Fertilizer Outlook and Technology Conference
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IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Managing Plant Nutrition to Sustain Human Health

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Director, Northeast Region, North America Program

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
- CF Industries Holdings, Inc.
- Incitec Pivot
- International Zinc Association (IZA)
- Intrepid Potash, Inc.
- K+S KALI GmbH
- The Mosaic Company
- OCP S.A.
- PotashCorp
- Simplot
- Sinofert Holdings
- SQM
- 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)

Fertilizer Use and Human Health: a scientific review, edited by IFA & IPNI

Objective: to describe the contribution of fertilizers to achieving food and nutrient security for the health of a growing global population.

Editorial Committee:

- Patrick Heffer, IFA, France
- Tom Bruulsema, IPNI, Canada
- Kevin Moran, Yara, UK
- Ismail Cakmak, Sabanci University, Turkey
- Ross Welch, Cornell University, USA

Publication target date: Spring 2011

Why would the fertilizer industry want to publish a technical review of human health impacts of fertilizer use?

- **Informing industry:** to raise awareness of the positive impacts of fertilizer use, communicators must be aware of the negatives, and communications must be based on science.
- **Correcting misperceptions** among the critics of the industry – with credible evidence-based approach.
- **Inviting constructive contributions** toward resolving the issues that exist.
- Who's going to read such a technically detailed book?
  - Scientists, educators and policymakers involved with fertilizer, agriculture, food-chain, government, civil society organizations, university faculty and students
  - Create a positive impression of industry commitment to stewardship

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Outline

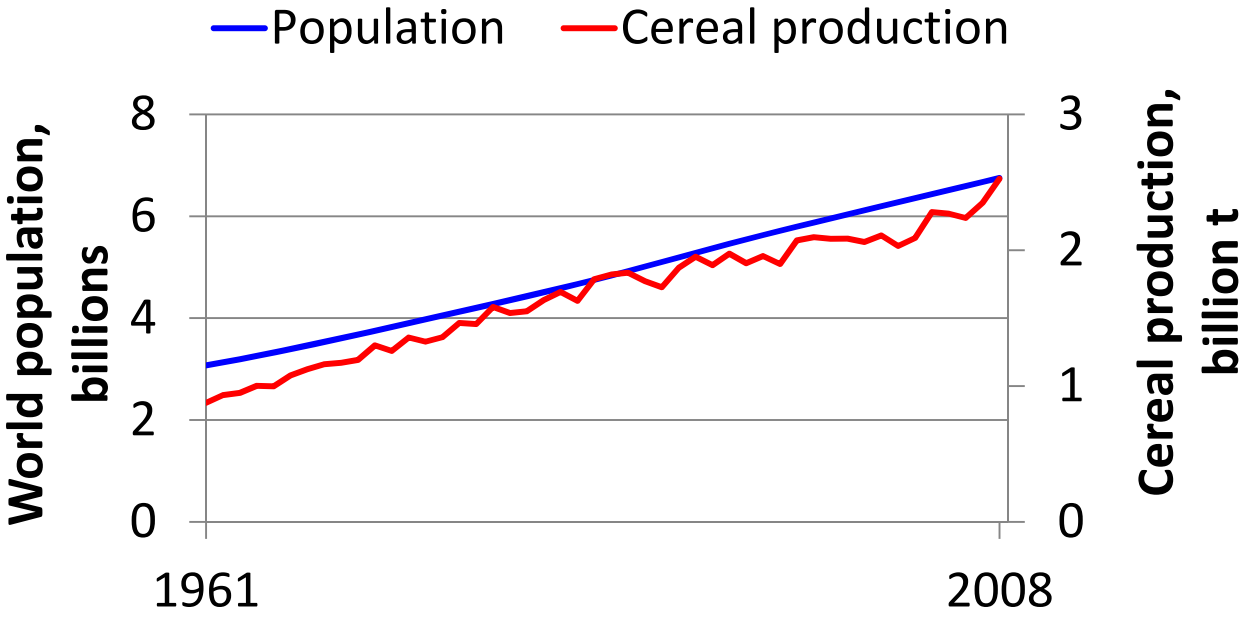
– highlights from Fertilizer Use and Human Health

- Food security
- Micronutrients:
  - Malnutrition
  - Biofortification
  - Agronomic biofortification
- Selenium and cancer
- Functional foods
- Proteins, oils and carbohydrates
- Nitrate
- Food safety
- Eutrophication
- Ammonia
- Plant disease
- Farming systems

