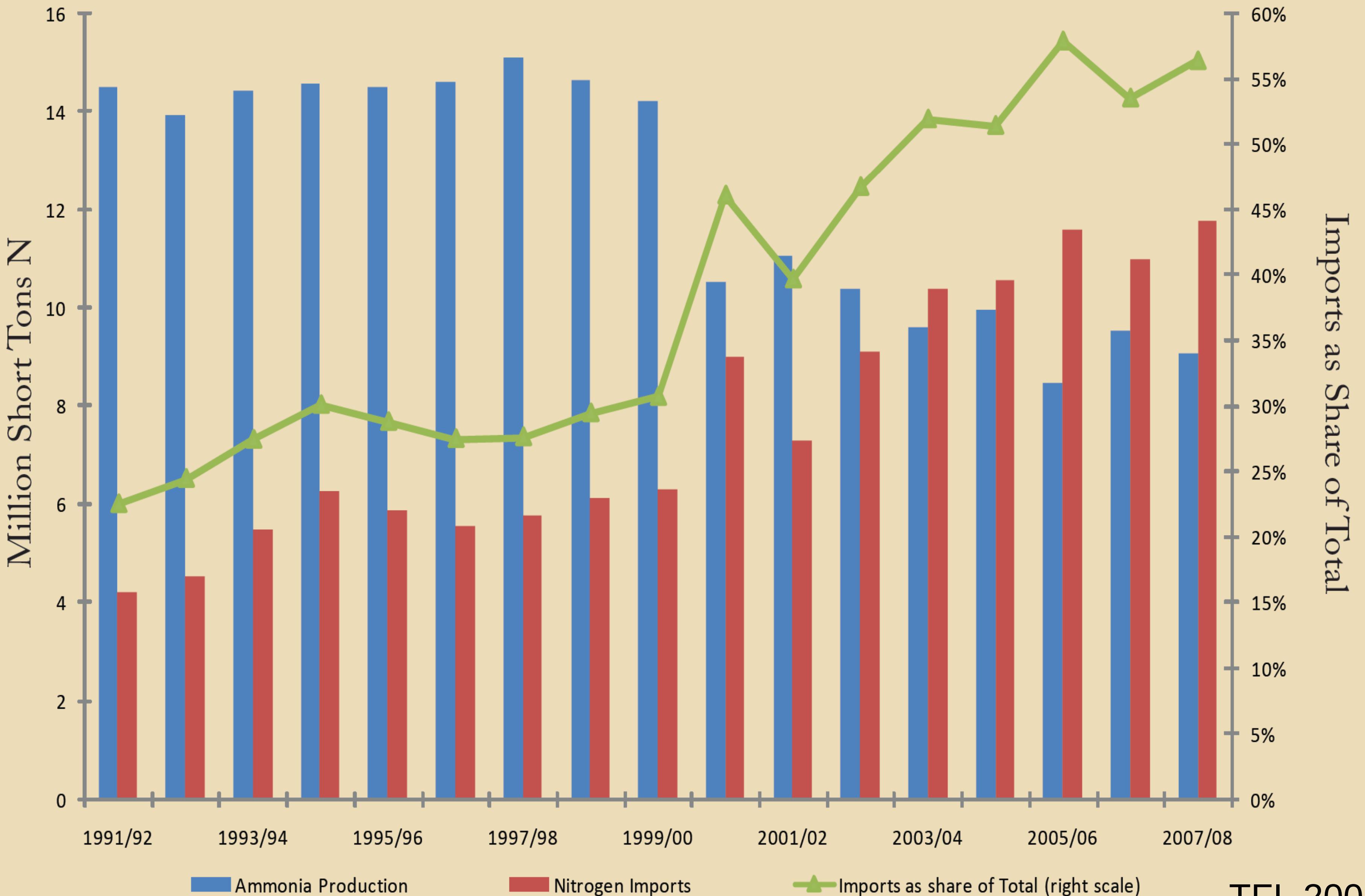
LEGEND:

