Mid-Atlantic Crop Management School
November 19-21, 2013
Ocean City, MD

IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Stewarding world reserves of fertilizer

Tom Bruulsema, Northeast
Steve Phillips, Southeast
Mike Stewart, Great Plains

4R nutrient stewardship

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

Toros Tarım

Uralchem

Uralkali

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

Its mission is to promote scientific information on responsible management of plant nutrition.

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Outline

1. N
2. P
3. K
4. Stewardship

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

nutrient stewardship

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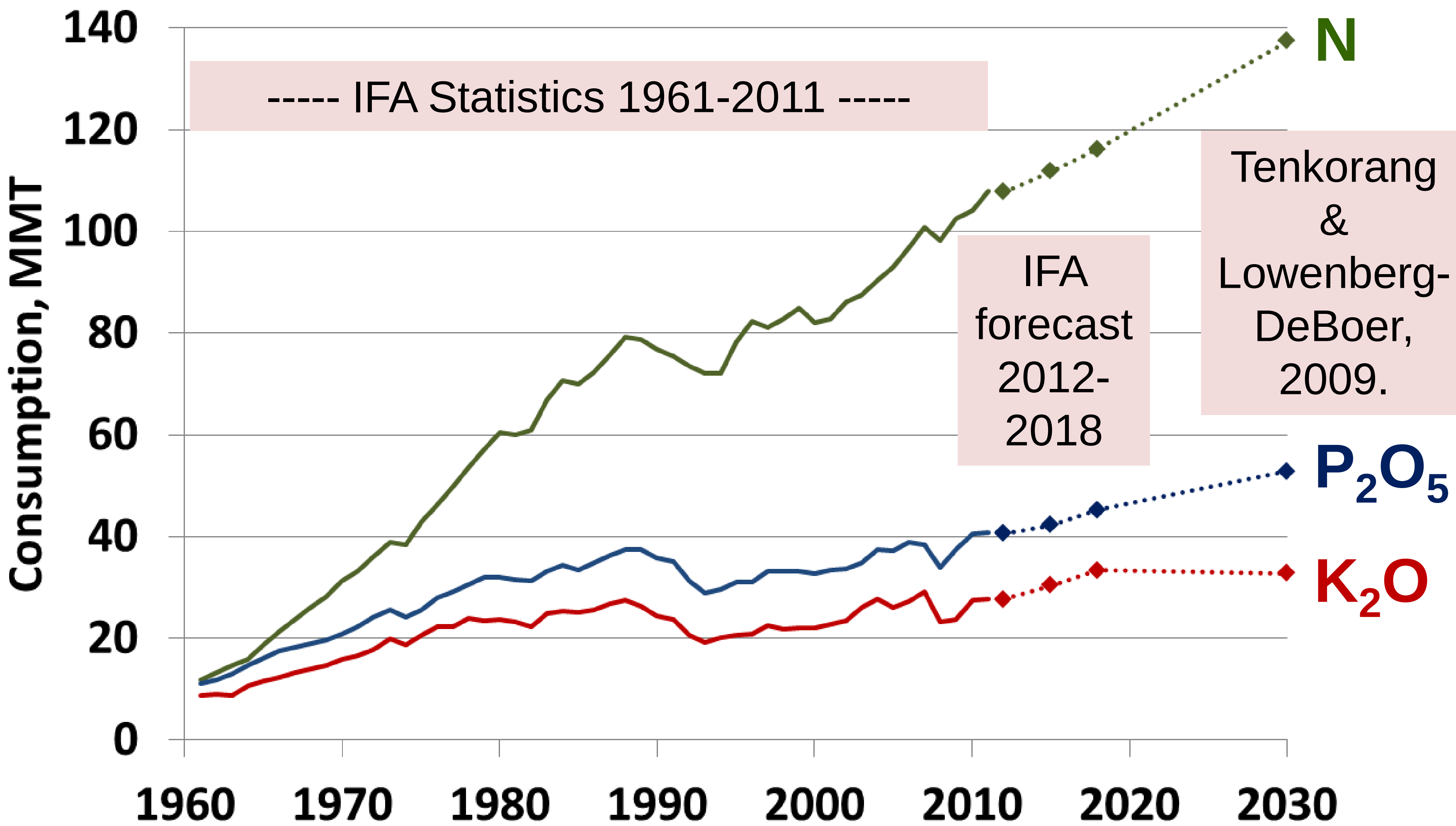
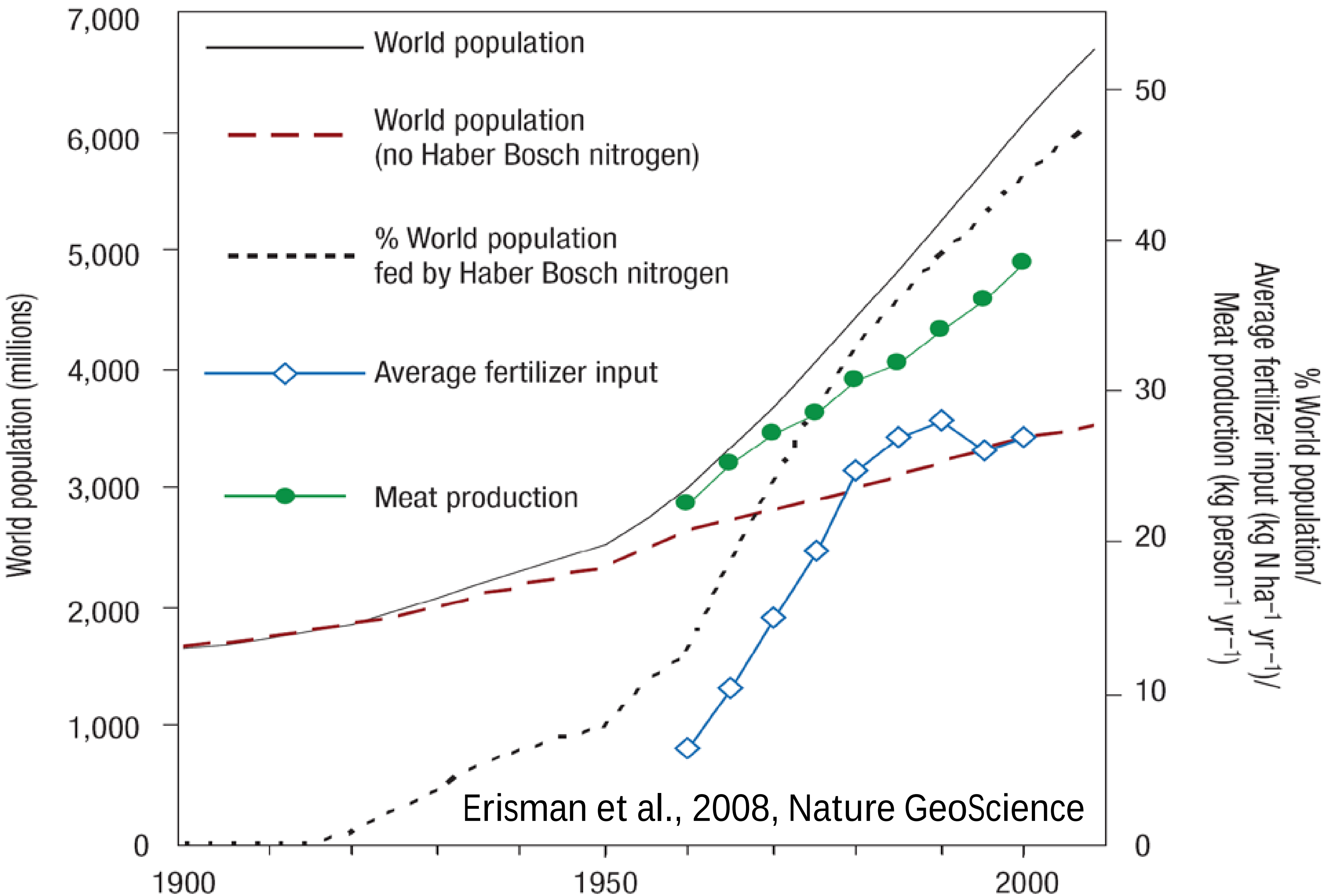
World Fertilizer Consumption
Historical and Projected

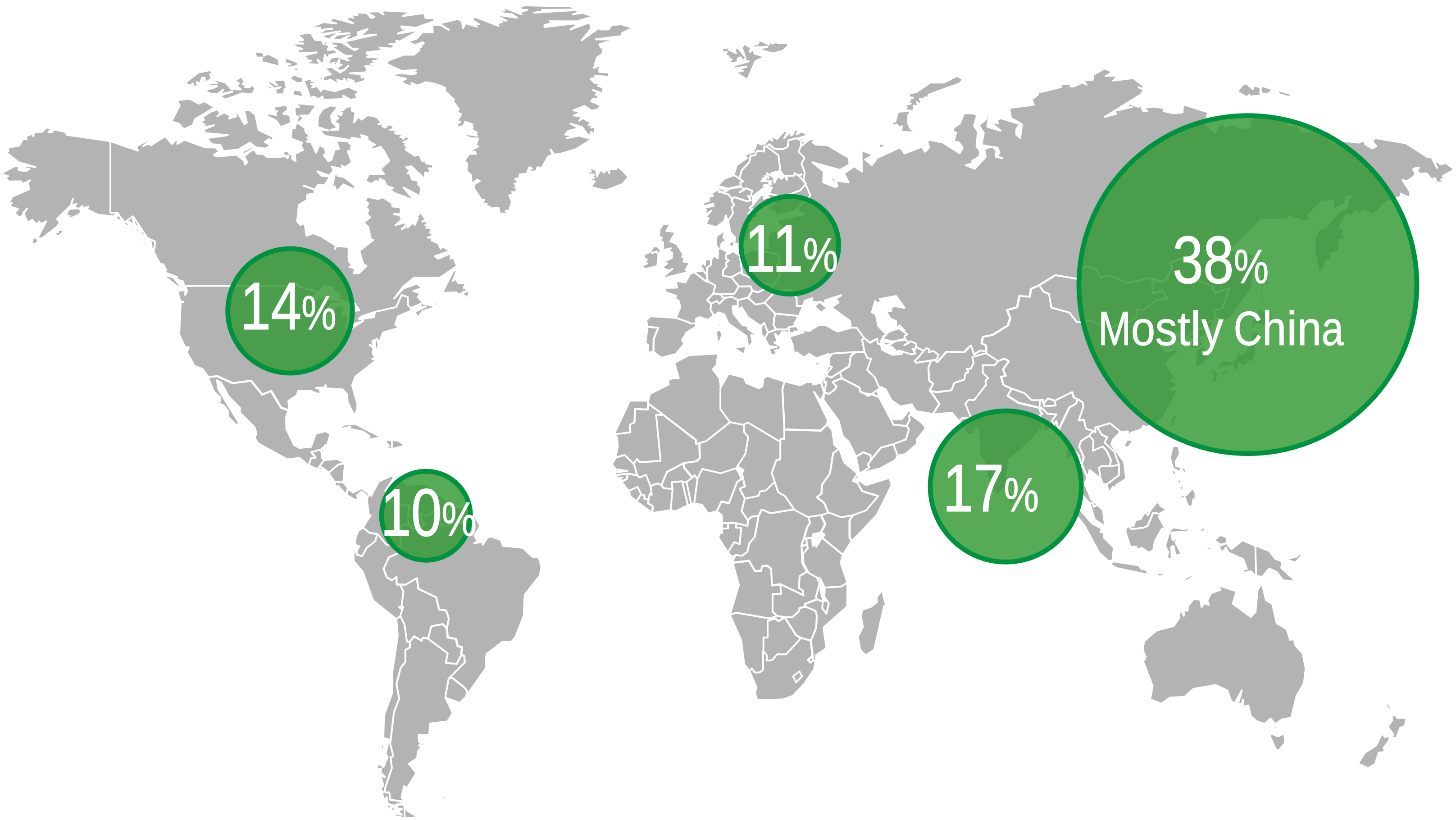


Human Population and N Use



Erisman et al., 2008, Nature GeoScience

Fertilizer consumption (2005/06 – 2007/08)