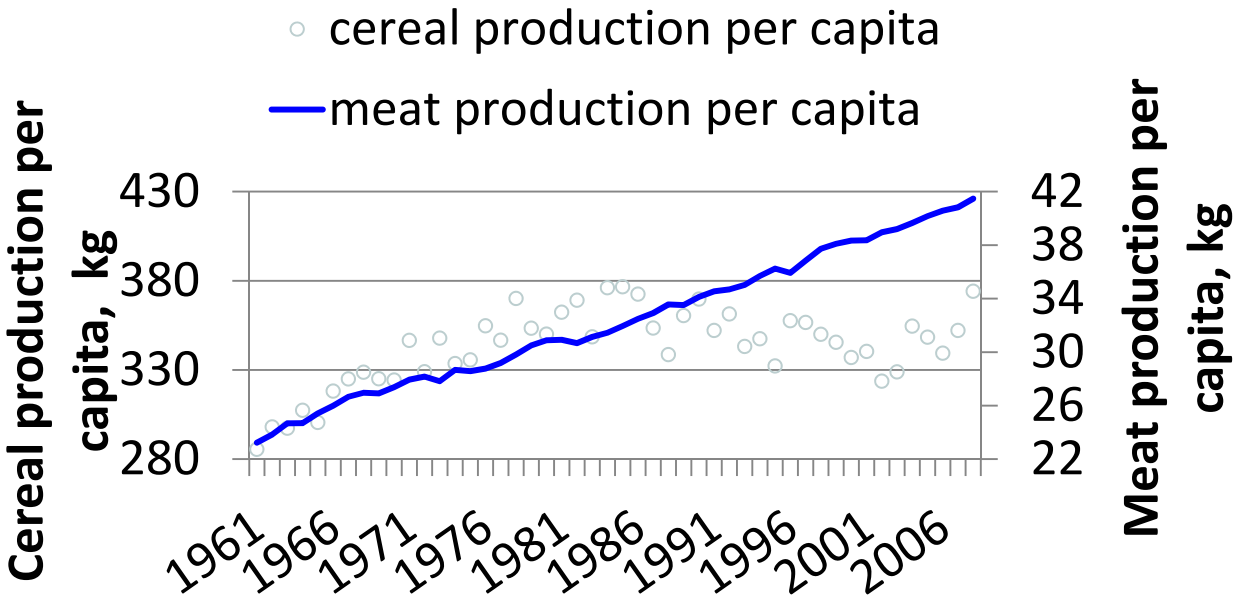
Food Security

- Roberts & Tasistro

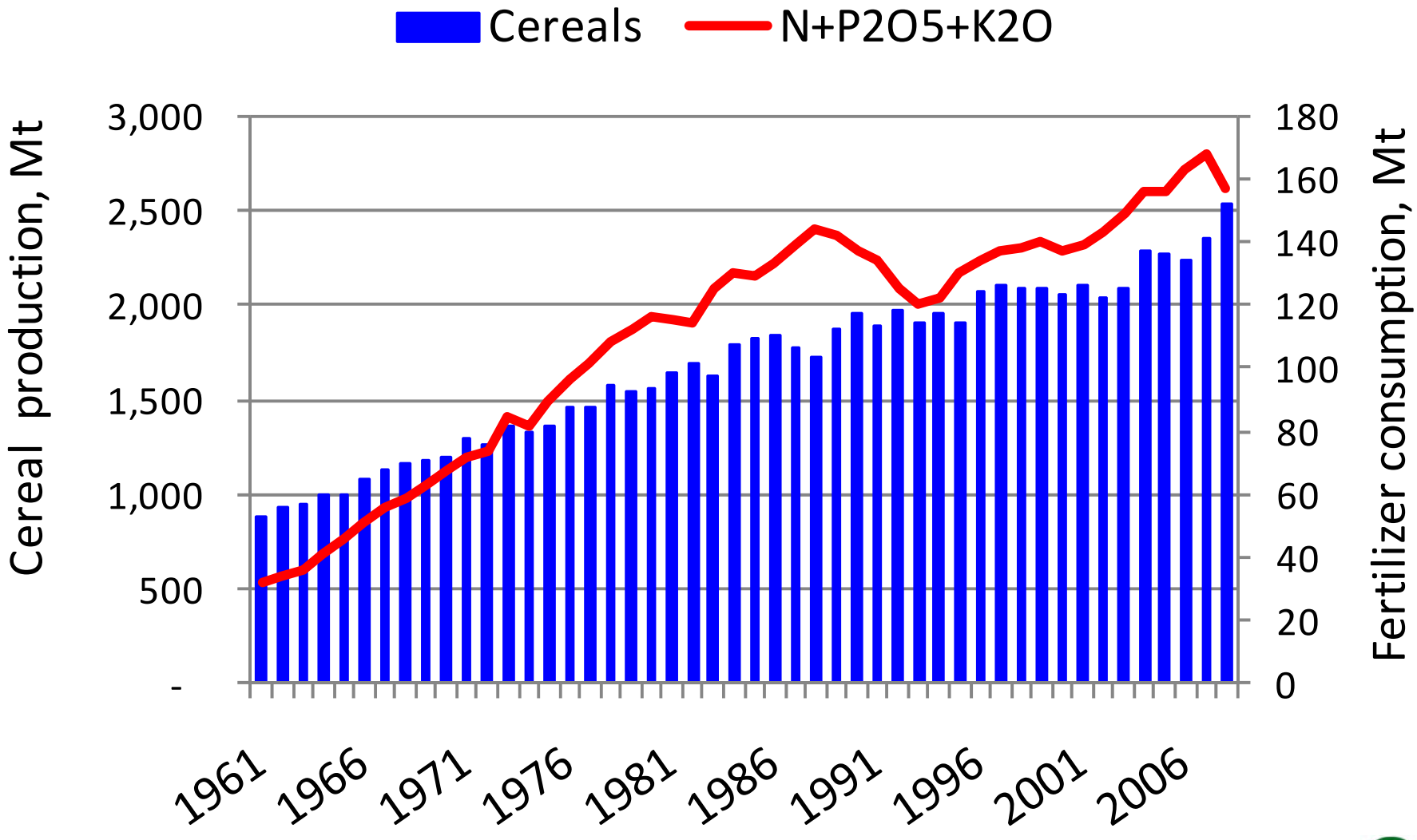
(A) Change in global cereal production and population, 1961-2008.