Closed

Operational

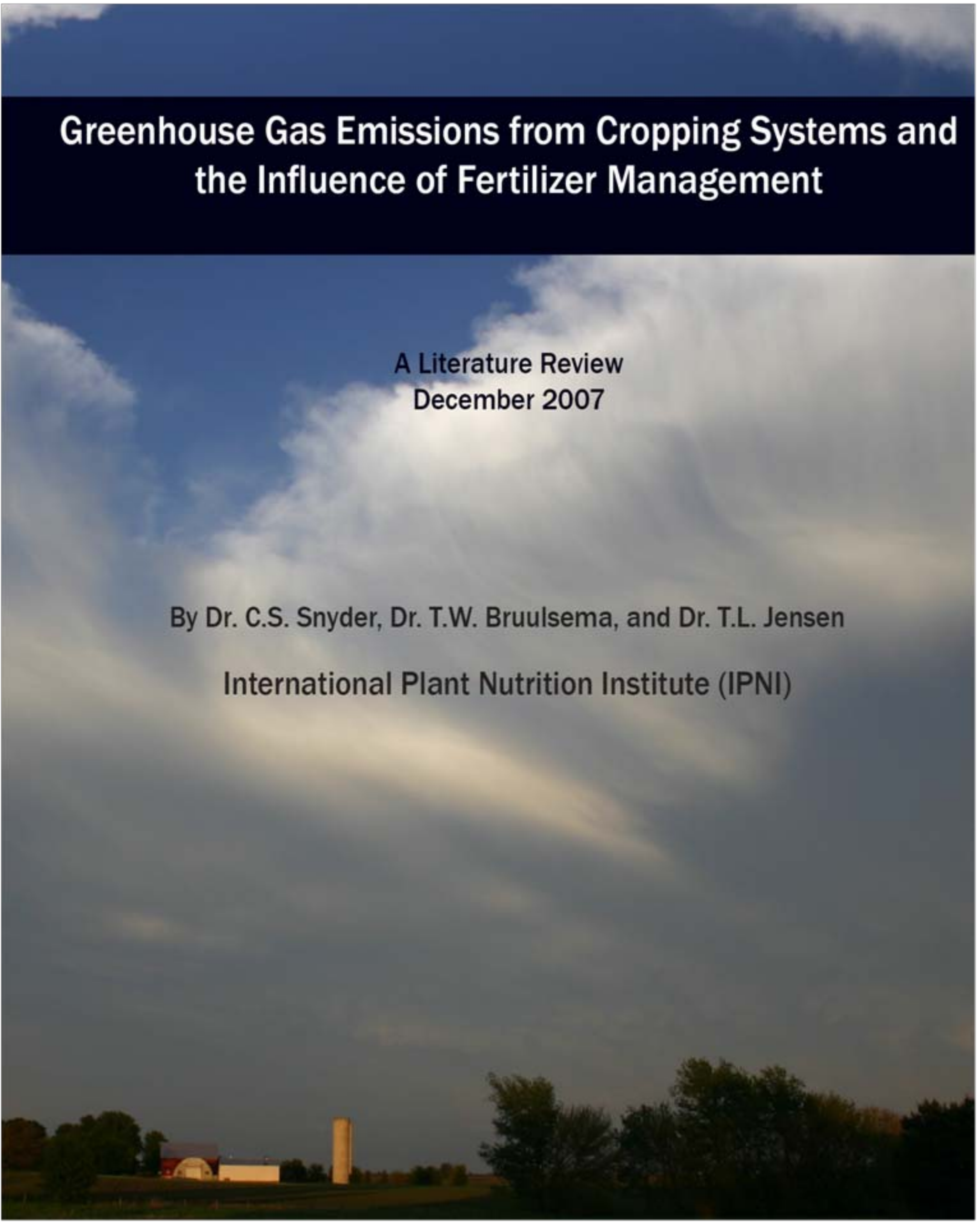
TFI, 2009

U.S. Nitrogen Sources - Ammonia Production and N Imports



TFI 2009

Greenhouse Gases and Fertilizer



GHG cost of N use

(kg CO_2 kg^{-1} N)

$0.88\ CH_4 + 1.26\ \text{Air} + 1.24\ H_2O$

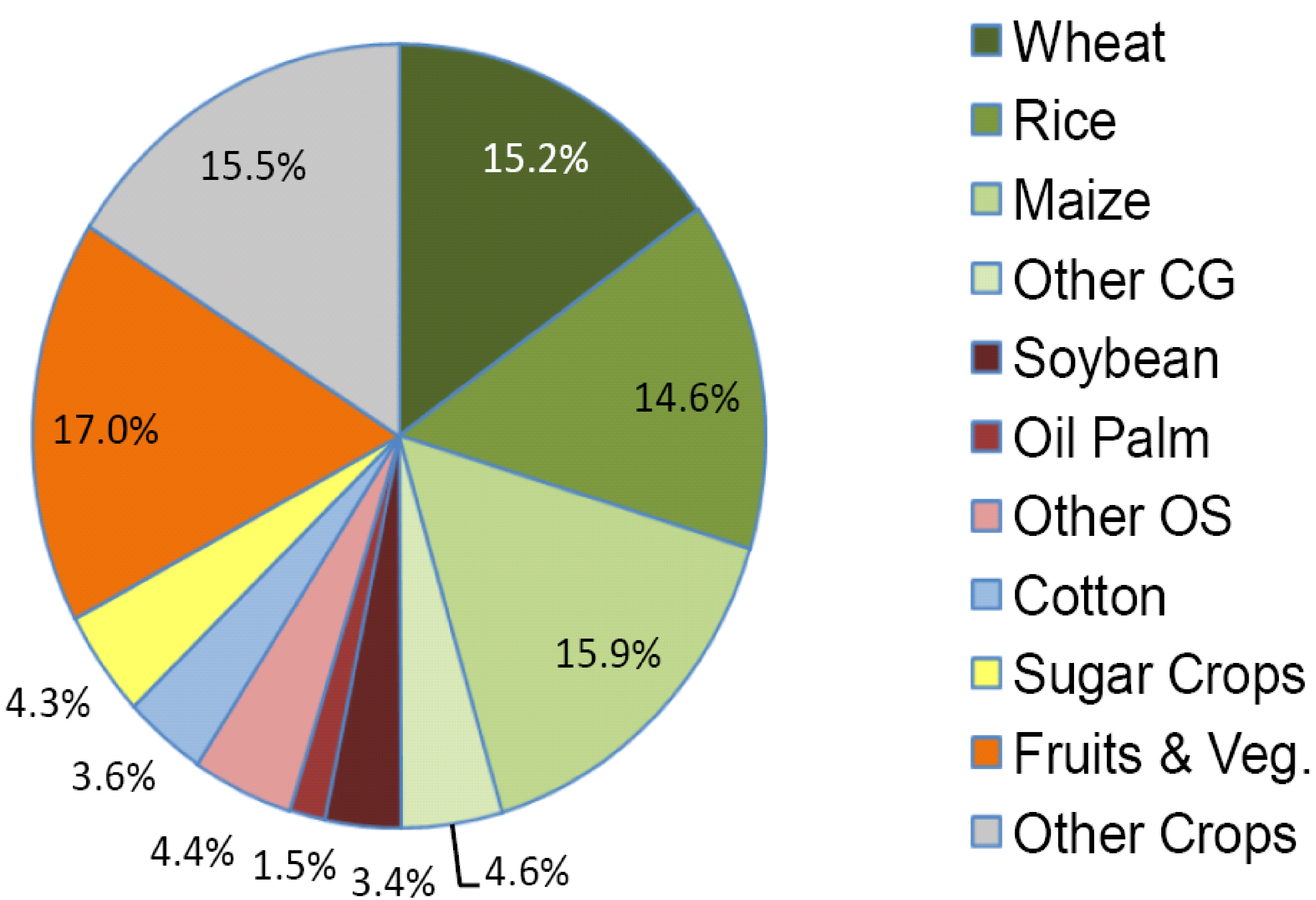
$\rightarrow 0.88\ CO_2 + N_2 + 3\ H_2 \rightarrow 2\ NH_3$

Manufacture & transport	3.0 – 4.5
Emission of N_2O from soil	0.7 – 4.7
Lime requirement	0.0 – 0.4
Soil C storage	?