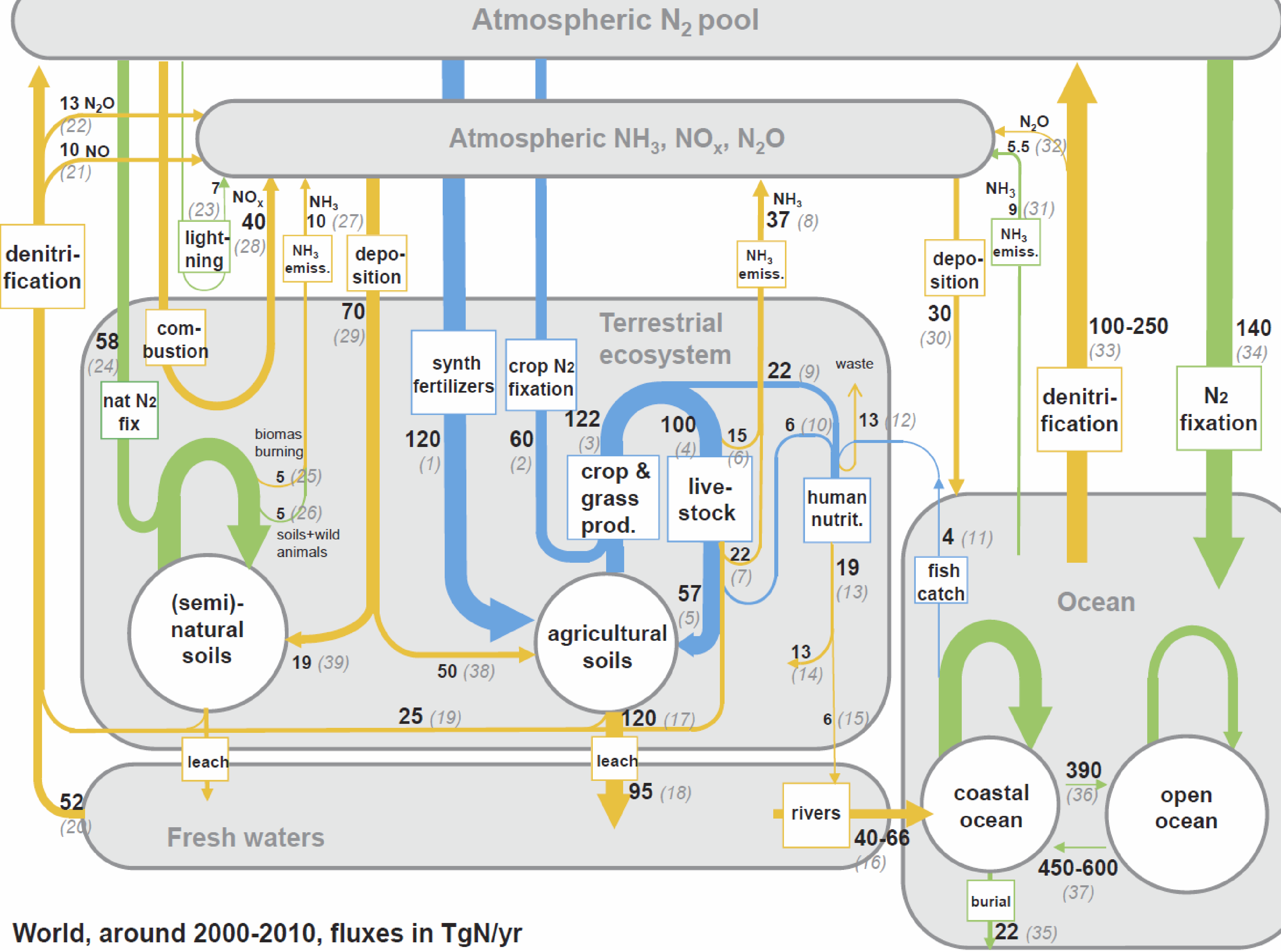
Our Nutrient World

The challenge to produce more food and energy with less pollution

Prepared by the Global Partnership on Nutrient Management in collaboration with the International Nitrogen Initiative

Global Overview on Nutrient Management

- GPNM 2013, 128 pages
- Analysis of global N & P cycles
- Essential for food [fuel & fiber]
- Threats to WAGES
- Full-chain N use efficiency 8% [could be higher than 16%]
- Multiple definitions of crop NUE
- Deserves attention… and refinement



World, around 2000-2010, fluxes in TgN/yr

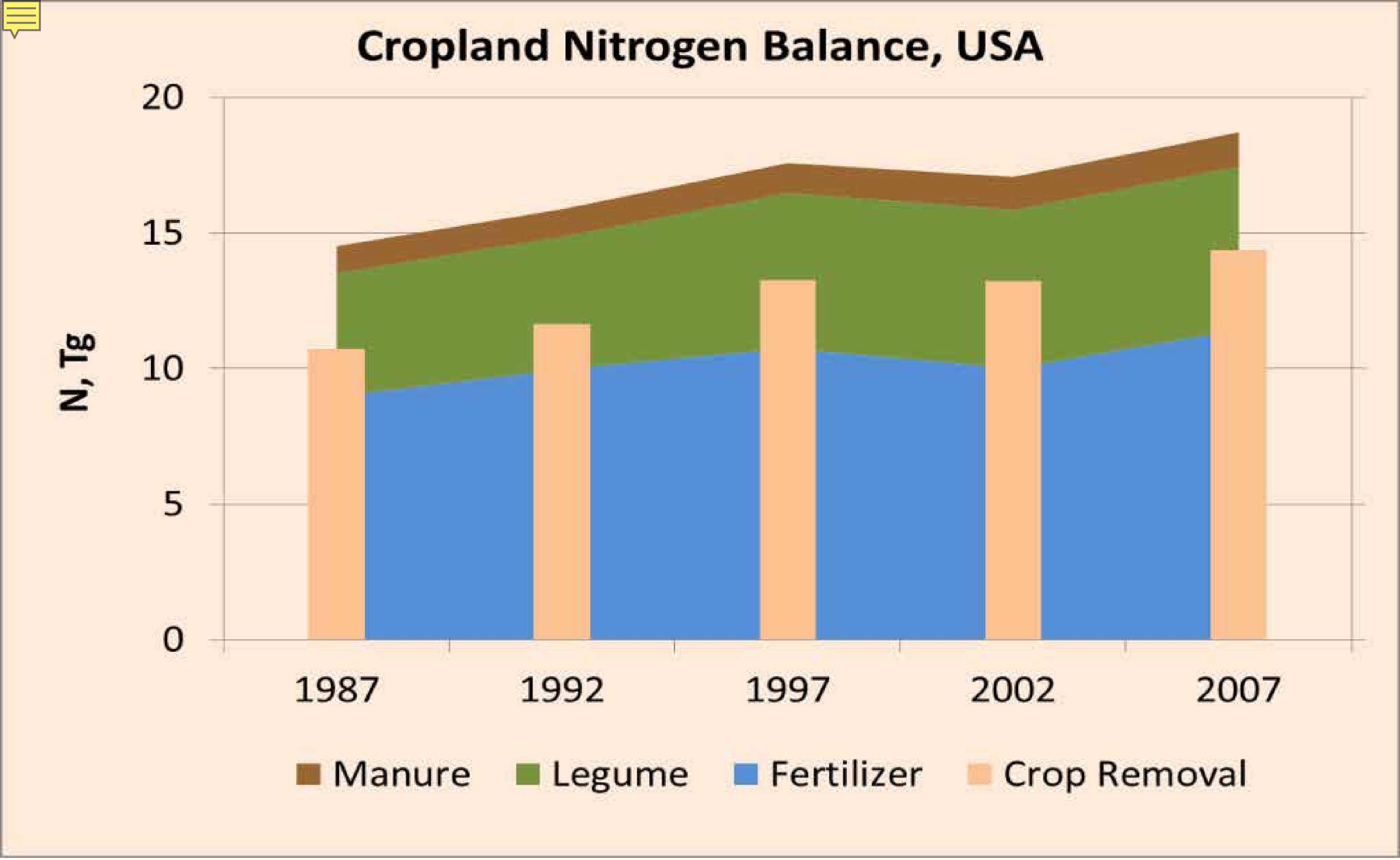


Figure 4.1: Inputs of N to US agricultural land, including recoverable manure, legume fixation, and commercial fertilizers, as compared to removal by crops (adapted from IPNI NuGIS, 2011). *[In Robertson et al., 2012, Biogeochemistry]*

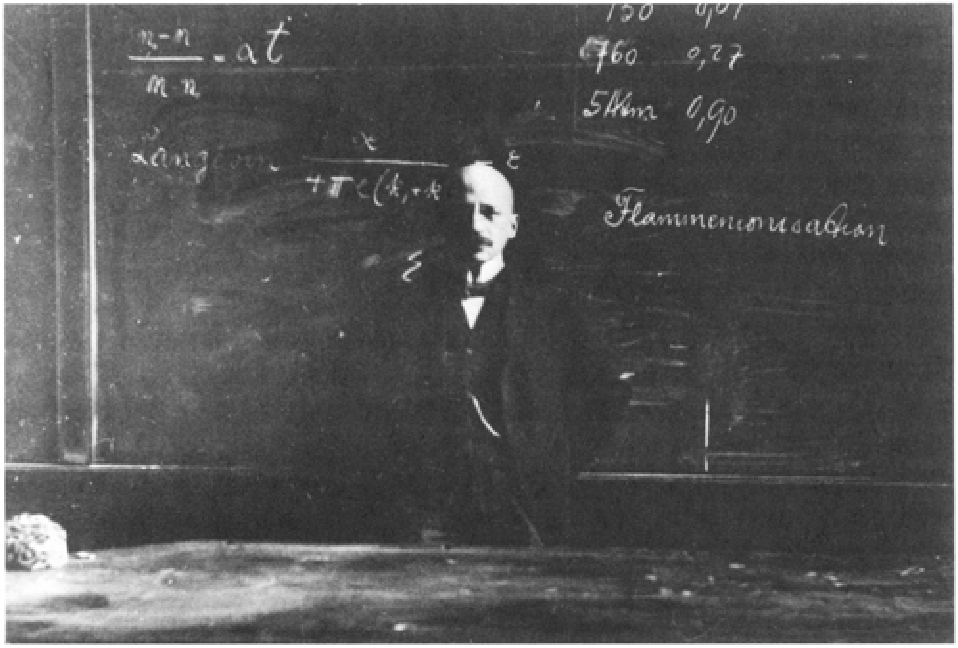
A quick look at N

- Ammonia (NH_3) basic N source used in making most N fertilizers
- Natural gas (CH_4) is feedstock for 75-80% of ammonia production
- Topic of reserves for N fertilizers is mostly a discussion of natural gas reserves

Natural gas longevity ...

- Previous reserve and consumption data = 55 years
- However, reserves estimates generally trending upward
  - Thus far producers have been replenishing reserves with new resources over time
  - Largest recent additions to reserve estimates
    - Venezuela
    - Saudi Arabia