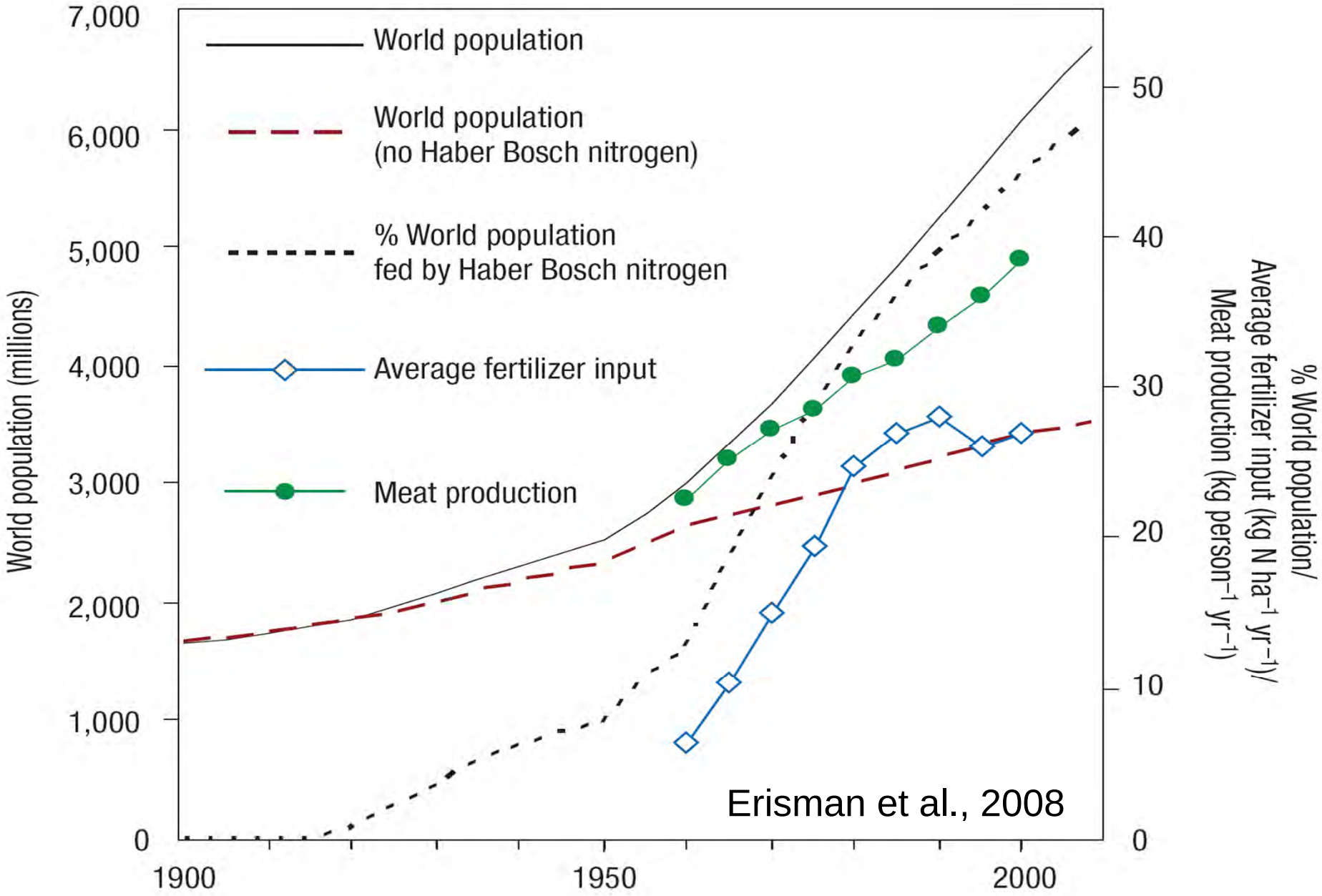
(B) Change in cereal and meat production per capita from 1961-2008. (FAO, 2010b)



Global cereal production and total world fertilizer consumption from 1961-2008 (FAO 2010b; IFA 2010)



Human Population and N Use



Micronutrient Malnutrition (% prevalence)

Bouis, Boy-Gallego & Meenakshi

Region	Zn	Fe	I	Vitamin A
North America	8-11	18-29	11	2-16
Latin America	13-37	18-29	11	2-16
Europe	6-16	19-25	52	12-20
Sub-Saharan Africa	13-43	48-66	44	14-44
Southeast Asia	27-39	46-66	30	17-50
South Asia	18-36			
Global	**10-32**	**30-47**	**32**	**15-33**

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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Enhancing the Nutritional Quality of Food Crops with Trace Elements – Welch and Graham

Percentage of nutrient-deficient soils among 190 soils in 15 countries, based on a field experiment at each site and soil and test crop analyses (Sillanpaa, 1990)

Nutrient	*acute*	*latent*	*total*
N	71	14	85
P	55	18	73
K	36	19	55
Zn	25	24	49
B	10	21	31
Mo	3	12	15
Cu	4	10	14
Mn	1	9	10
Fe	0	3	3

"This review concludes that it is imperative … that fertilizer technology be used to improve the nutritional quality of staple food crops that feed the world's malnourished poor. "