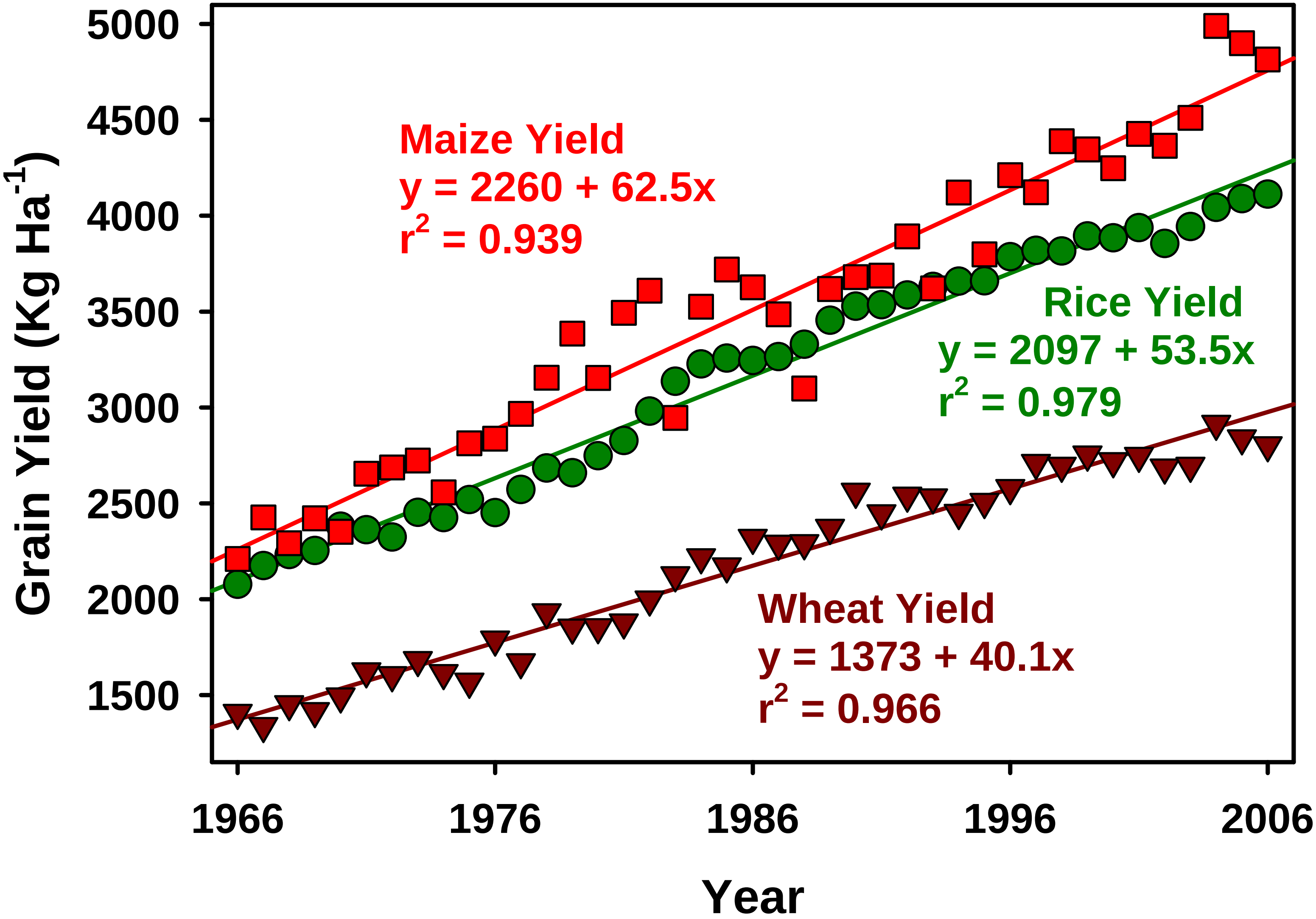
Biotic Sphere

Total Fertilizer Use by Crop at the Global Level: 2006/07–2007/08

IFA, 2009

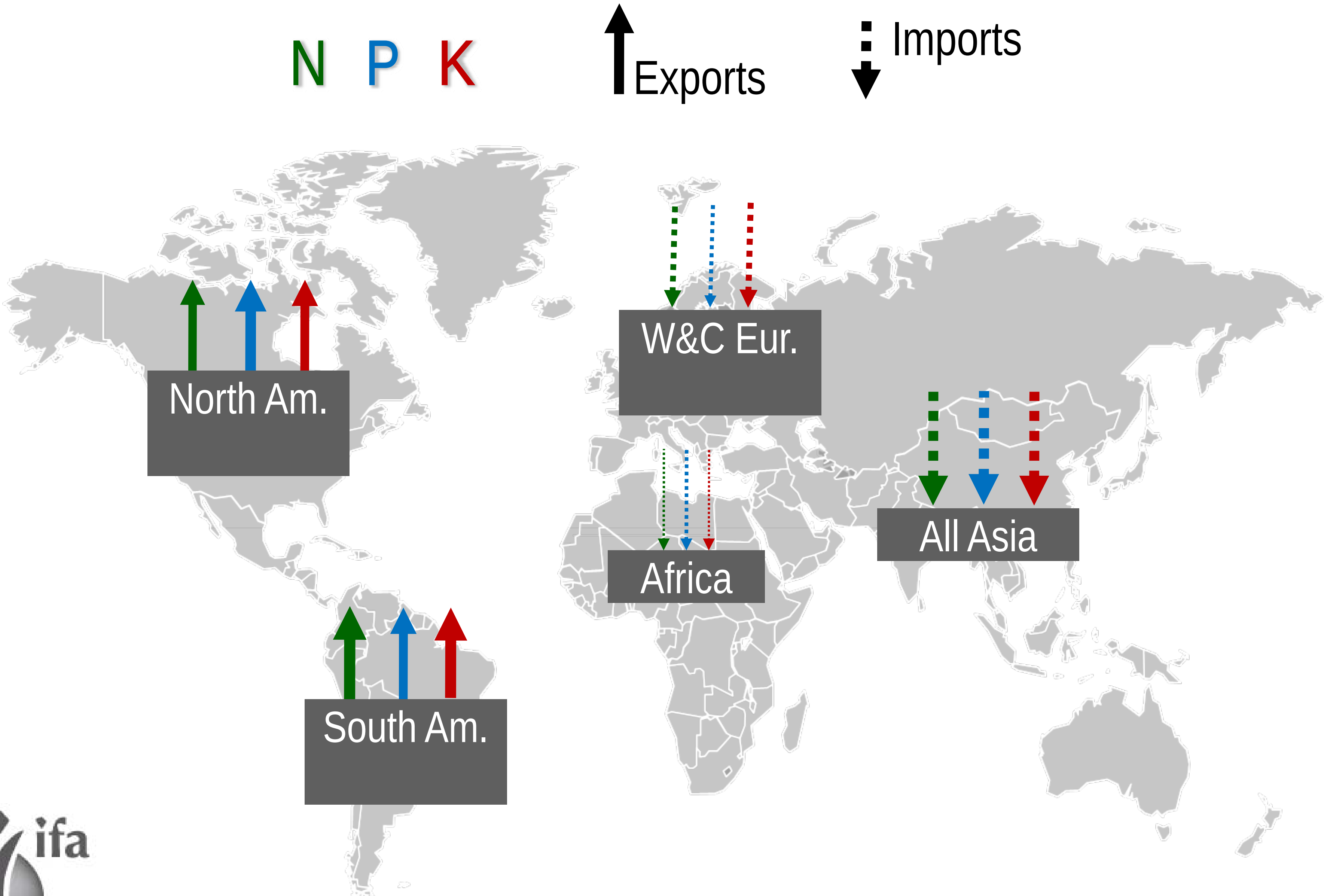


Global Cereal Yield Trends, 1966-2006

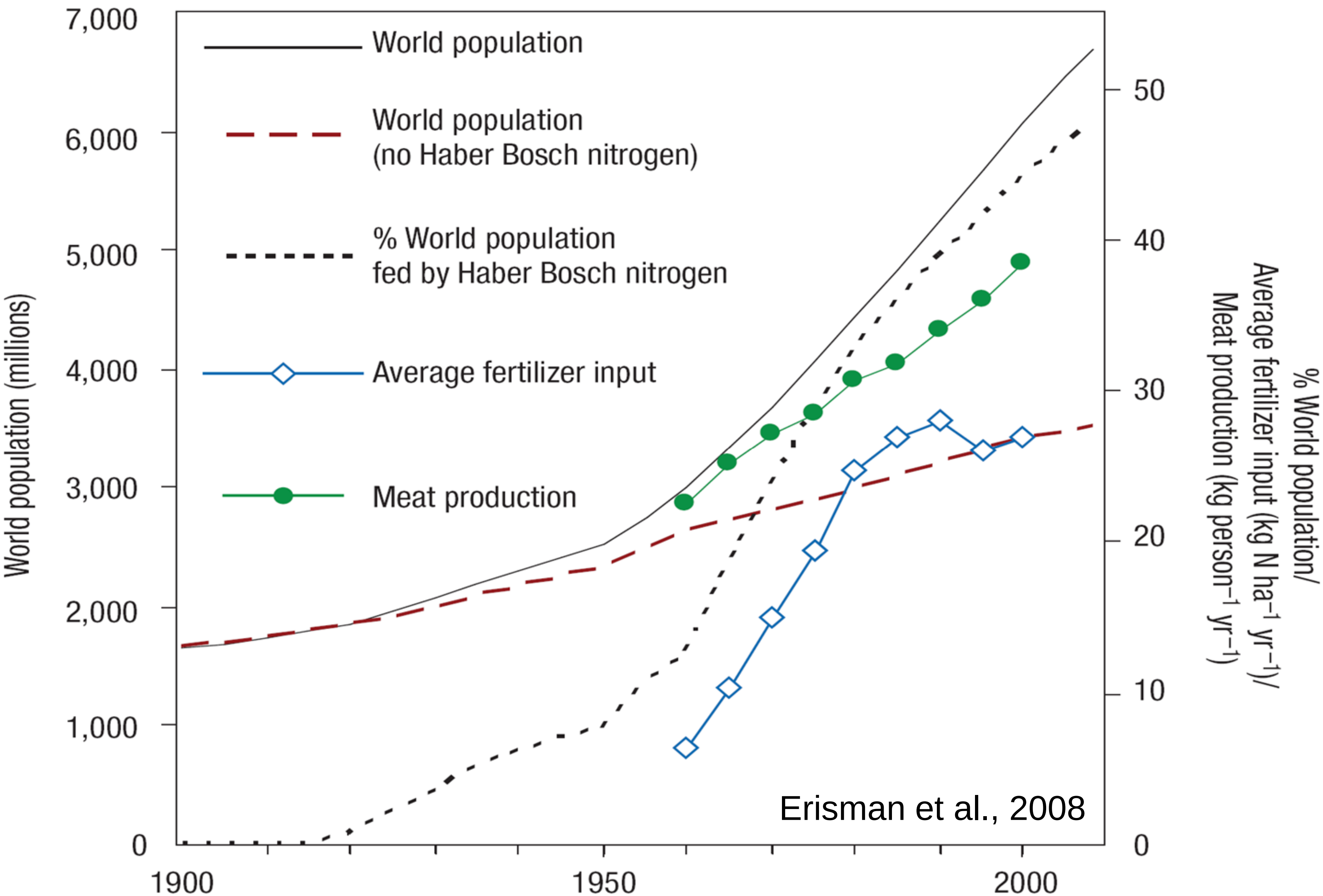


THESE RATES OF INCREASE ARE NOT FAST ENOUGH TO MEET EXPECTED DEMAND ON EXISTING FARM LAND! *Ken Cassman, 2008.*

Net import/export of plant nutrients in cereals and soybeans



Human Population and N Use

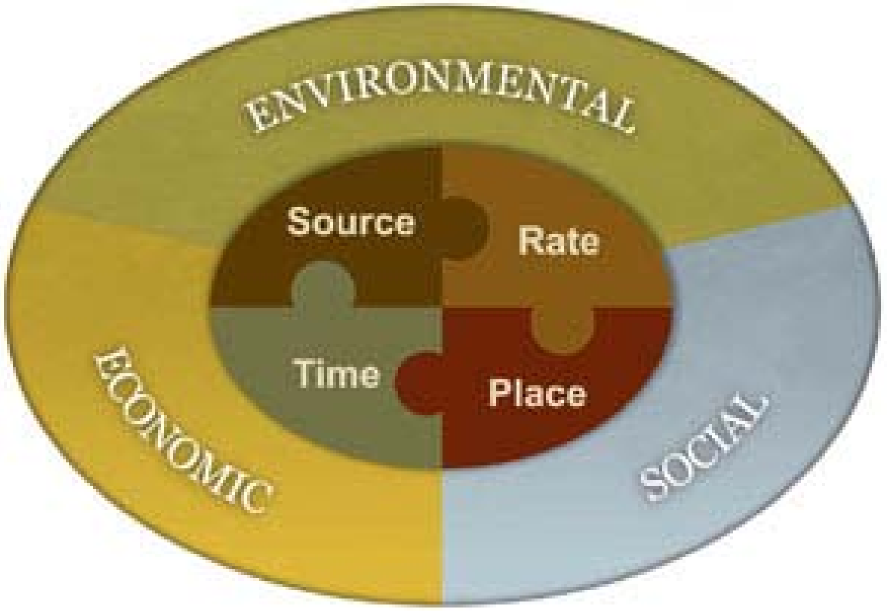


The Nösphere

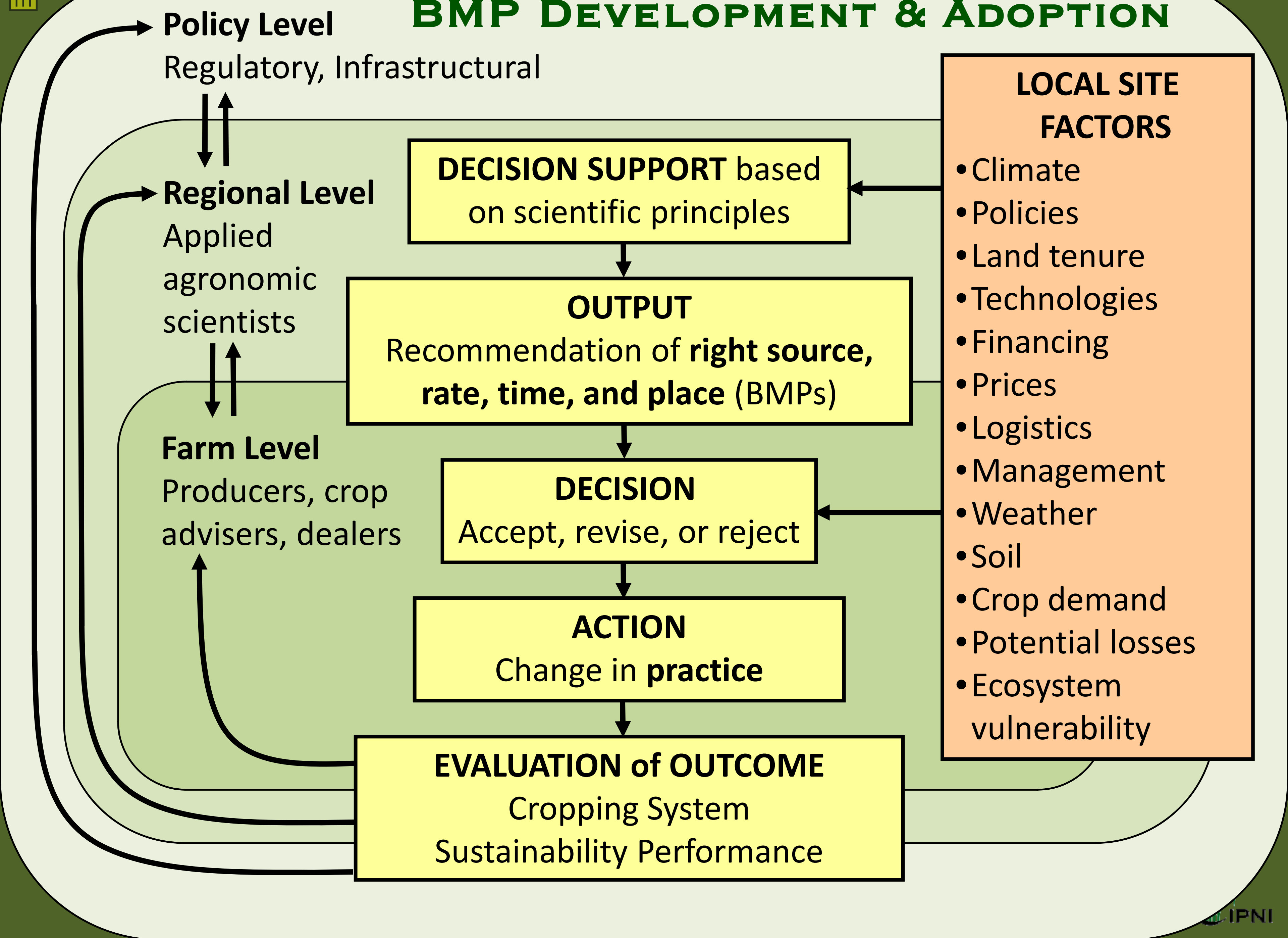
- Vladimir Vernadsky – *The Biosphere* (1926)