Fritz Haber

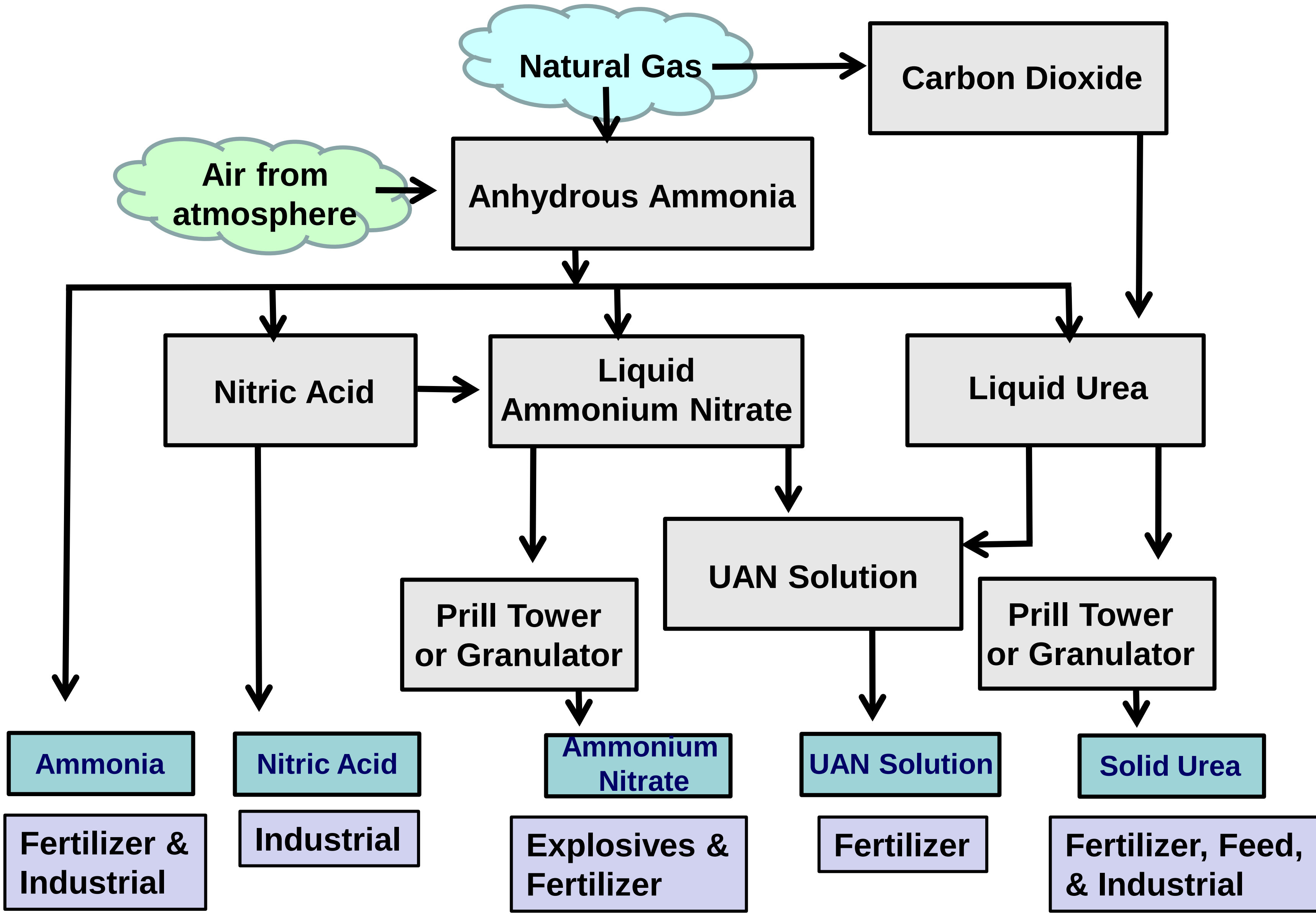


$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

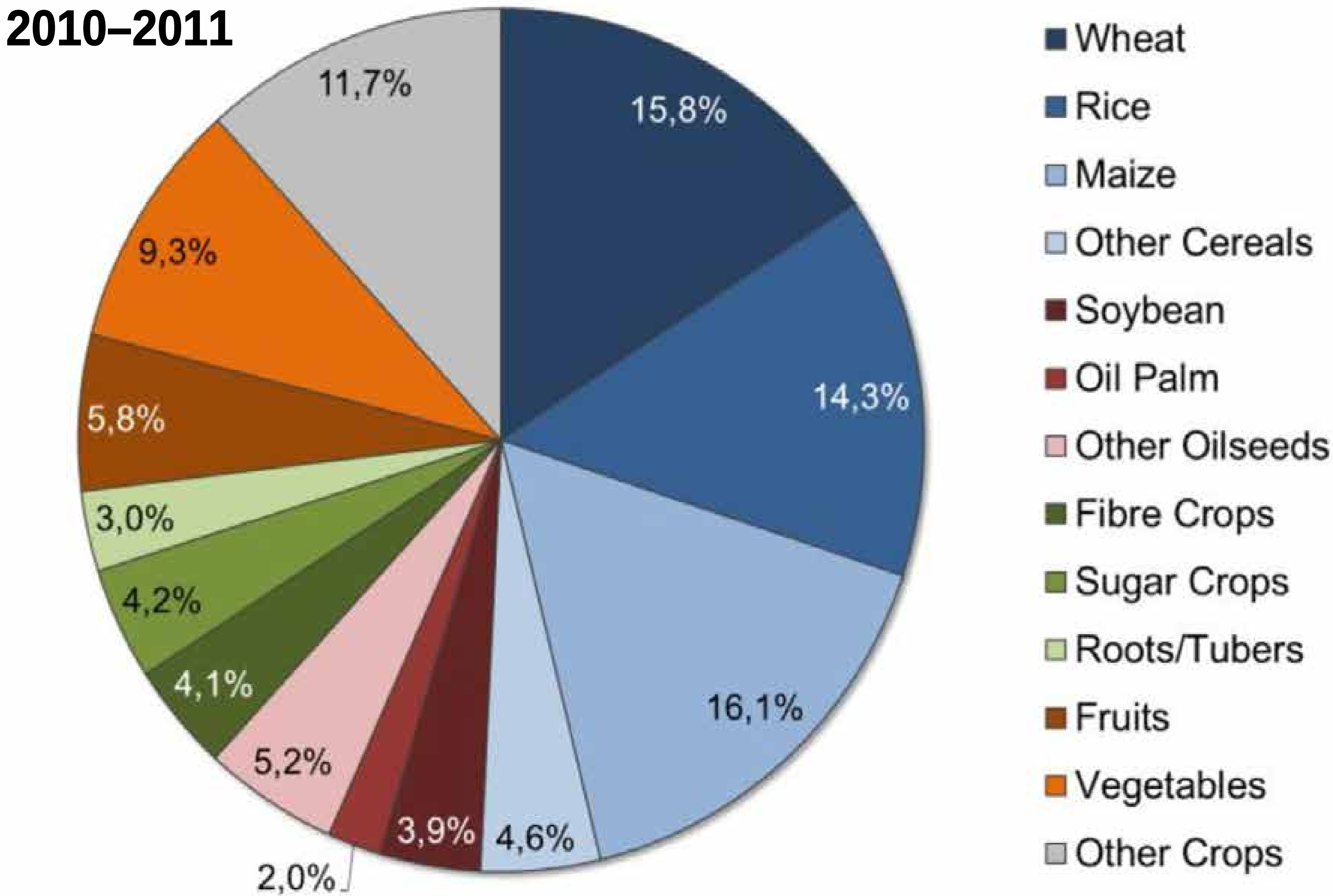
1904…I supported the opinion that the technical realization of a gas reaction under high pressure <u>was impossible</u>

1908… high temperatures (500-600 C), high pressures (100 atm) and osmium catalyst make the reaction possible

Nitrogen Fertilizer: A Simplified Process

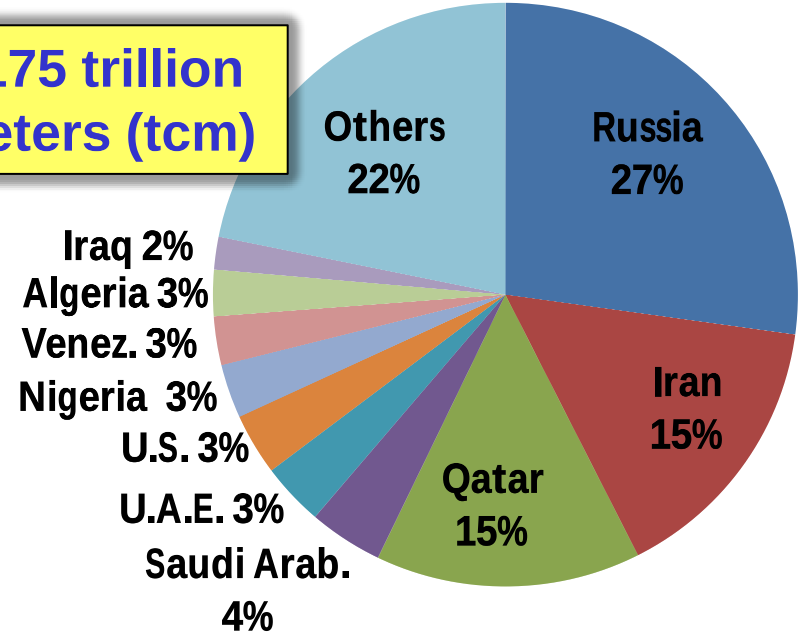


Total Fertilizer Use by Crop at the Global Level



IFA, 2013

Total = 175 trillion cubic meters (tcm)

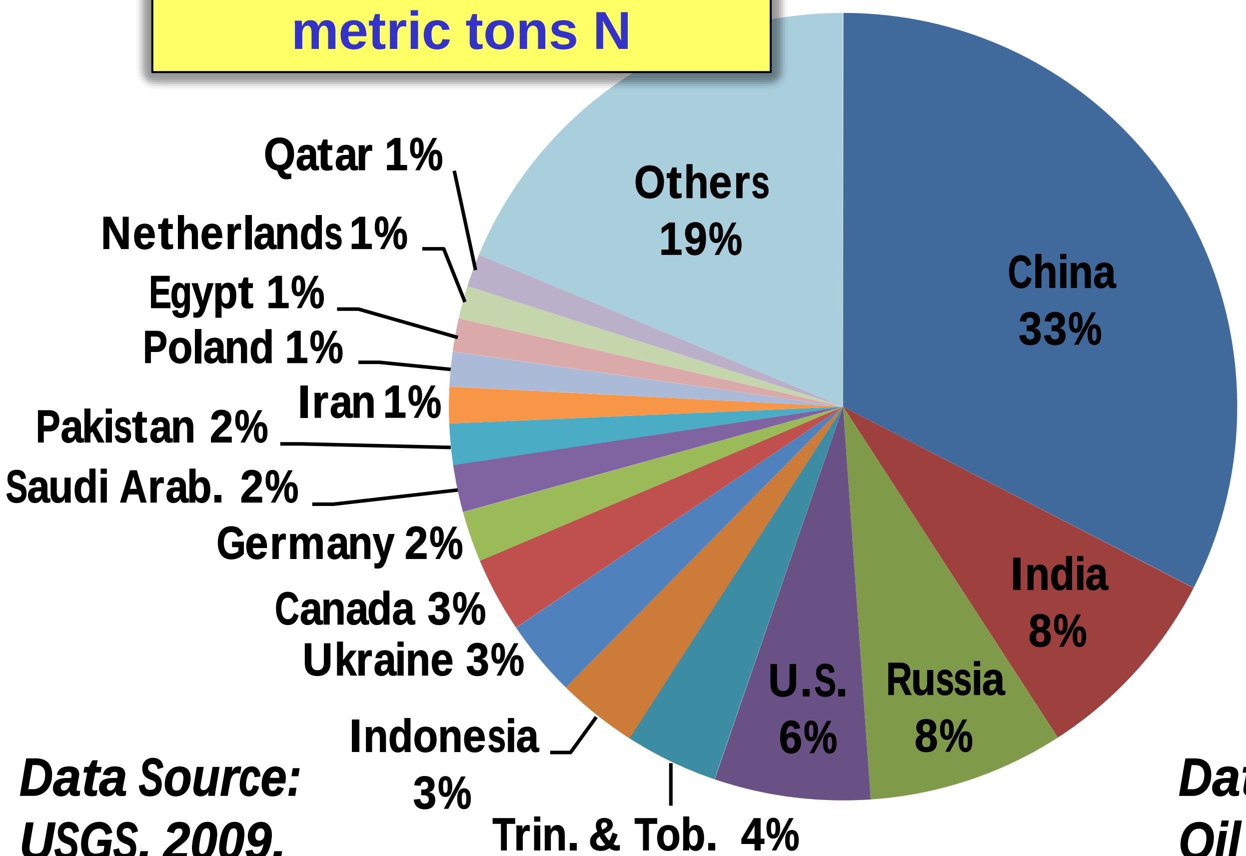


Natural gas reserves

Annual CH_4 consumption = 3.2 tcm

World annual ammonia production (average of 2007 and 2008)

Total = 133.6 million metric tons N



Data Source: USGS, 2009.

Data Source: Oil and Gas Journal, 2007.

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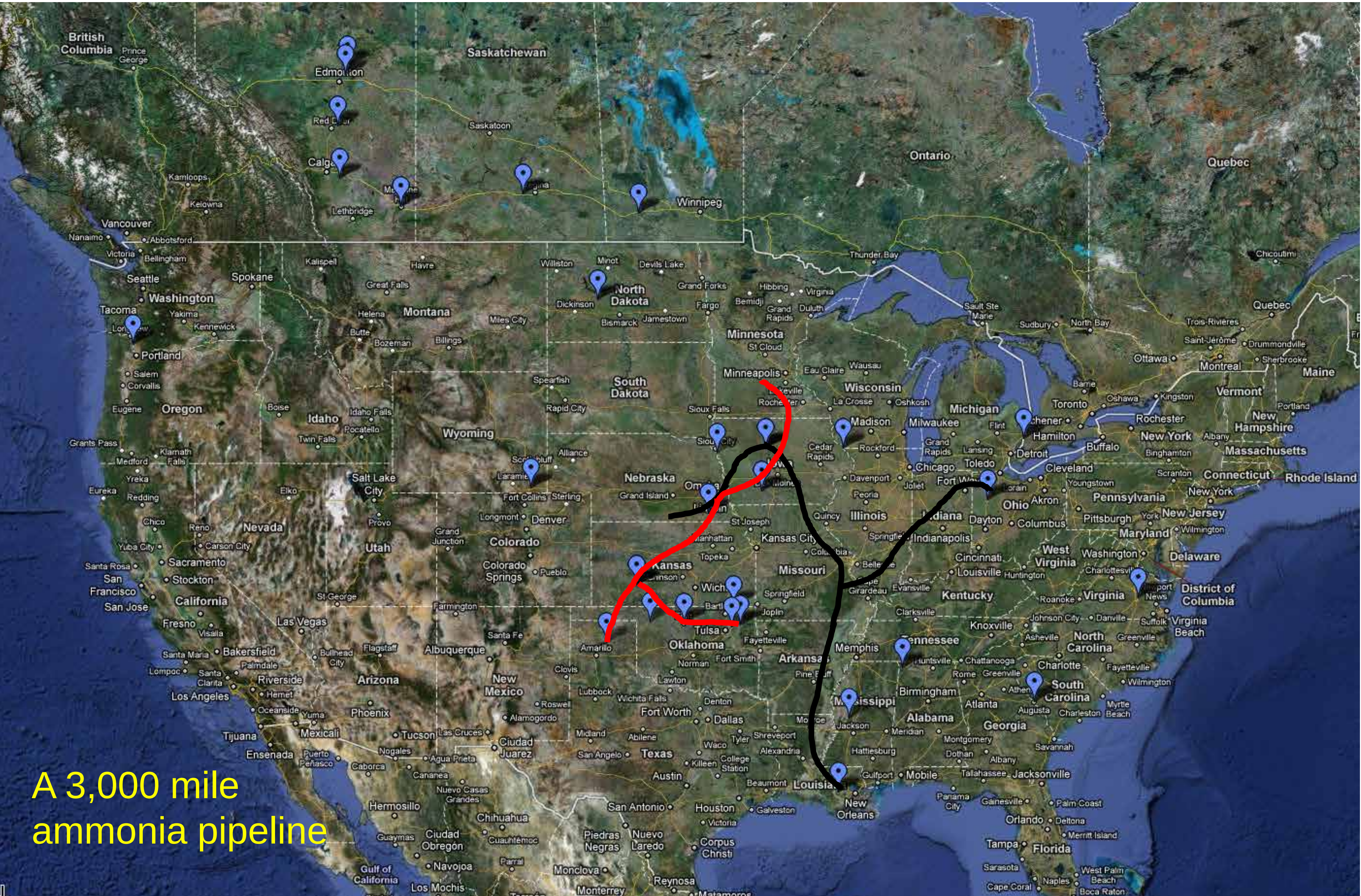
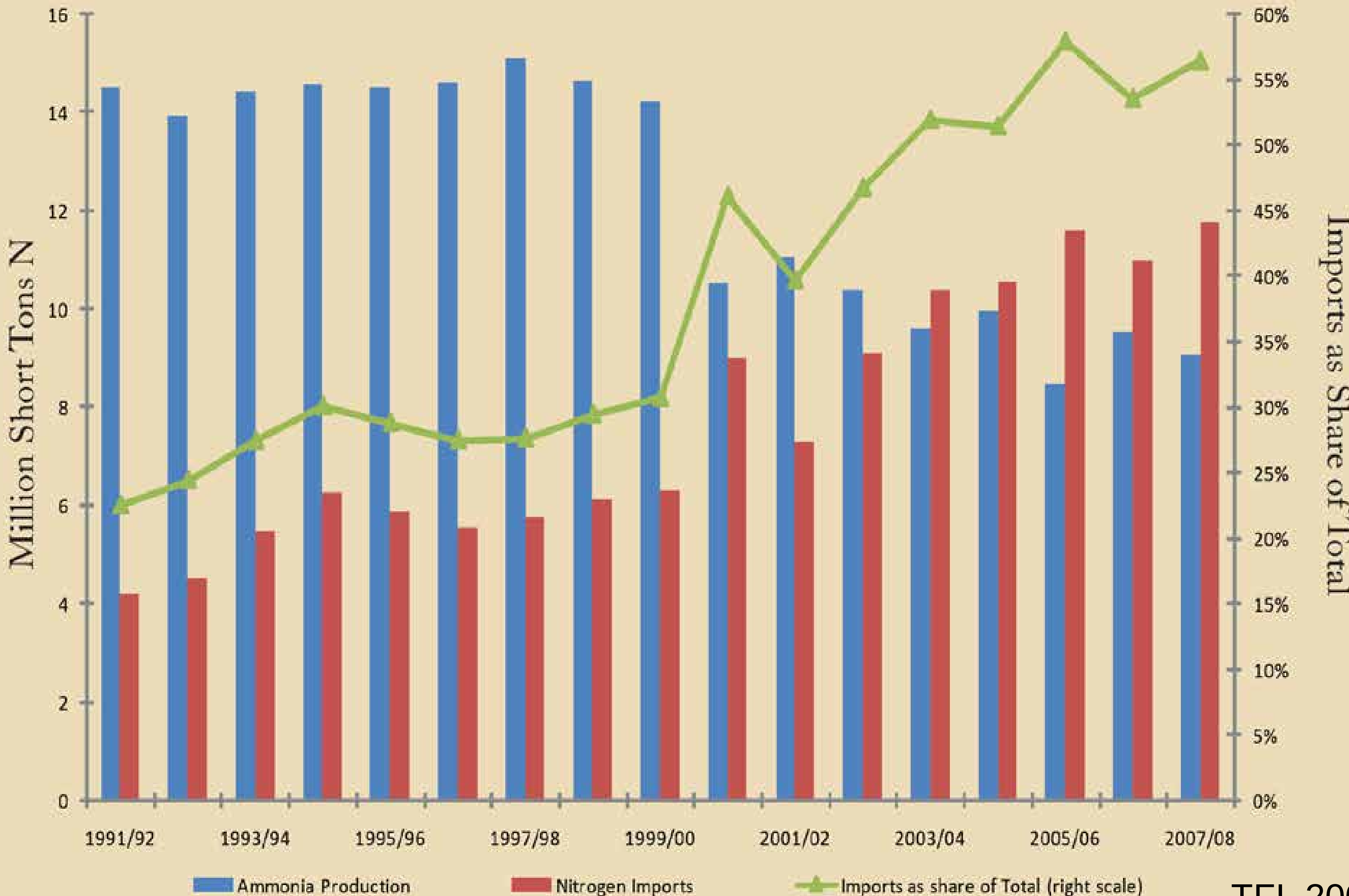
North America Ammonia Plants