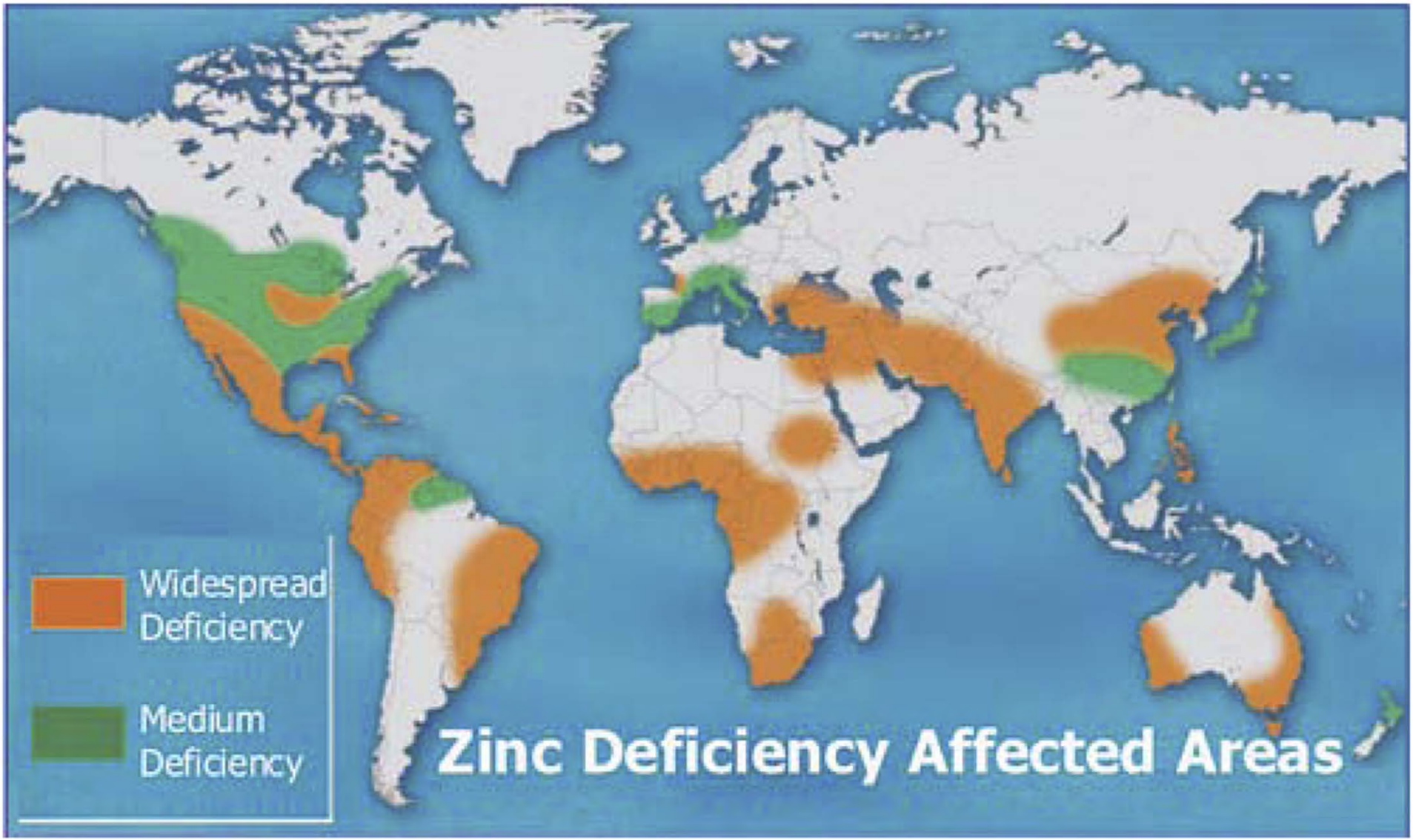

Figure 2: Global distribution of Zn-deficiency affected regions (Alloway, 2007)

Agronomic biofortification of food crops with micronutrients – Lyons & Cakmak

Zinc level:	Rice		Wheat	
	Yield, t/ha	Grain Zn, ppm	Yield, t/ha	Grain Zn, ppm
Urea	4.0	30	3.7	40
Urea+1%Zn	4.7	39	4.3	49
% increase	**17%**	**30%**	**14%**	**23%**

Shivay et al, 2008

- **Iodine:** Fertigation with potassium iodate increased soil iodine 3x and cut infant mortality in half in Xinjiang, NW China.
- **Cobalt:** provided through plants consumed by ruminants, increases vitamin B12 in meat.

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Selenium-Enhanced Foods in Cancer Prevention – Combs

- Selenoproteins – Se essential to the antioxidant enzyme glutathione peroxidase (GPX)
- In 1983, Finnish Ministry of Agriculture and Forestry directed that all agricultural fertilizers contain Se.
- By 1990, the per-capita intake of Se in the Finnish diet more than quadrupled.
- Average serum Se in Finnish adults increased from 70 to nearly 119 ng/ml
- Epidemiological studies have found Se status to be inversely associated with cancer risk. While relatively few clinical trials have been conducted, all but one have shown cancer risk reduction due to Se.

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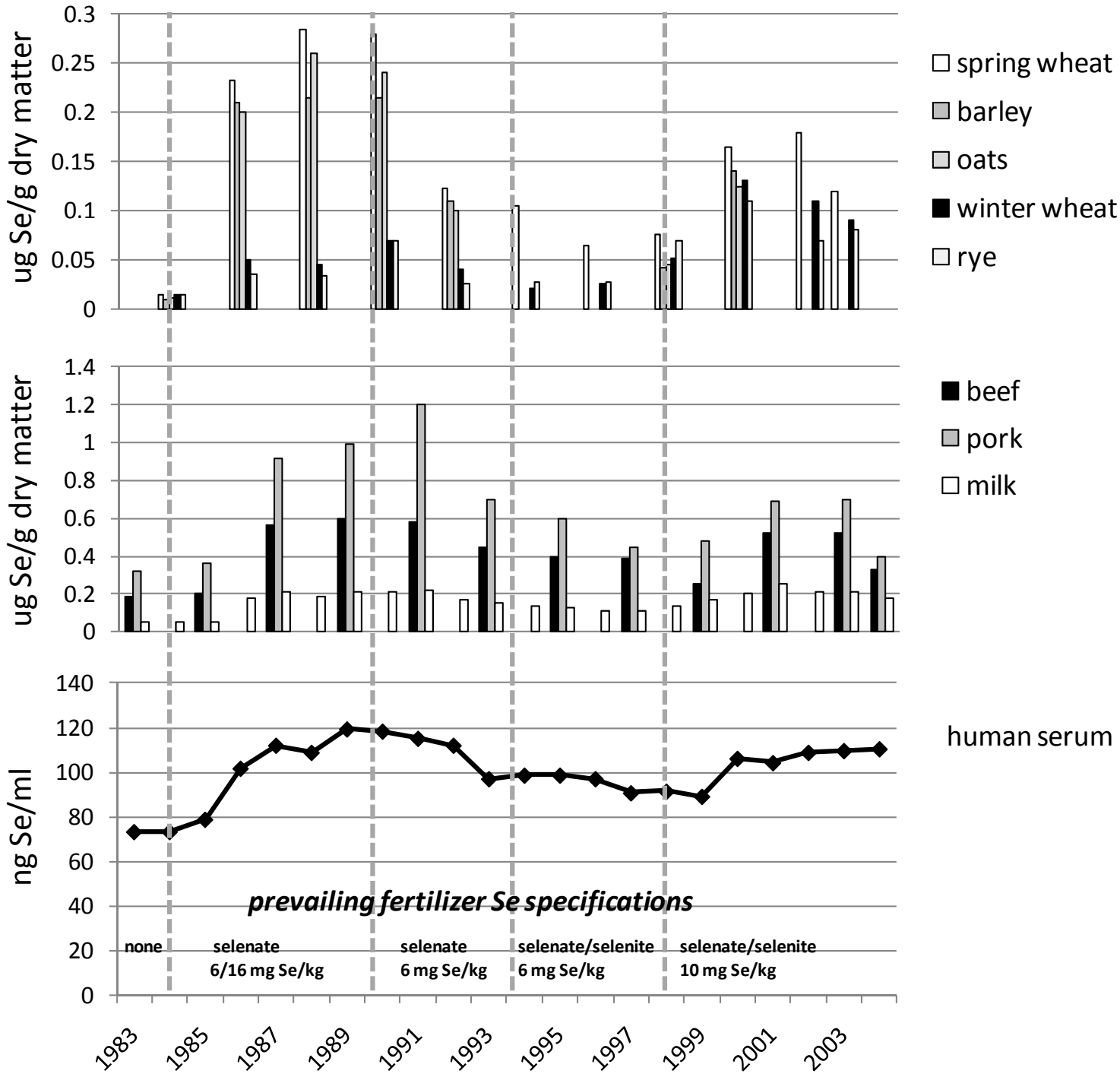

Efficacy of Finish national Se fertilization on Se contents of wheat and Se status of consumers. (*after* Alfthan, 2005, and Ekholm et al, 2005).