  - **Abiotic sphere**
  - **Biosphere**
  - **Nösphere** - the sphere of the cognitive process of man

4R Nutrient Stewardship

- Sustainability issues associated with fertilizer use:
  - Food and nutrition security
  - Employment
  - Soil fertility
  - Cadmium in soil
  - Eutrophication
  - Non-renewable resources
  - Greenhouse gas emissions
  - Stratospheric ozone depletion
  - Air quality: ammonia, smog
  - Water quality: nitrate, algae
  - Public perception



BMP Development & Adoption



Nutrient Use Efficiency – Definitions...

NUE Term	Calculation	Reported Examples
PFP - Partial factor productivity	Y/F	**40 to 80** units of cereal grain per unit of N
AE - Agronomic Efficiency	$(Y-Y_0)/F$	**10 to 30** units of cereal grain per unit of N
PNB - Partial nutrient balance (removal to use ratio)	U_H/F	**0 to > 1.0** - depends on native soil fertility and fertility maintenance objectives
RE – Recovery efficiency of applied nutrient	$(U-U_0)/F$	**0.1 to 0.3 – P, 1st year recovery** **0.5 to 0.9 – P, long-term recovery** **0.3 to 0.5 – N in cereals, typical** **0.5 to 0.8 – N in cereals, BMP**

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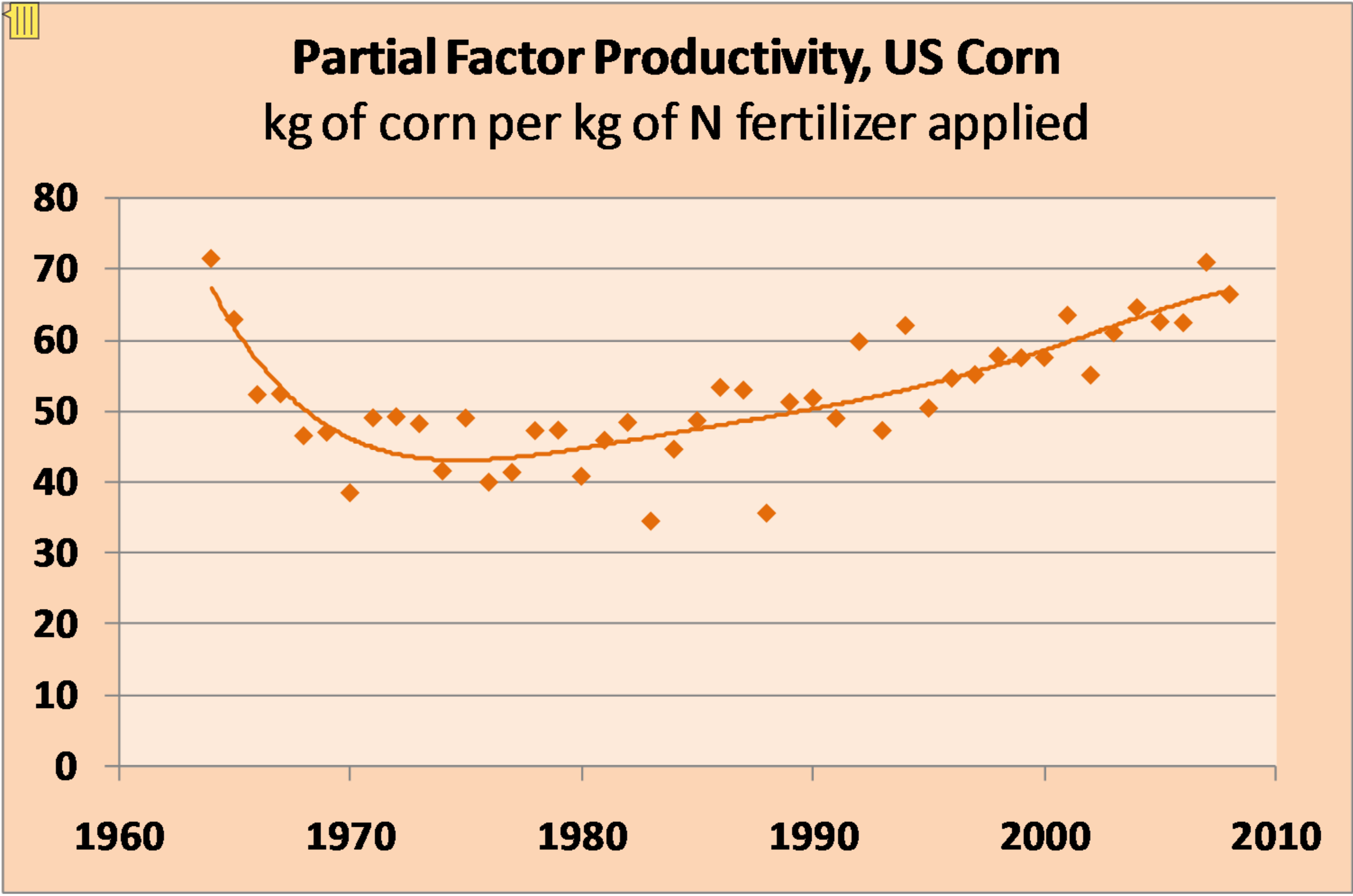