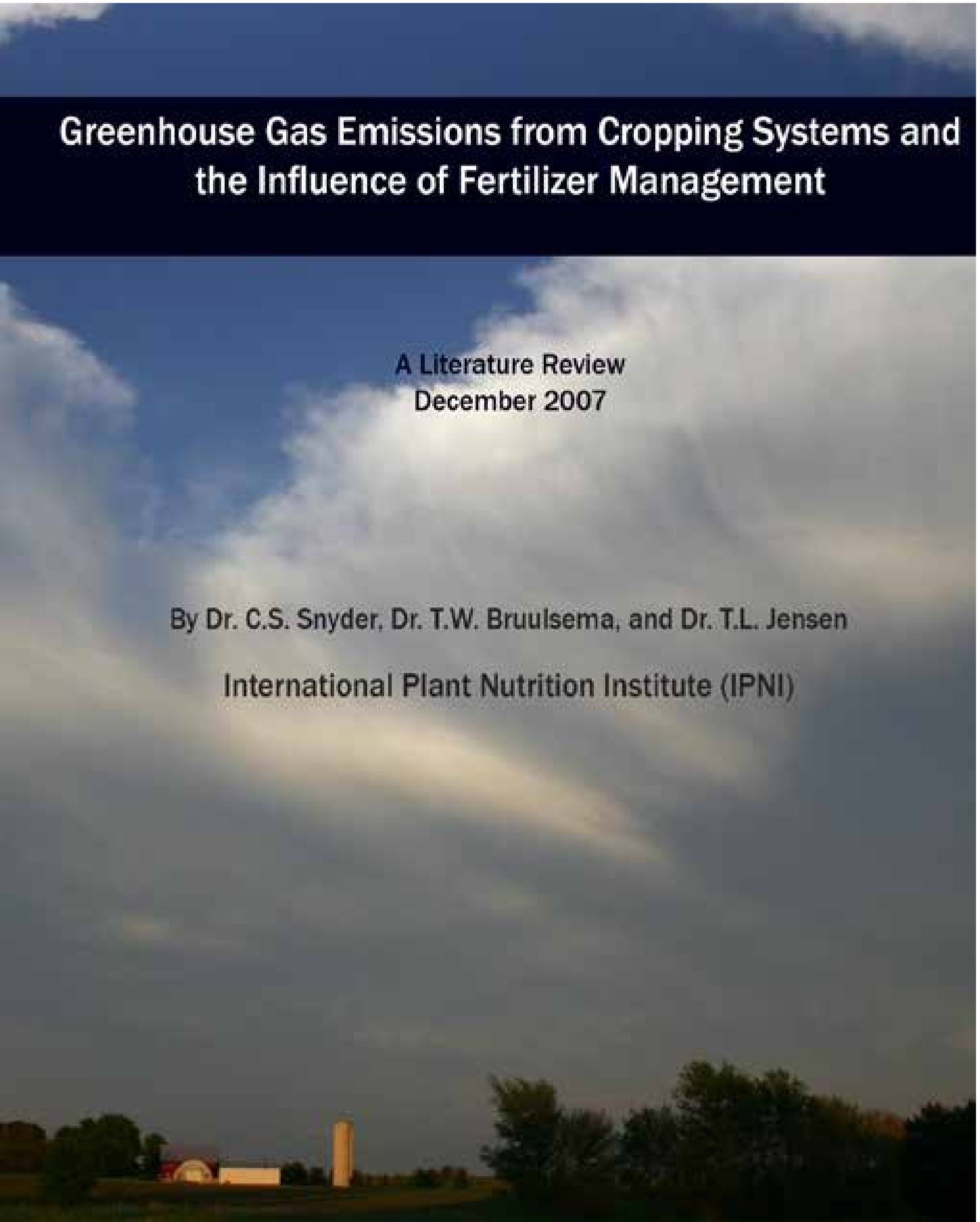


U.S. Nitrogen Sources - Ammonia Production and N Imports



TFI 2009

Greenhouse Gases and Fertilizer



$$0.88\ CH_4 + 1.26\ \text{Air} + 1.24\ H_2O$$
$$\rightarrow 0.88\ CO_2 + N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

GHG cost of N use	kg CO_2-eq /kg N
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	?

Stewarding N – summary

- Increasing production of ammonia for fertilizers is substantially increasing the global cycling of N
- Increase is projected to continue
- Huge benefits: feeding at least half of humanity
- Huge costs: cascade of impacts on air and water quality and greenhouse gases
- Reducing impacts demands improvement of N use efficiency

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TALKS | TEDX

Mohamed Hijri: A simple solution to the coming phosphorus crisis

FILMED OCT 2013 • POSTED OCT 2013 • TEDxUdeM

162,562 Views

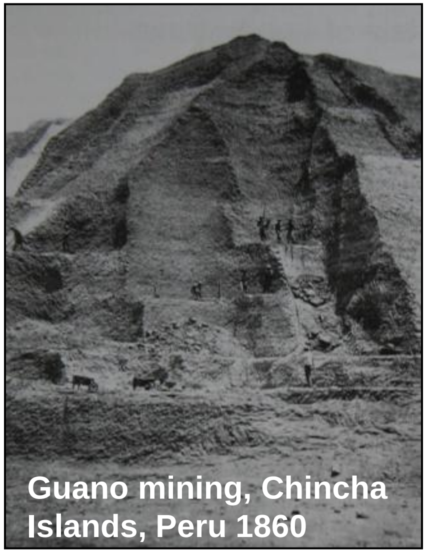
Biologist Mohamed Hijri brings to light
no one is talking about: We are runnin
phosphorus, an essential element tha
component of DNA and the basis of ce
communication. All roads of this crisis
how we farm -- with chemical fertilizers
element, which plants are not efficient
One solution? Perhaps ... a microsco
(*Filmed at TEDxUdeM.*)

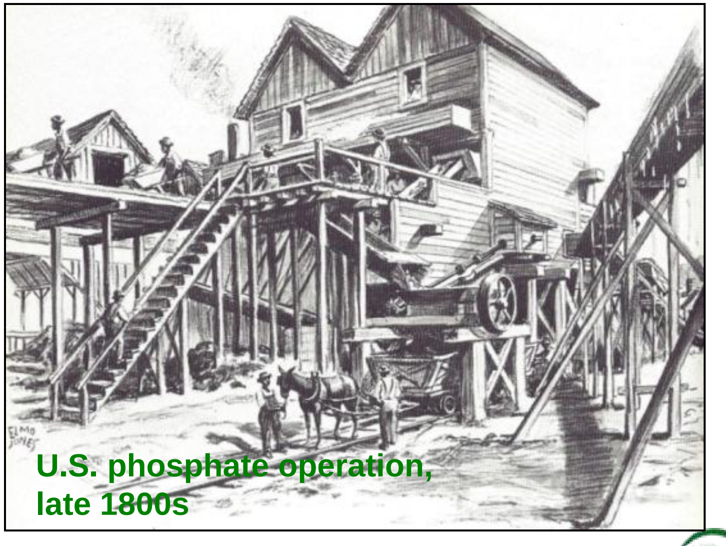
Mohamed Hijri studies arbuscular my
(AMF), seeking to understand the struc
and reproduction of these organisms,
symbiotic relationship with plant roots
Full bio »

Translated into English by Jane Roffe
Reviewed by Els De Keyser
Comments? Please email the translator

History of Phosphate Fertilizer

- Early sources were mostly animal based – bones, guano, manure
- Treatment of bones with acid to increase P solubility started early to mid 1800s
- Sulfuric acid treatment process of bones and P minerals (apatite) was patented in mid 1800s.
- Today most P fertilizer production is based on acidification of apatite from phosphate rock (PR)

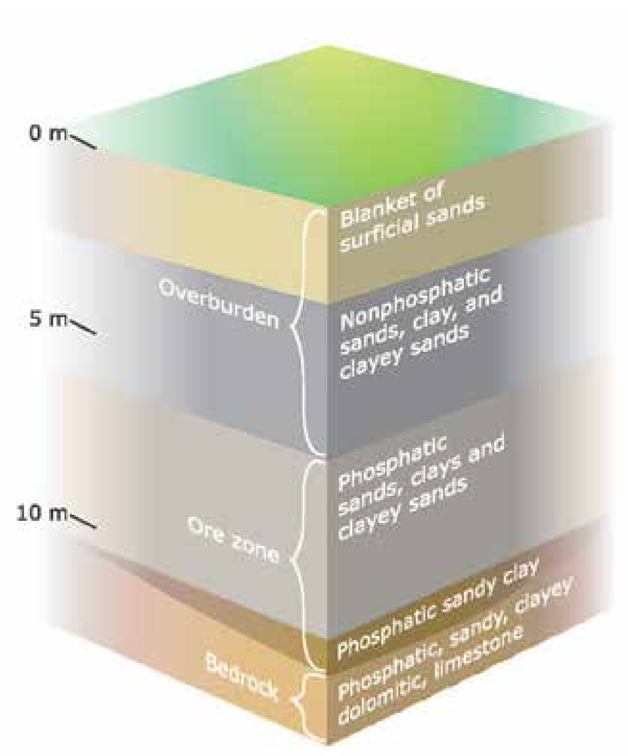

Guano mining, Chincha Islands, Peru 1860


U.S. phosphate operation, late 1800s

Formation of Phosphate Rock (PR) Deposits

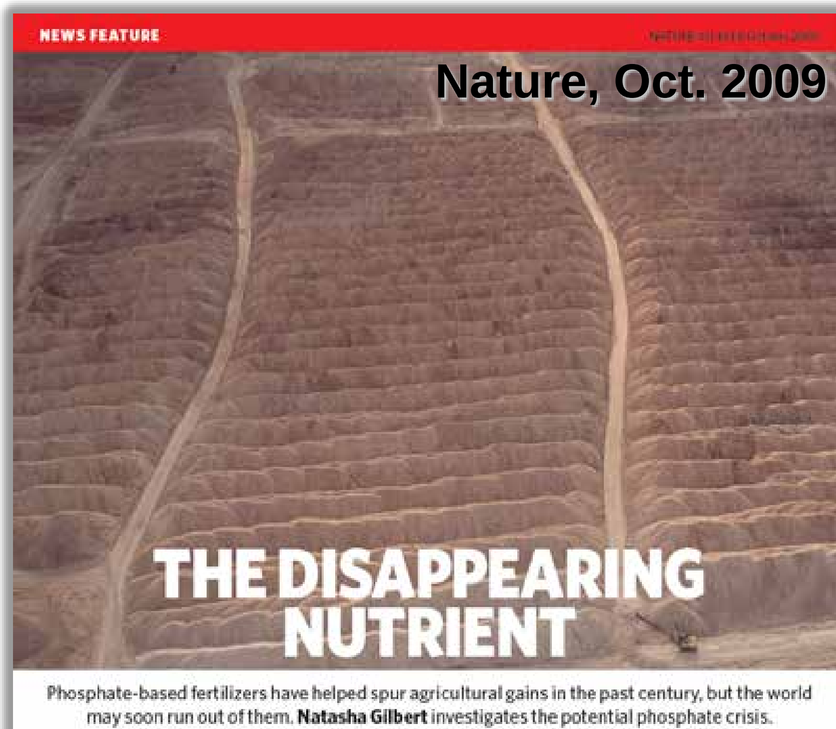
- Most (>80%) PR used in fertilizer production is sedimentary, but igneous deposits are also used
- Sedimentary PRs were formed in continental shelf marine environments, and are thus taken from present or former continental margins
- Igneous PR was formed mostly in shield areas and rift zones