Functional Quality of Fruits and Vegetables

- Jifon, Lester, Stewart, Crosby & Leskovar

- Foliar K with S enhanced sweetness, texture, color, vitamin C, beta-carotene and folic acid contents of muskmelons
- In pink grapefruit, supplemental foliar K resulted in increased lycopene, beta-carotene, and vitamin C concentrations
- Several studies have reported positive correlations between K nutrition and banana fruit quality parameters such as TSS, reducing sugars, non-reducing sugars, total sugars and ascorbic acid, and negative correlations with fruit acidity

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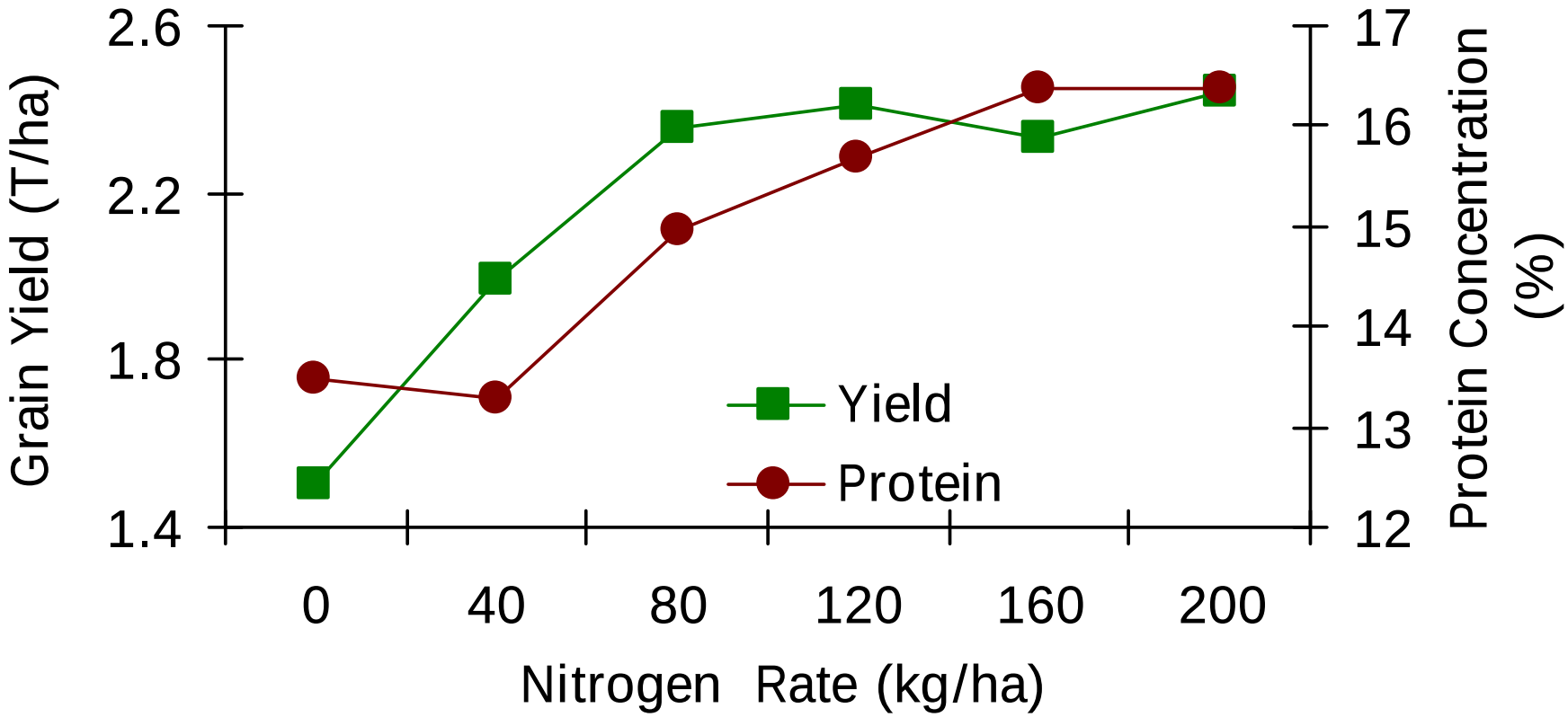
Protein, Oil, Carbohydrate

Grant & Bruulsema



Katepwa hard red spring wheat (Grant, unpublished)

Protein, Oil & Carbohydrate

Rice: Overall, grain quality was less responsive to N than crop yield… (Yang et al., 2007).

Maize: "Nitrogen fertilizer increased protein content and test weight and decreased maize oil and extractable starch content" (Miao et al, 2007).

Wheat: "Nitrogen fertilizer increased both protein content and Hagberg falling number" (Kindred et al., 2005).

Soybean: Slight increase in protein and oil with P, slight increase in oil and decrease in protein with K (Yin and Vyn, 2003).

Potato: Nitrogen increases yield, starch and protein but reduces biological value of protein; P&K reduced protein but increased its biological value; S increased biological value (methionine and cysteine) – Eppendorfer and Eggum, 1994.