Partial Factor Productivity, US Corn
kg of corn per kg of N fertilizer applied
80
70
60
50
40
30
20
10
0
1960
1970
1980
1990
2000
2010

Replenishing Soil Fertility

Partial nutrient budget for North American crops, 1998-2000 (Tg).					
Nutrient	Crop Removal	Legume Fixation	Applied Fertilizer	Recoverable Manure	Removal to Use Ratio
N	16.8	7.7	12.9	1.3	77%
P_2O_5	6.0	-	4.7	1.7	95%
K_2O	9.9	-	4.9	2.0	144%

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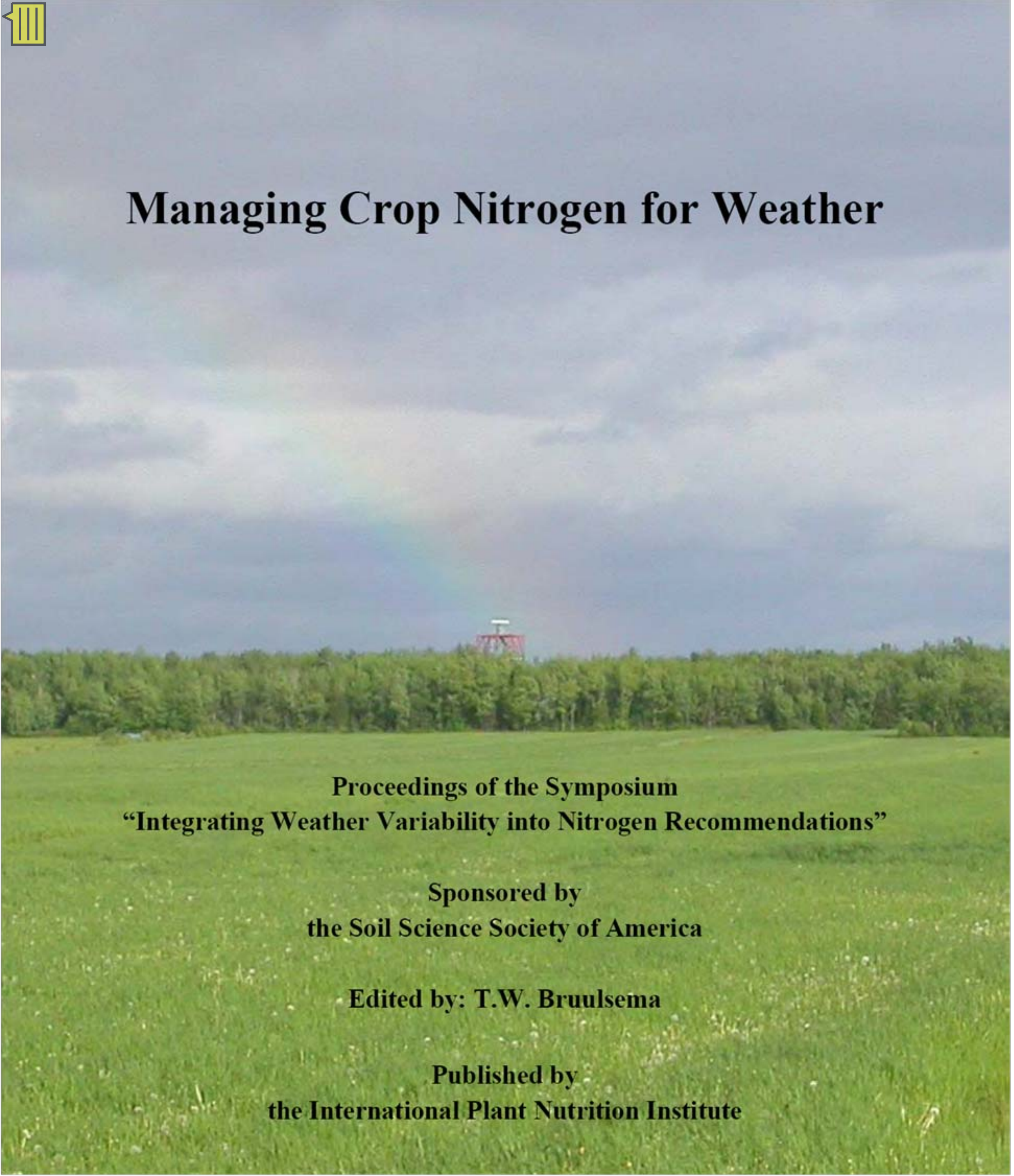
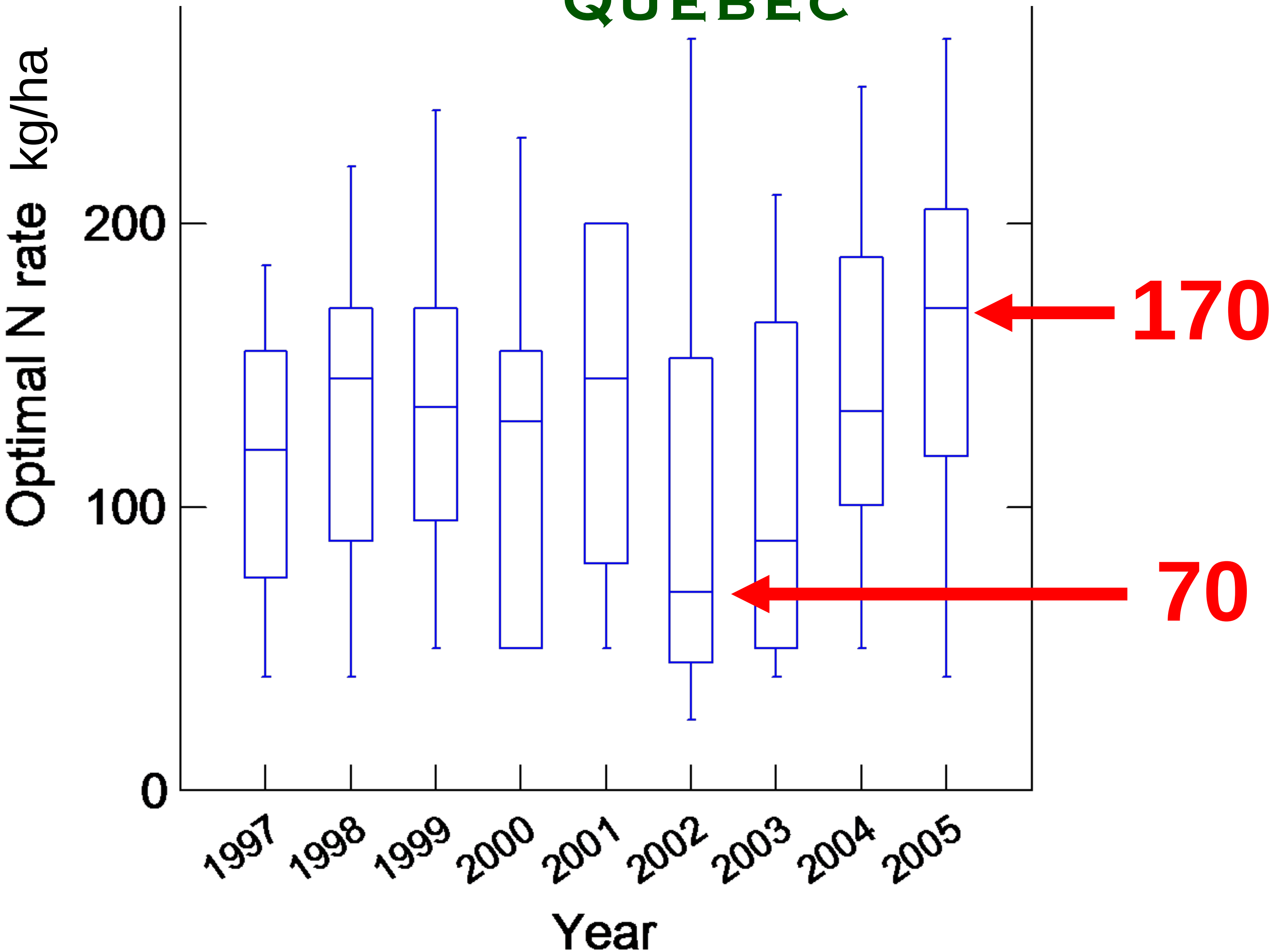
Improving Fertilizer N Use Efficiency (NUE)