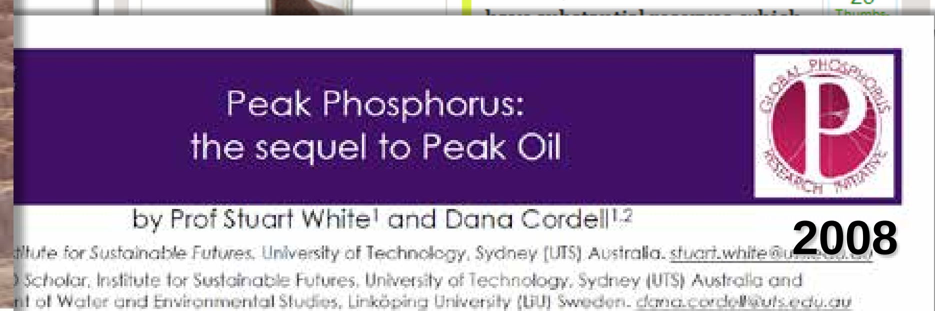
Generalized sedimentary deposit (Florida)



PR- reserves and resources

- Relevant history
  - Since mid to late 2000's there have been numerous articles (based on USGS data) pointing to a looming shortage of PR



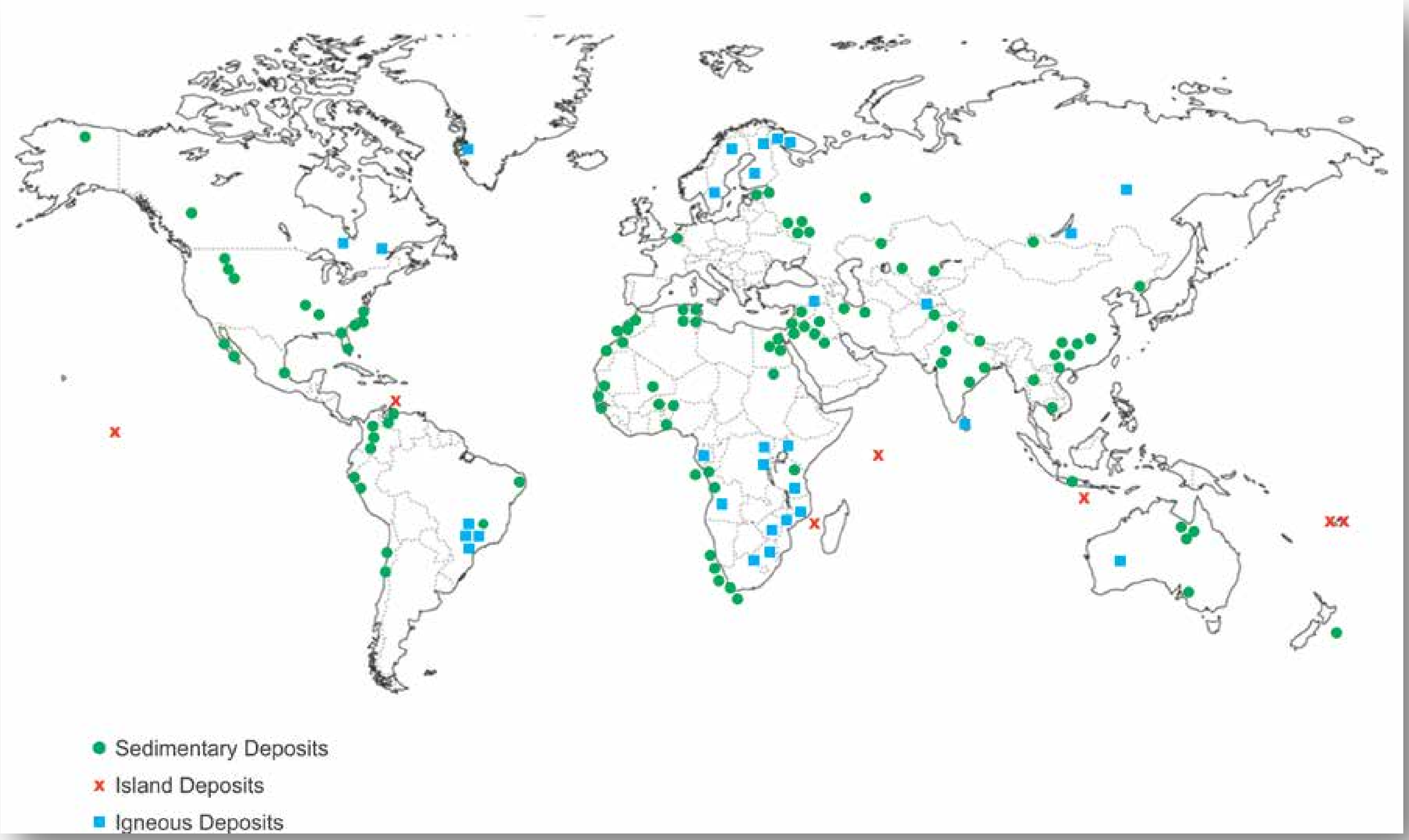


PR- reserves and resources

- Definitions:
  - Reserves- PR that can be economically produced at the time of the determination using existing technology.
  - Resources- PR of any grade, including reserves, that may be produced at some time in the future.

- System appears straightforward, but estimates are plagued with uncertainty

Map of World P Resources



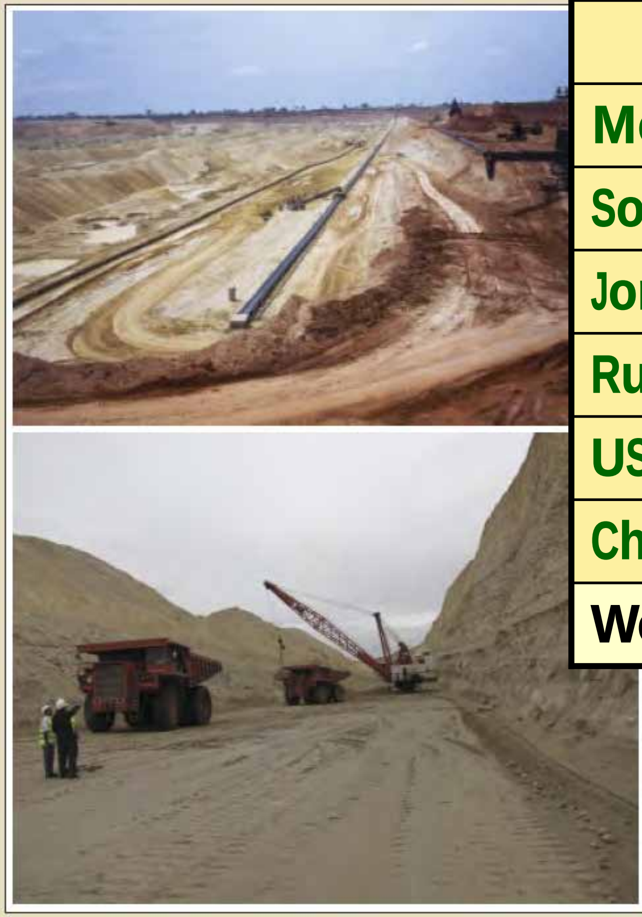
Source: IFDC

PR- reserves and resources

- Factors affecting uncertainty in reserve/resources accounting
  - Some countries incompletely explored
  - Producers may consider this information confidential
  - System requires massive data input and maintenance, and typically insufficient data are present in traditional literature
  - Inconsistency (worldwide) in terms and definitions
- Reserve estimates impacted by fluctuations in technology and economics
- These estimates are dynamic
- Should be viewed as general approximations

IFDC

World Phosphate Rock Reserves and Resources



Country	2011-12 Production	Reserves	Reserve Life
	Mt		Years
Morocco	28	50,000	1790
South Africa	2.5	1,500	600
Jordan	6.5	1,500	230
Russia	11	1,300	115
USA	29	1,400	49
China	85	3,700	43
World Total	**204**	**67,000**	**328**

Source: USGS, 2013

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

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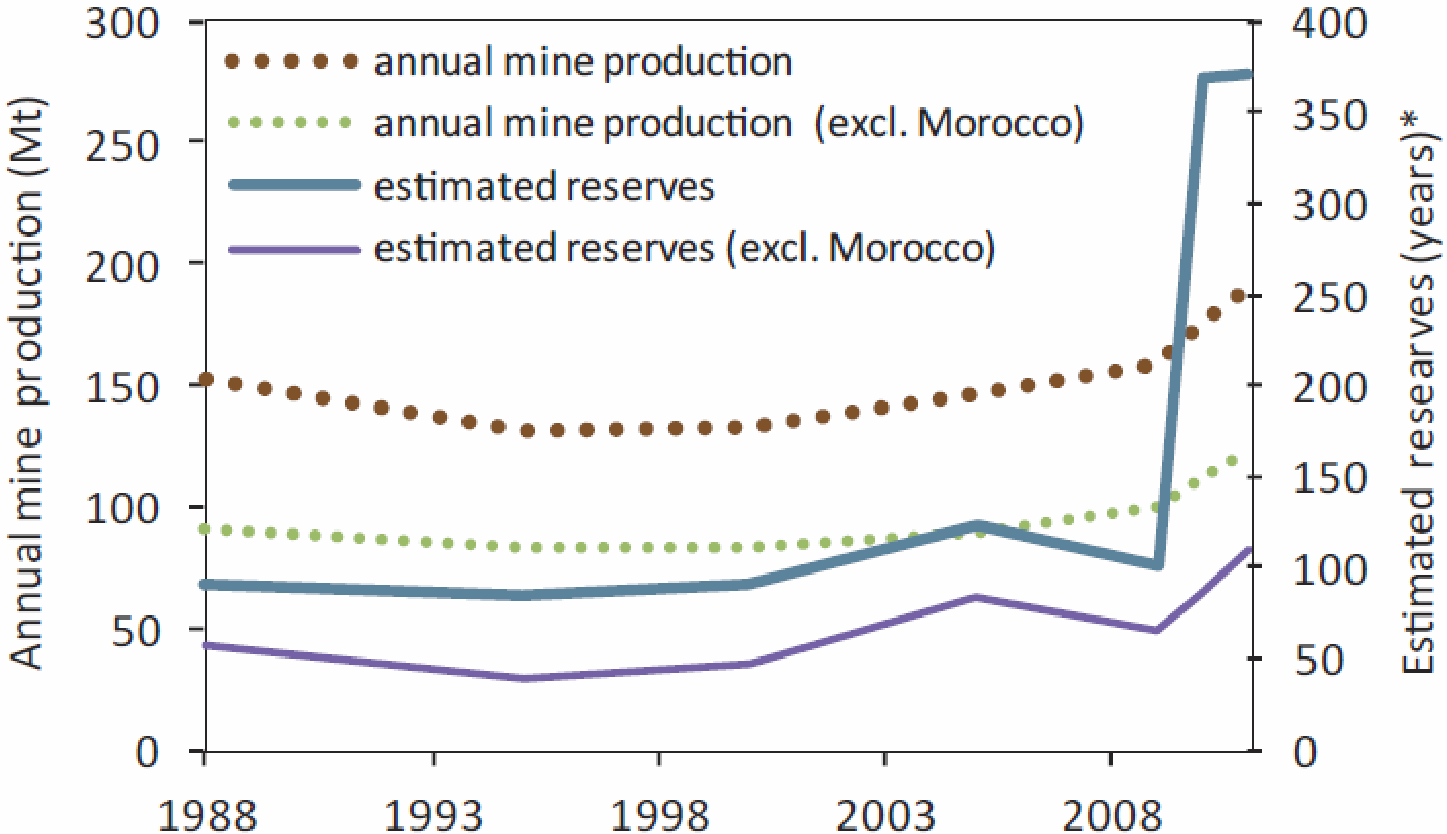

Sutton et al. 2013. *Our Nutrient World: The challenge to produce more food and energy with less pollution.* Global Partnership on Nutrient Management.