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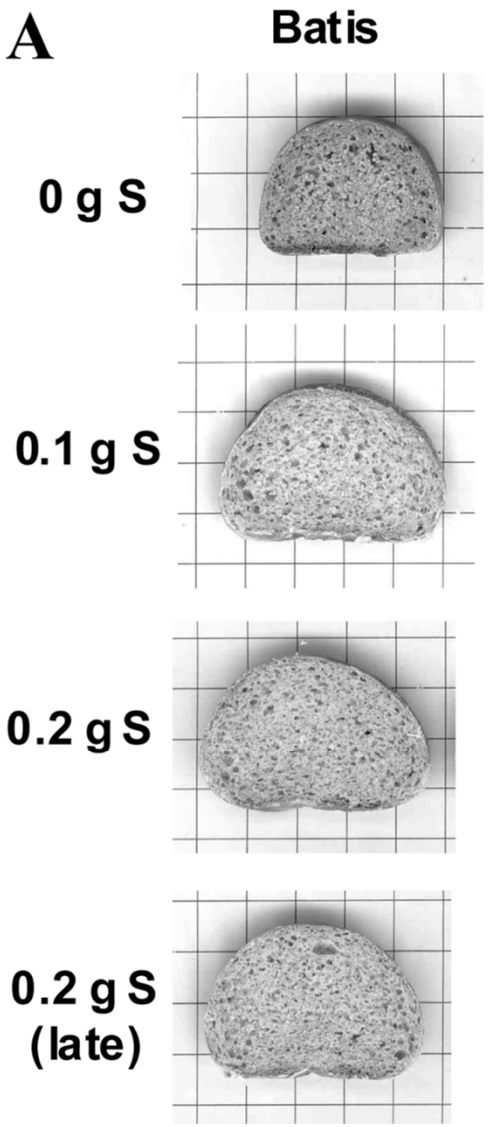
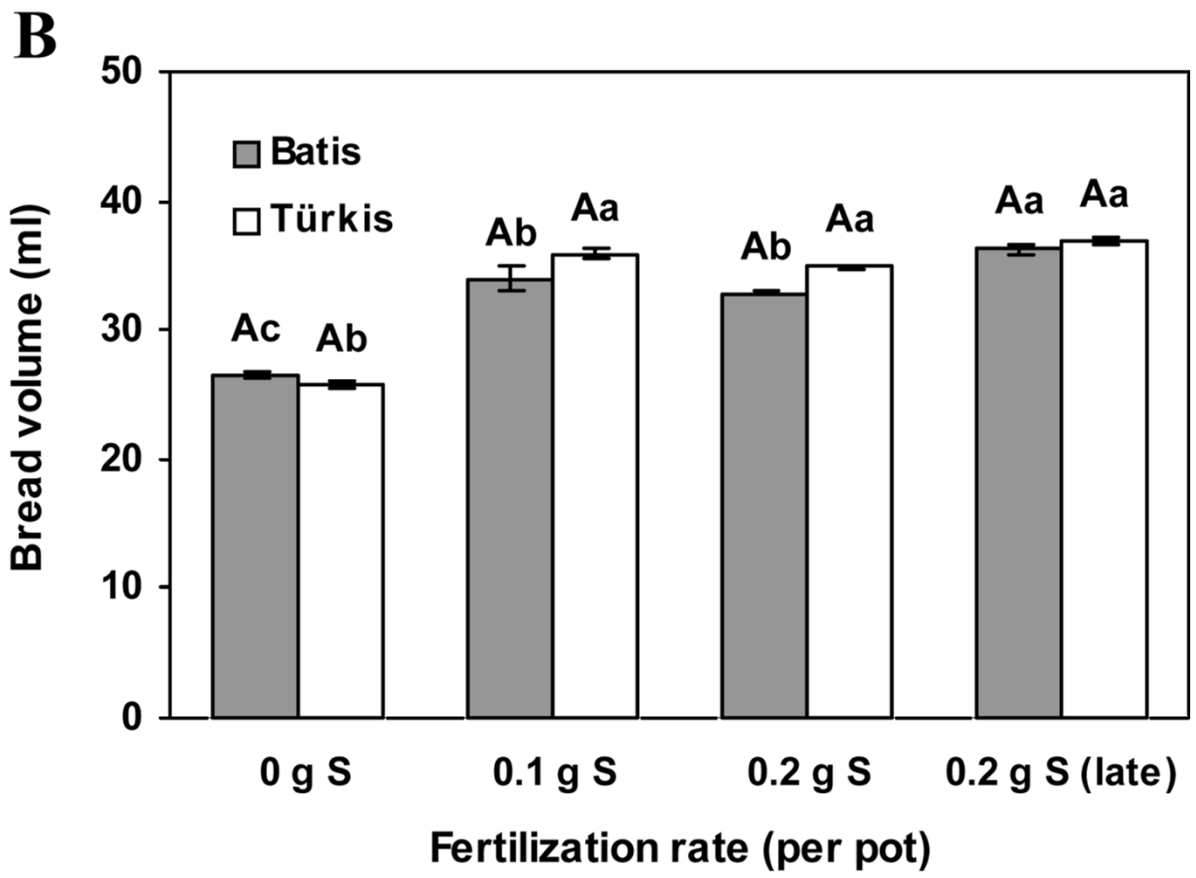
Sulfur and Wheat Bread-making Quality