- **The 4Rs: Right source-rate-time-place**
- **Nitrification inhibitors** – slow the conversion of NH_4^+ to NO_3^-
- **Urease inhibitors** – slow conversion to NH_4^+ and reduce potential NH_3 volatilization
- **Controlled-release N fertilizers** – release N over the growing season, matching availability and crop needs
- **Site-specific applications**
  - Variable rate, and possibly variable source
  - In-season sensing and variable rate/place application

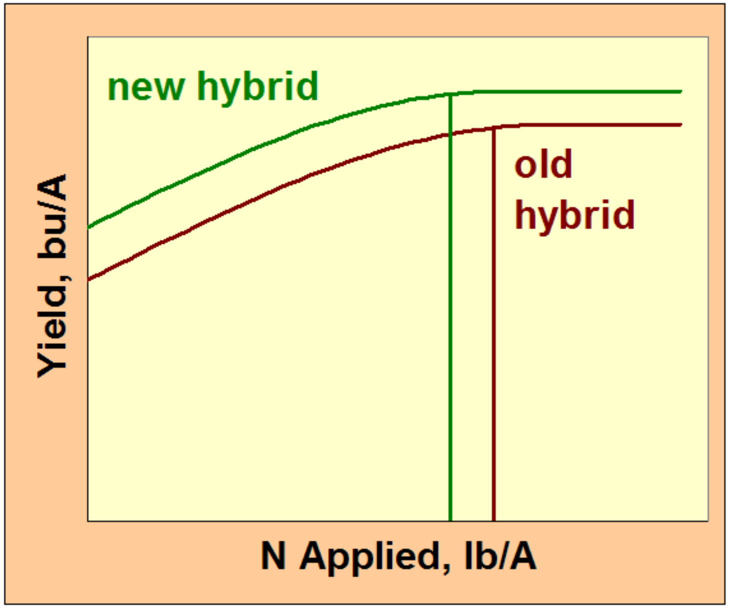

Managing Crop Nitrogen for Weather
Proceedings of the Symposium
“Integrating Weather Variability into Nitrogen Recommendations”
Sponsored by
the Soil Science Society of America
Edited by: T.W. Bruulsema
Published by
the International Plant Nutrition Institute