Figure 2.8 Time course of global annual mine production of phosphate rock and estimated reserves at current rates of mine production, also showing the estimates without including Morocco. Based on Scholz and Wellmer (Scholz & Wellmer, 2013), from the series of USGS reports (e.g., U.S. Geological Survey, 2012a). The estimated reserves without Morocco are shown based on current total global production, assuming that this is market driven. * Calculated as the ratio of global estimated reserve to annual mine production.

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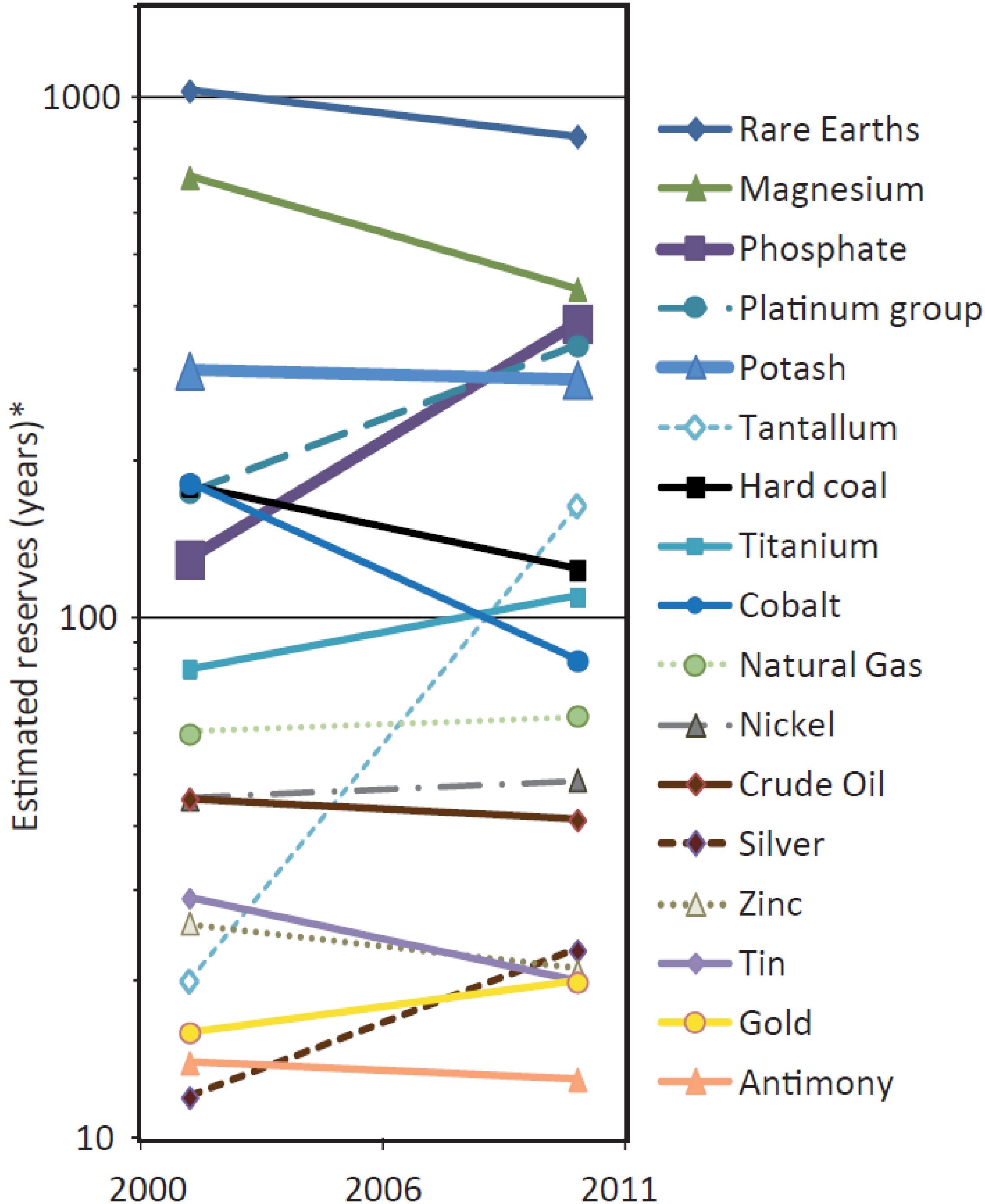
Many commodities have shorter reserve life than P

Figure 2.9 Putting phosphorus and potassium (potash) reserves into context: Changes in estimated reserves of different commodities as estimated in 2002/2003 and 2010 (Based on Scholz & Wellmer, 2013; U.S. Geological Survey, 2012a; U.S. Geological Survey, 2012c). * Ratio of estimated reserve to annual mine production.

Our Nutrient World, 2013



PR production as reported by USGS/USBM (Mineral Commodity Summaries)

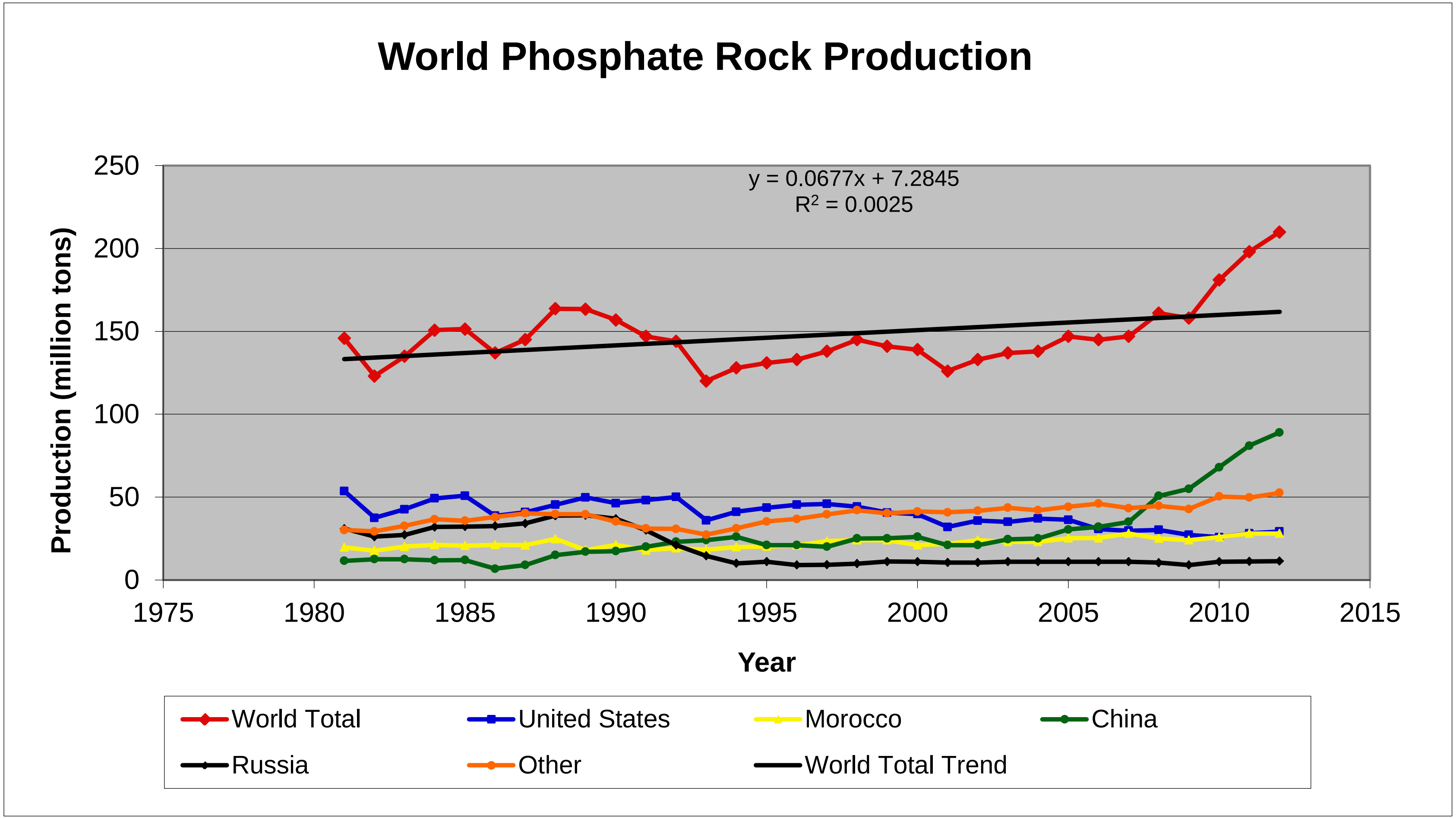
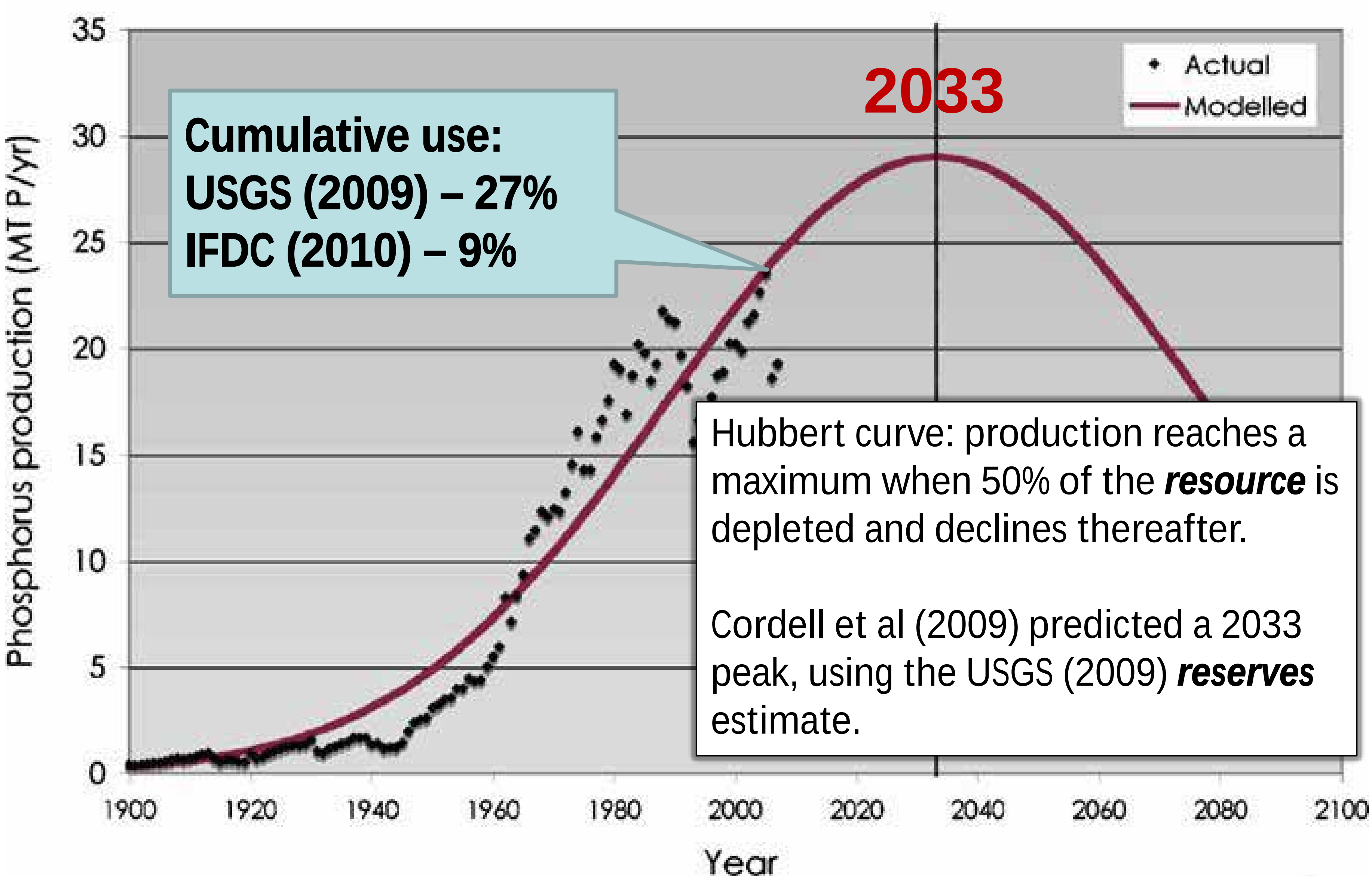


Figure provided by Van Kauwenbergh, IFDC

Peak phosphorus … like peak oil??



Cumulative use:
USGS (2009) – 27%
IFDC (2010) – 9%

Hubbert curve: production reaches a maximum when 50% of the ***resource*** is depleted and declines thereafter.

Cordell et al (2009) predicted a 2033 peak, using the USGS (2009) ***reserves*** estimate.

Cordell et al, 2009.

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Stewarding P – summary

- Worldwide there appears to be ample phosphate rock for the foreseeable future.
  - Based on USGS 2012 production and reserve estimates- 319 years of production
  - Based on USGS 2012 production and resource estimates- >1,400 years of production
- Reserves unevenly distributed geo-politically
  - Morocco, 75%; China, 6%; US 2% (USGS, 2012 reserves)
- Nonrenewable resource
- Managing water quality impacts demands attention to timing and placement, as well as control of P surplus (rate).

Potassium (K) and Potash

- K present in most rocks and soils
- Economic sources ...
  - sedimentary salt beds remaining from ancient inland seas (evaporite deposits)
  - salt lakes and natural brines
- Potash refers to a variety of K-bearing minerals

Most common examples:

Sylvite	Sylvinite	Hartsalz	Langbeinite
KCl	$KCl + NaCl$	Sulfate salts	$K_2SO_4 \cdot 2MgSO_4$

First U.S. Patent issued:
July 31, 1790
Improved production of potash

The United States.