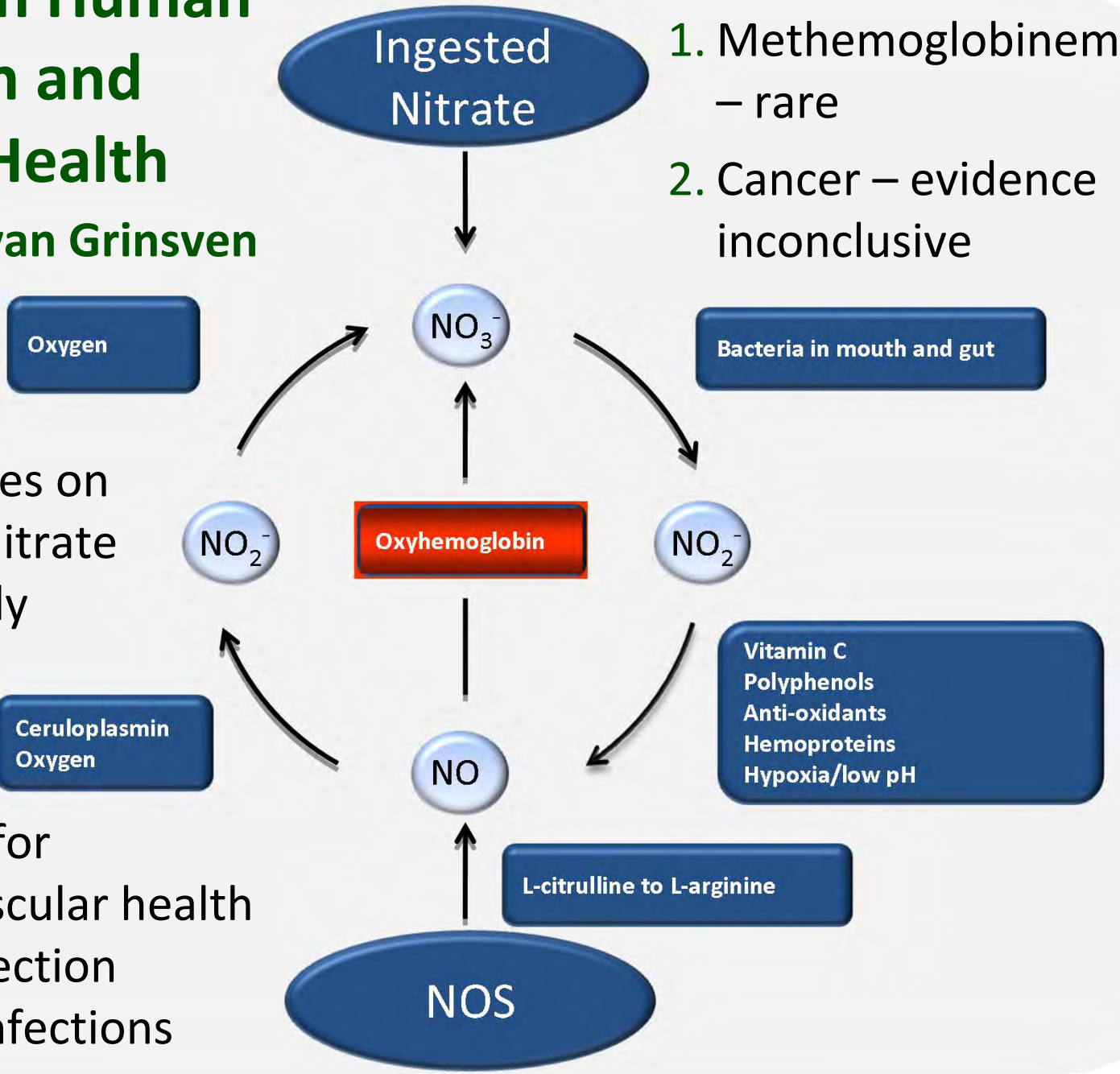




Nitrate in Human Nutrition and Human Health

– Bryan & van Grinsven

1. Methemoglobinemia – rare
2. Cancer – evidence inconclusive
3. Discoveries on NO and nitrate since early 1980s
4. Benefits for cardiovascular health and protection against infections



Food safety issues

Mineral Fertilizers
– Chaney

- Non-nutritive trace elements
- Cd, F, Mo, Se, As, Co, U
- Regulatory standards

Organic Fertilizers
– Goss

- Pathogens
- Trace elements
- Antibiotics
- Hormonally active compounds
- Risk management

Eutrophication – Snyder and Bruulsema

- Eutrophic = well nourished
- Acceleration due to many causes including fertilizer use
- Focus on risks to human health through harmful algal blooms (HABs)
- Red tides, microcystins, Pfiesteria, domoic acid, seafood poisoning, cholera, malaria, West Nile virus, water disinfection by-products

- Many HABs associated with natural nutrient upwelling
- Some HABs occur at low nutrient levels
- Causes of HABs vary – US mid-Atlantic most strongly related to anthropogenic sources
- “top-down” versus “bottom-up” causes

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Scientific perspectives vary…

- Need to continue improving N & P use efficiency.
- Need dialogue based on data.
- "Ecological feedbacks to excess nitrogen can …potentially affect the dynamics of several vector-borne diseases, including West Nile virus, malaria, ..."
  (Townsend et al., 2003, Frontiers in Ecology).
- Among countries with WHO-reported malaria cases, those with high per-capita rates of malaria tend to have low rates of fertilizer use per unit of agricultural land.