Variability in Optimal N Rates: Quebec

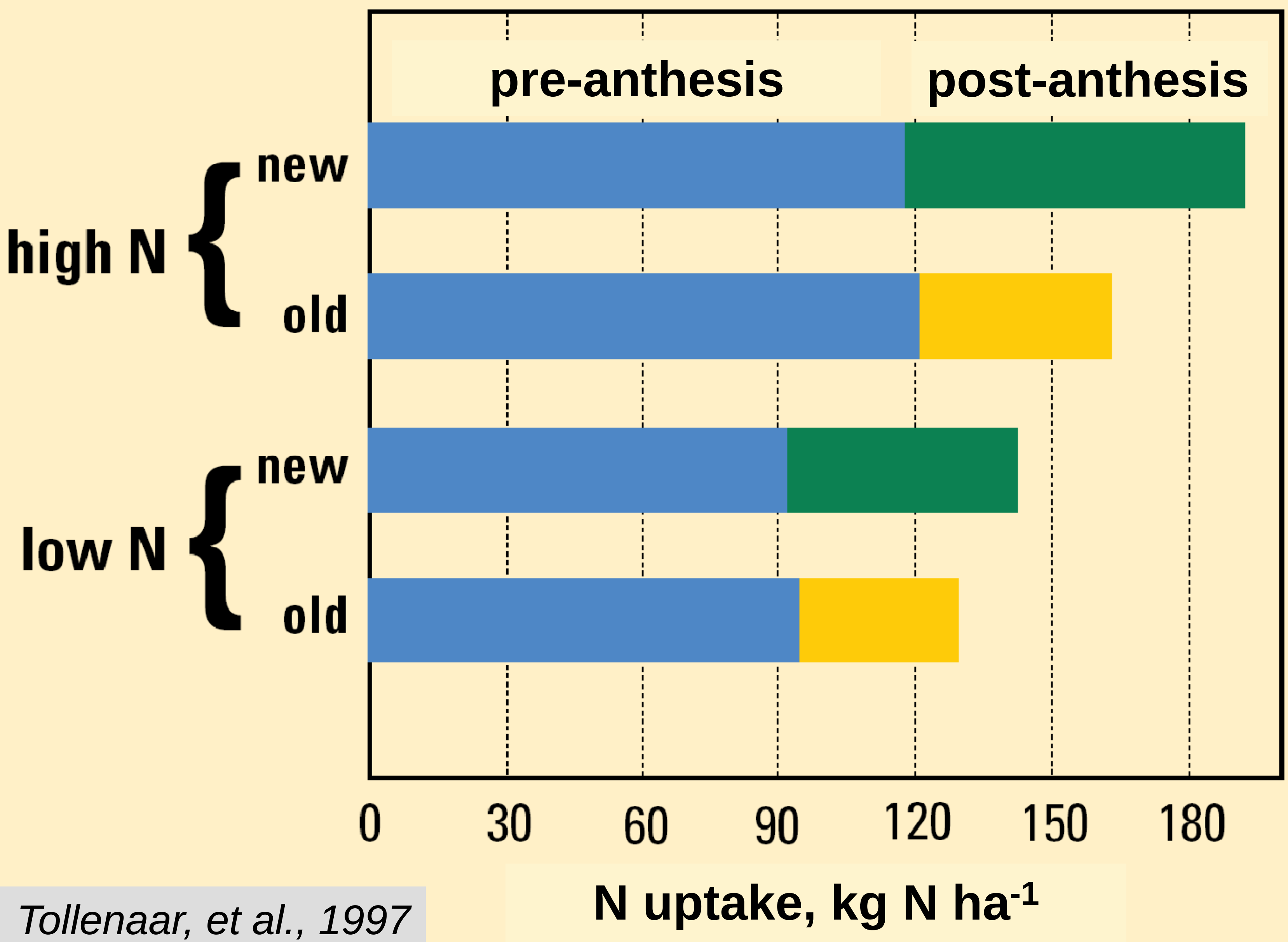


Ecological Intensification

- Grow more on less land, preserving natural ecosystems
- Grow more with less impact; minimize losses
- Apply principles of ecology to increase cropping system productivity



New Hybrids prolong N Uptake



Tollenaar, et al., 1997

Global Warming Potential
Life-Cycle Analysis

Cropping system	GWP in CO_2 equivalents (kg/ha/yr)				Mean Crop Yields (t/ha)			GWP/ Yield
	Soil C	N fertilizer	N_2O	Net GWP	C	W	S	$kgCO_2$ /Gcal
Nebraska, irrigated								
CC BMP	-1613	807	1173	1980	14.0			41
CC intensive	-2273	1210	2090	3080	15.0			60
Michigan, rainfed								
C-S-W, CT	0	270	520	1140	5.3	3.2	2.1	95
C-S-W, NT	-1100	270	560	140	5.6	3.1	2.4	11
Cropland conversion to forest	-1170	50	100	-1050				

Robertson et al. (2000); Adviento-Borbe et al. (2007)

			Indirect effects on N_2O emissions			Direct greenhouse gas emission[3] N_2O
			Water discharges as NO_3^-		NH_3 volatilization	
N Source[2]	Fertilizer N Management Practice		Leaching	Runoff		
	Right N placement					
	Scenario 1	Scenario 2				
AS, PA,U, UAN, AN	Subsurface incorporation	Surface broadcast				
U, UAN	Surface banded	Surface broadcast				
AS, PA, U, UAN, AN, PN	Shallow sidedress band – 1 in. (2 cm)	Sidedress band deeper than necessary – ≥ 4 in. (10 cm)				
U, UAN	Surface applied with urease inhibitor; abundant crop residues	No inhibitor				
U, UAN	Surface applied with urease inhibitor; minimal crop residues	No inhibitor				

Legend for ratings in table:

Ratings can represent broad, multiple ranges (e.g. negative to positive), or a single quartile. The rating scheme is based to some extent on a conservation practice rating scheme in Table 17 in EPA SAB (2008).

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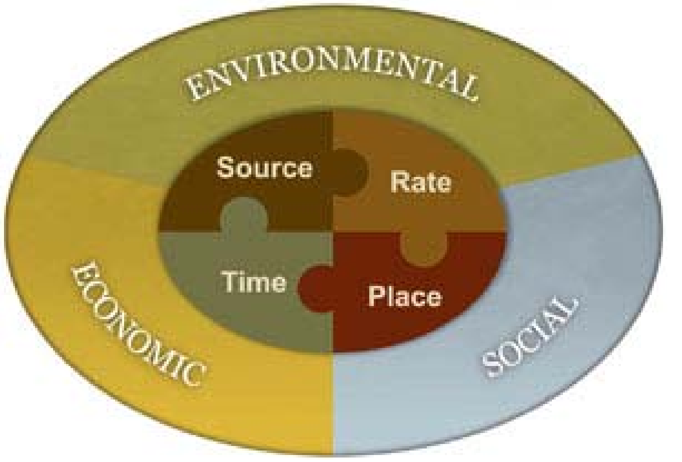
Knowledge Gaps & Research Priorities



- Contribution to sustainability goals
- Site-specific:
  - Global science for local impact
  - Global impacts of local management
- Stakeholder input
- Greenhouse gases:
  - LCA for CO_2, N_2O and CH_4
  - Soil microbiology for N_2O mitigation
  - Evaluation of EE fertilizer products
- Air & Water quality – NH_3 emissions, leakage of N & P
- Genetics for nutrient use efficiency – responsive to weather

Thank You

Better Crops, Better Environment … through Science

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