To all to whom these Presents shall come Greeting.

Whereas Samuel Hopkins of the City of Philadelphia and State of Pensylvania hath discovered an Improvement, not known or used before such Discovery, in the making of Pot ash and Pearl ash by a new Apparatus and Process; that is to say, in the making of Pearl ash 1st by burning the raw Ashes in a Furnace, 2d by dissolving and boiling them when so burnt in Water, 3d by drawing off and settling the Ley, and 4th by boiling the Ley into Salts which then are the true Pearl ash; and also in the making of Pot ash by fluxing the Pearl ash so made as aforesaid; which Operation of burning the raw Ashes in a Furnace, preparatory to their Dissolution and boiling in Water, is new, leaves little Residuum, and produces a much greater Quantity of Salt: These are therefore in pursuance of the Act, entituled "An Act to promote the Progress of useful Arts", to grant to the said Samuel Hopkins, his Heirs, Administrators and Assigns, for the Term of fourteen Years, the sole and exclusive Right and Liberty of using, and vending to others the said Discovery, of burning the raw Ashes previous to their being dissolved and boiled in Water, according to the true Intent and Meaning of the Act aforesaid. In Testimony whereof I have caused these Letters to be made patent, and the Seal of the United States to be hereunto affixed. Given under my Hand at the City of New York this thirty first Day of July in the Year of our Lord one thousand seven hundred & Ninety.

G Washington

City of New York July 31st 1790. –

I do hereby Certify that the foregoing Letters patent were delivered to me in pursuance of the Act, entituled "An Act to promote the Progress of useful Arts"; that I have examined the same, and find them conformable to the said Act.

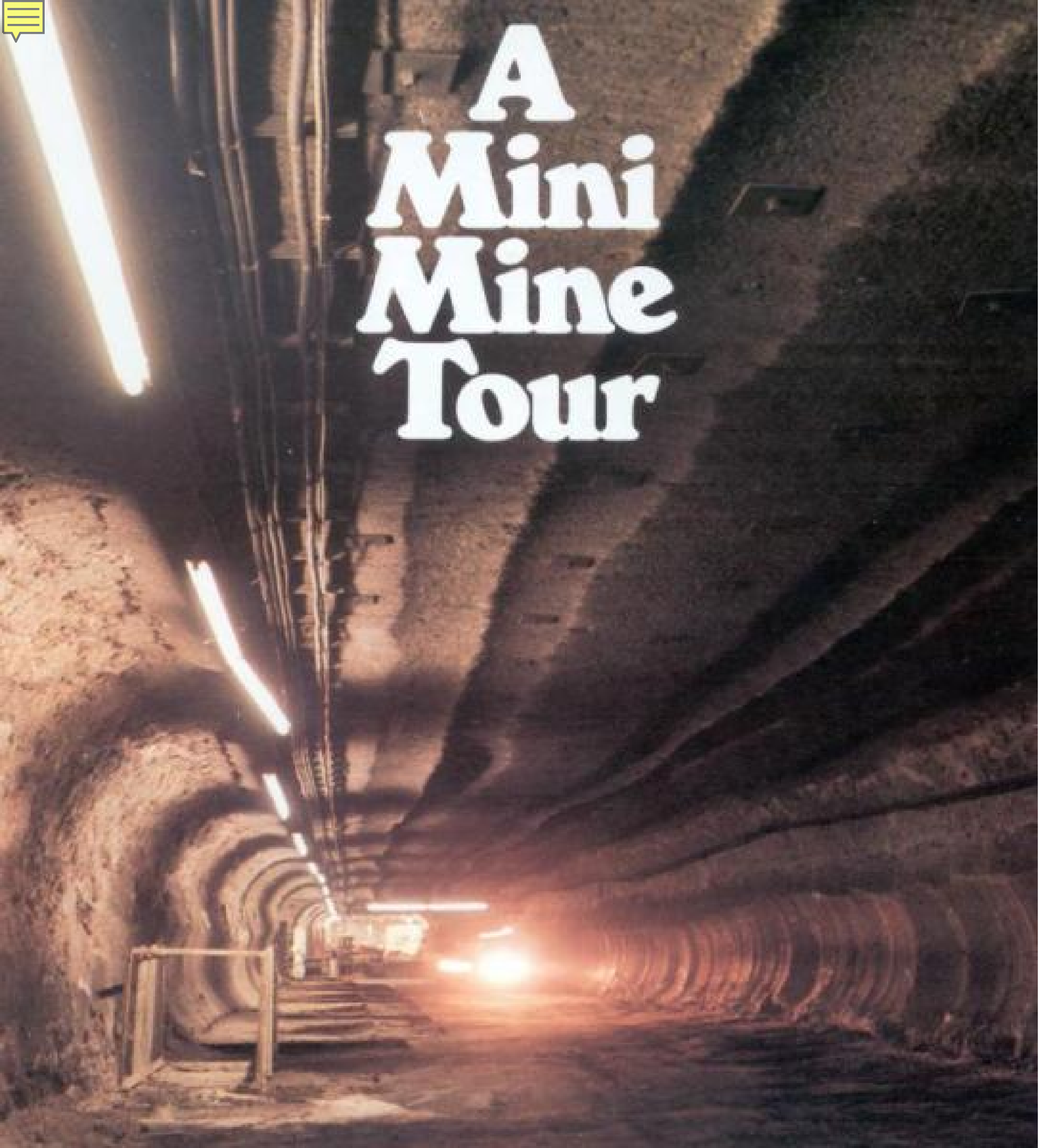
Edm: Randolph Attorney General for the United States. –

(Endorsement on back of grant)

Delivered to the within named Samuel Hopkins this fourth day of August 1790.

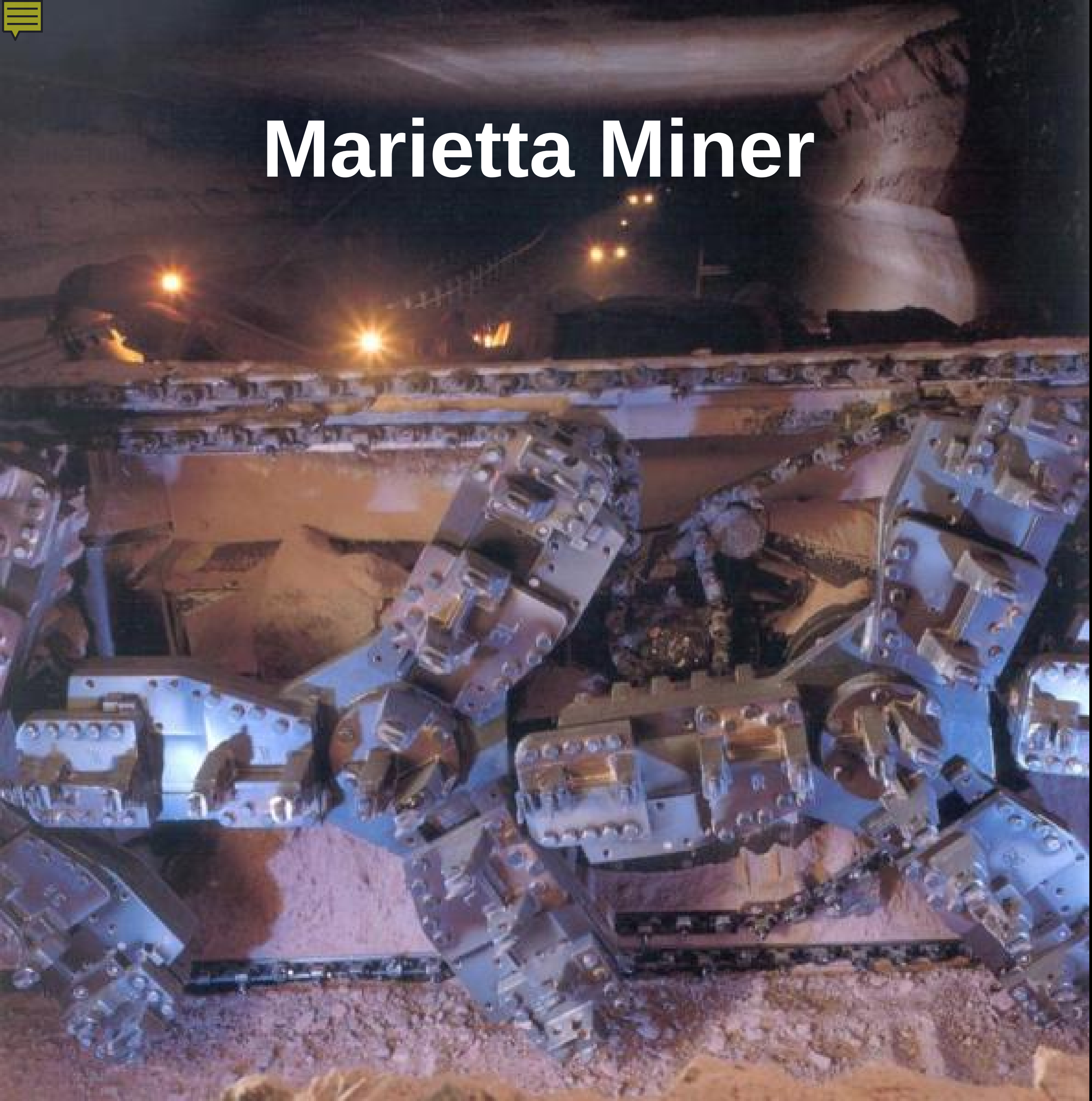
Th: Jefferson

First United States Patent Grant
July 31, 1790
(Reproduced from the original in the collection of the Chicago Historical Society)


A
Mini
Mine
Tour


GLACIAL TILL (Water-bearing sand, clay & boulders)
300 CRETACEOUS (Shale)
1200 BLAIRMORE (Sand, clay, silt & water)
1400 MISSISSIPPIAN (Limestone)
1700 BAKKEN (Siltstone & water)
THREE FORKS (Dolomite, shale & water)
NISKU (Limestone, dolomite & water)
DUPEROW (Limestone, anhydrite, dolomite & water)
SOURIS RIVER (Limestone, anhydrite & water)
2800 FIRST RED BED (Dolomite)
DAWSON BAY (Limestone, dolomite & water)
SECOND RED BED (Shale)
PRAIRIE EVAPORATES (Salt)
3100
POTASH
3500

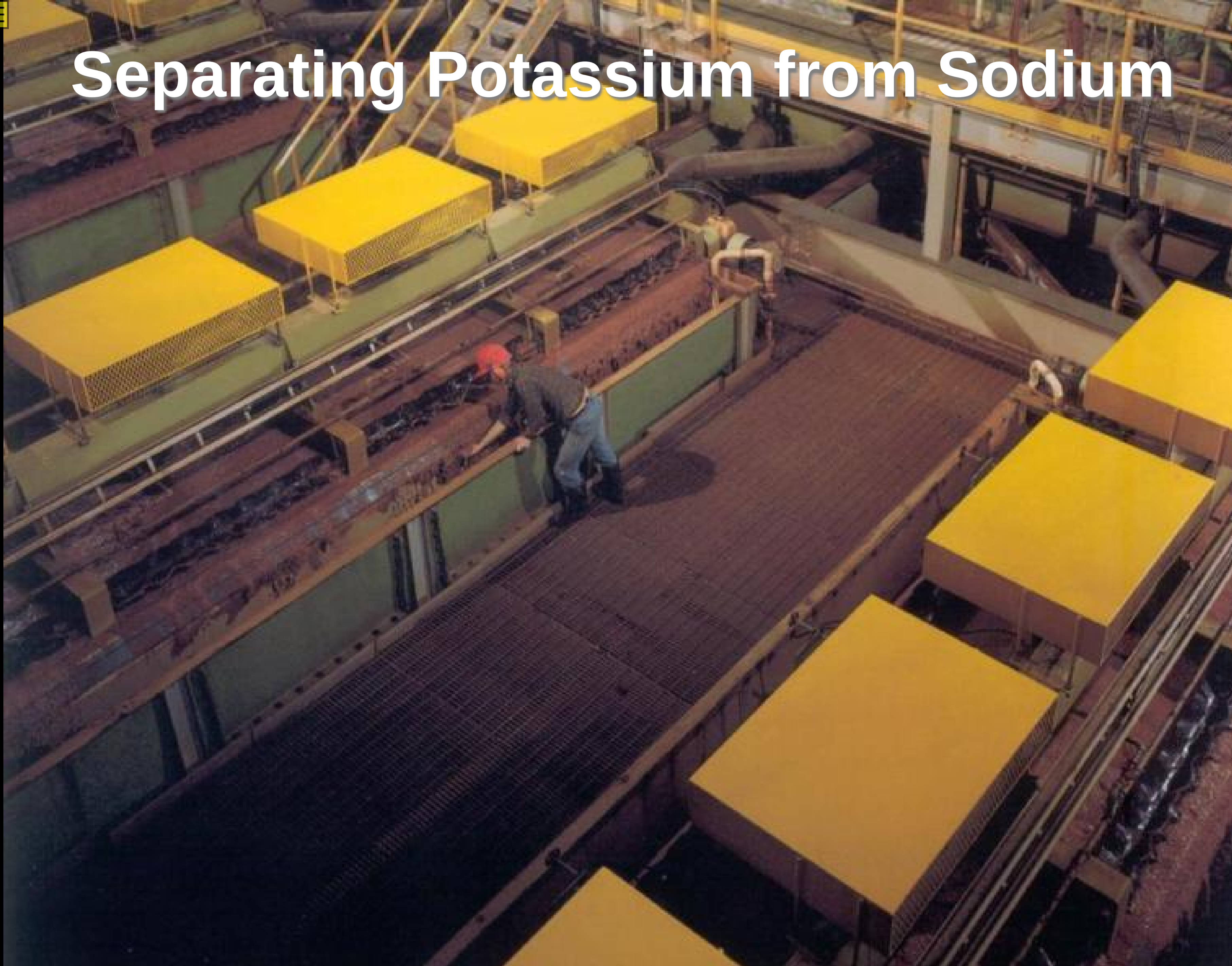
Marietta Miner



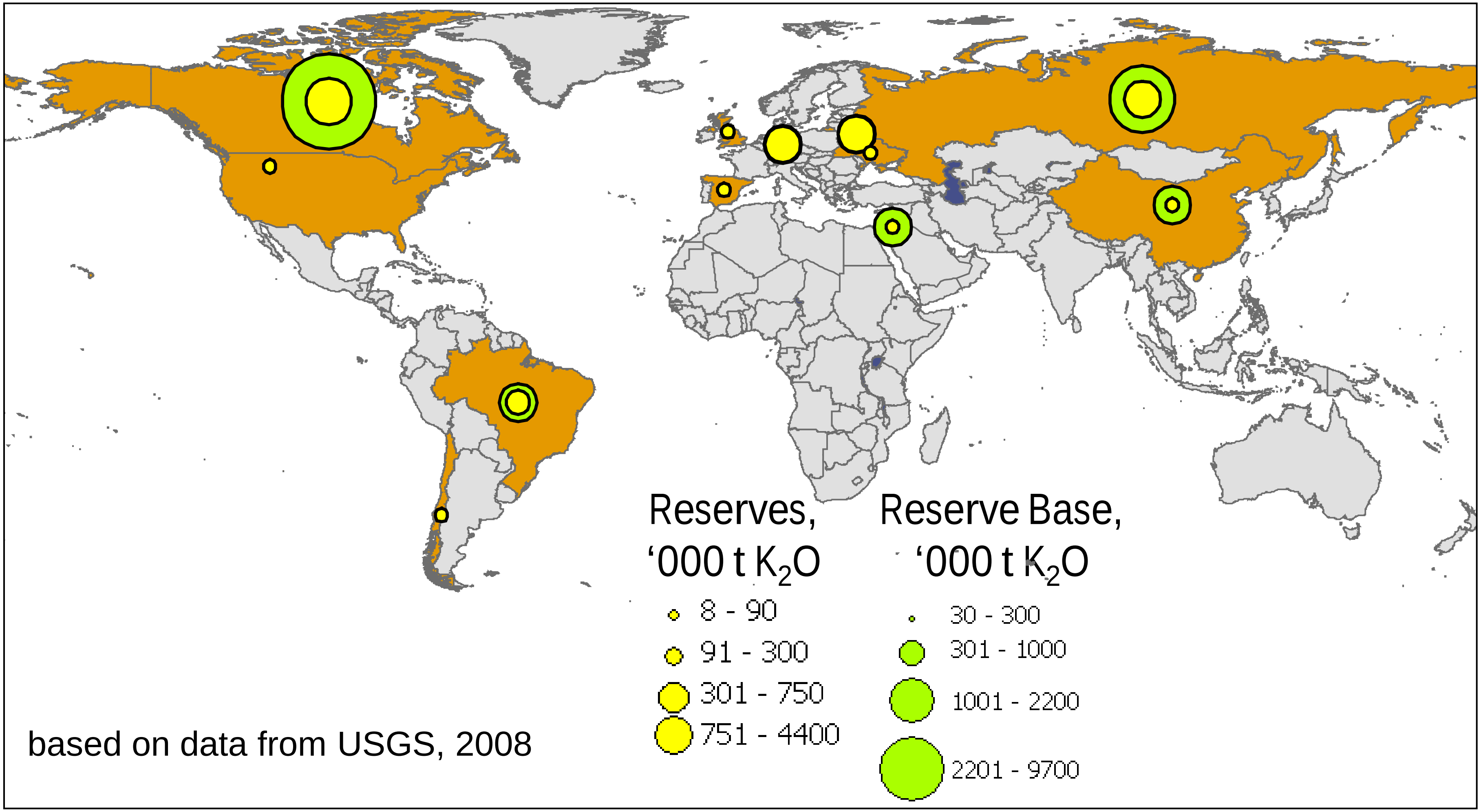
- Weighs 258 tons
- Four rotors
- 1600 hp
- 12 tons of ore per minute
- Cuts rooms 26’ wide x 8’ high

Sylvinite

Separating Potassium from Sodium



Potash reserves and reserve base



World Potash Reserves

Country	2012 Production	Reserves	Reserve Life	Resources
	Million tonnes K_2O		Years	Mt K_2O
Canada	9	4,400	490	
Russia	7	3,300	470	
Belarus	6	750	125	
Germany	3	140	45	
USA	1	130	130	7,000
World	34	9,500	280	250,000

USGS Mineral Commodities Summaries, 2013

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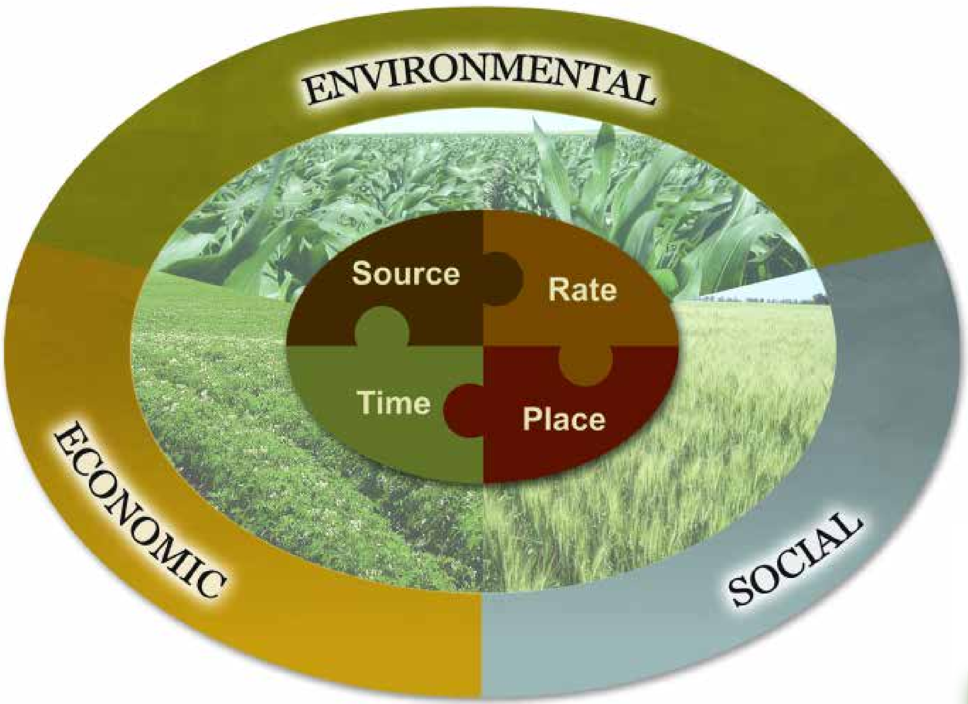
Stewarding K – summary

- Worldwide there appears to be K reserves for the foreseeable future.
- Reserves unevenly distributed geo-politically
  - two-thirds in Canada, Russia, Belarus
- Nonrenewable resource.
- Crop K balance often in deficit.
- Soil test needs improvement.

4R: “right” means sustainable



Field to Market™
The Keystone Alliance for Sustainable Agriculture

THE SUSTAINABILITY CONSORTIUM

Walmart
SustainabilityHUB

Home | Our Goals | How To Make A Difference | Share What You've

Home > How To Make A Difference > Fertilizer Optimization

How to Make a Difference - Fertilizer optimization

4R Stewardship – Nitrogen

- Source
  - U, UAN, AN, AA, AS, EEF, manure, legume
- Rate
  - MRTN, yield goal, Adapt-N, sensors
- Time
  - Planter band, sidedress, split
- Place
  - Soil cover for urea

4R Stewardship – Phosphorus

- Source
  - MAP, DAP, fluids, manure, biosolids
- Rate
  - Soil test: build/maintain, sufficiency
- Time
  - Fall, spring, avoid runoff after broadcasting
- Place
  - Broadcast, band, point
  - In the soil

4R Stewardship – Potassium

- Source
  - KCl, K_2SO_4, KNO_3, manure
- Rate
  - Soil test: build/maintain, sufficiency
- Time
  - Fall, spring
- Place
  - Broadcast, band

4R Research Fund – *environmental, social, economic impacts of 4Rs on sustainability*

- **Meta-analyses:** Review and analysis projects. $20K - $70K with duration 6-9 months. Total of $300,000 in 2014. **Due 15 Dec 2013.**
- **New Projects** – Measurement. Projects $50K to $300K/y for up to 5 y; total of $500,000/year. **Due 31 Jan 2014.**
- Both to contribute measures of performance for 4R
- For additional information: www.nutrientstewardship.com/funding

4R PLANT NUTRITION

nutrient stewardship

Summary

- World reserves and resources for **N, P, and K appear adequate** for the foreseeable future.
  - **Nutrient costs will rise over time** as the most easily extracted materials are consumed.

- Implementation of 4R nutrient stewardship will focus on reducing losses while increasing productivity.
  - The resulting **gain in efficiency will slow the increase in costs**.
- Wise stewardship of non-renewable nutrient resources is **a critical responsibility for the whole agricultural industry.**

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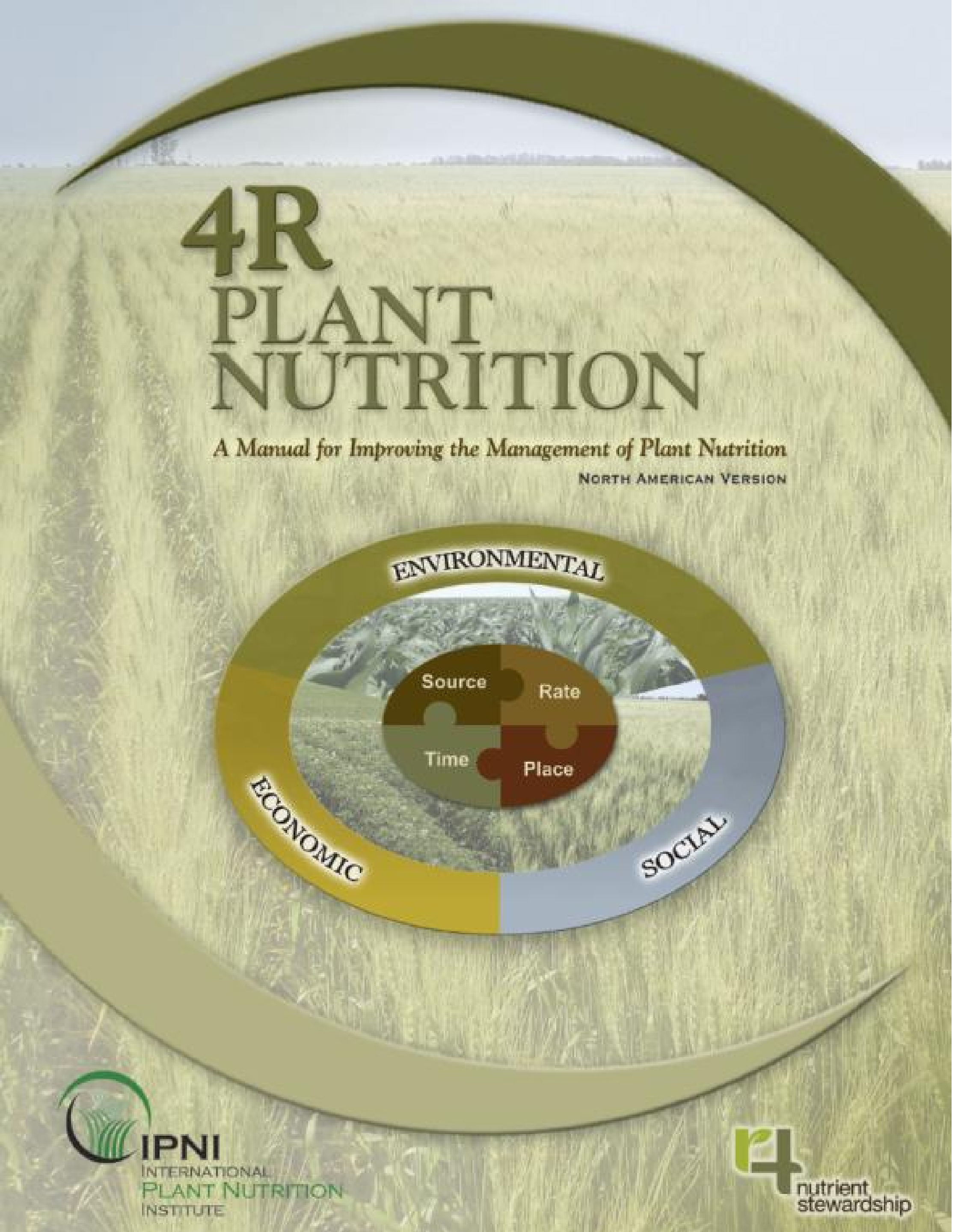

Thank You

nane.ipni.net

nutrient
stewardship