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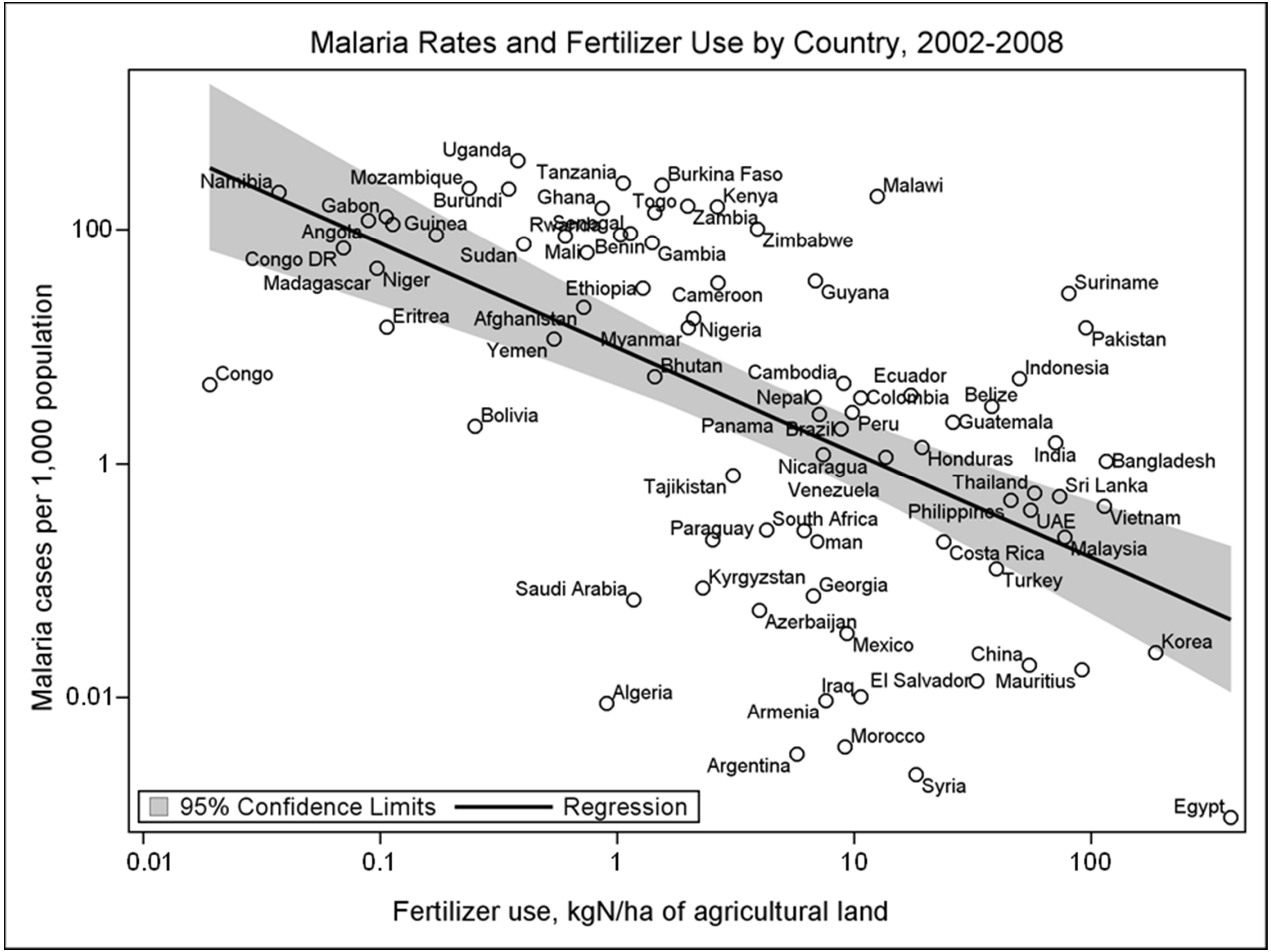
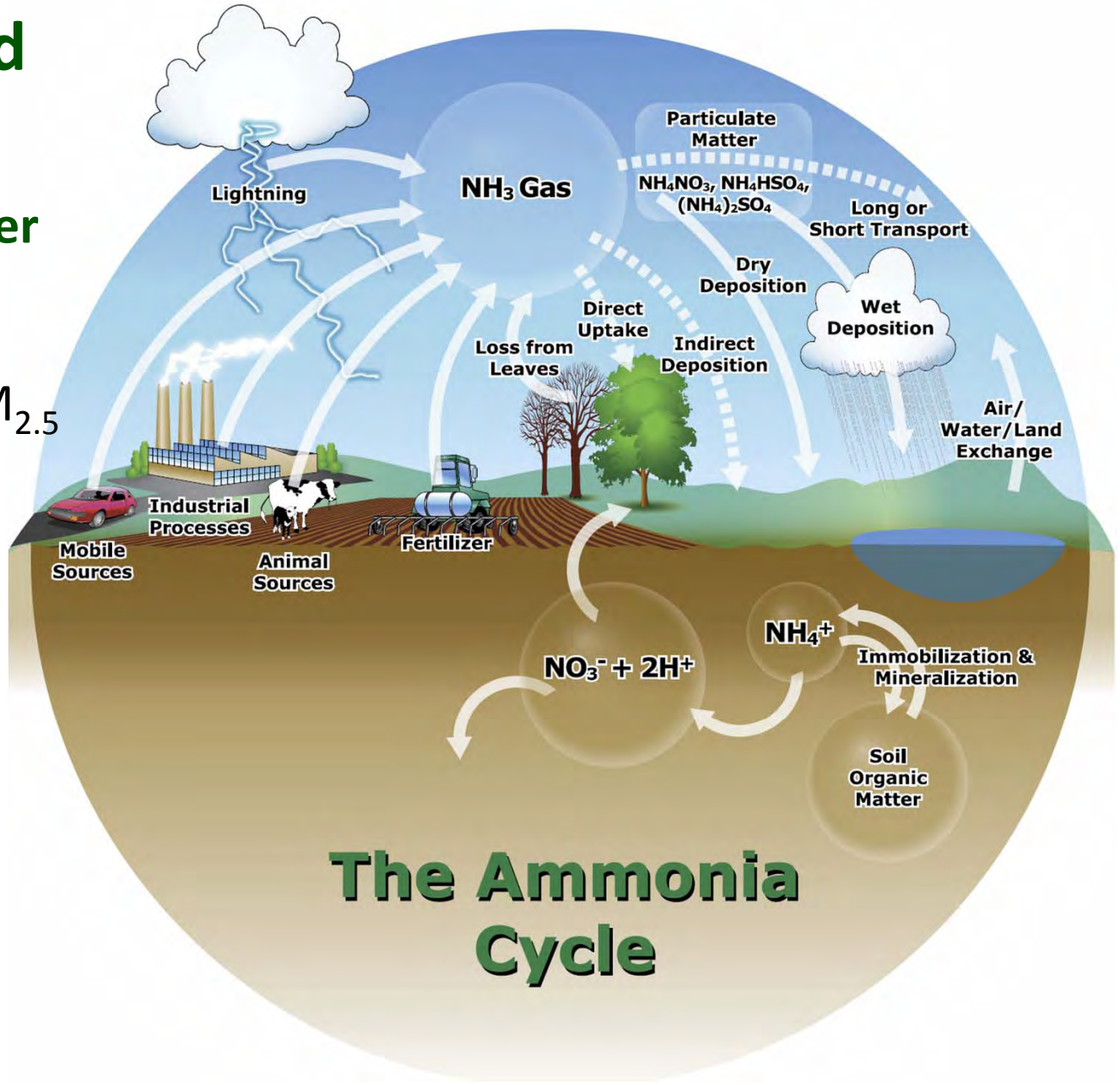

Malaria Rates and Fertilizer Use by Country, 2002-2008
Malaria cases per 1,000 population
100
1
0.01
0.01
0.1
1
10
100
Fertilizer use, kgN/ha of agricultural land
95% Confidence Limits
Regression
Uganda
Tanzania
Burkina Faso
Namibia
Mozambique
Malawi
Burundi
Ghana
Togo
Kenya
Gabon
Guinea
Zambia
Angola
Rwanda
Senegal
Zimbabwe
Congo DR
Sudan
Mali
Benin
Gambia
Madagascar
Niger
Ethiopia
Cameroon
Guyana
Suriname
Eritrea
Afghanistan
Nigeria
Pakistan
Yemen
Myanmar
Bhutan
Indonesia
Congo
Cambodia
Ecuador
Nepal
Colombia
Belize
Bolivia
Panama
Brazil
Peru
Guatemala
India
Honduras
Bangladesh
Nicaragua
Tajikistan
Thailand
Sri Lanka
Venezuela
Philippines
UAE
Vietnam
Paraguay
South Africa
Oman
Malaysia
Costa Rica
Kyrgyzstan
Turkey
Saudi Arabia
Georgia
Azerbaijan
Mexico
Korea
China
Iraq
El Salvador
Mauritius
Algeria
Armenia
Morocco
Argentina
Syria
Egypt

Ammonia and Air Quality

– Bittman, Bleeker & Brooks

- Ammonia and $PM_{2.5}$
- Emissions from livestock and fertilizer
- Emission factors specific to fertilizer source (urea)



Ammonia and Air Quality

– Bittman, Bleeker & Brooks

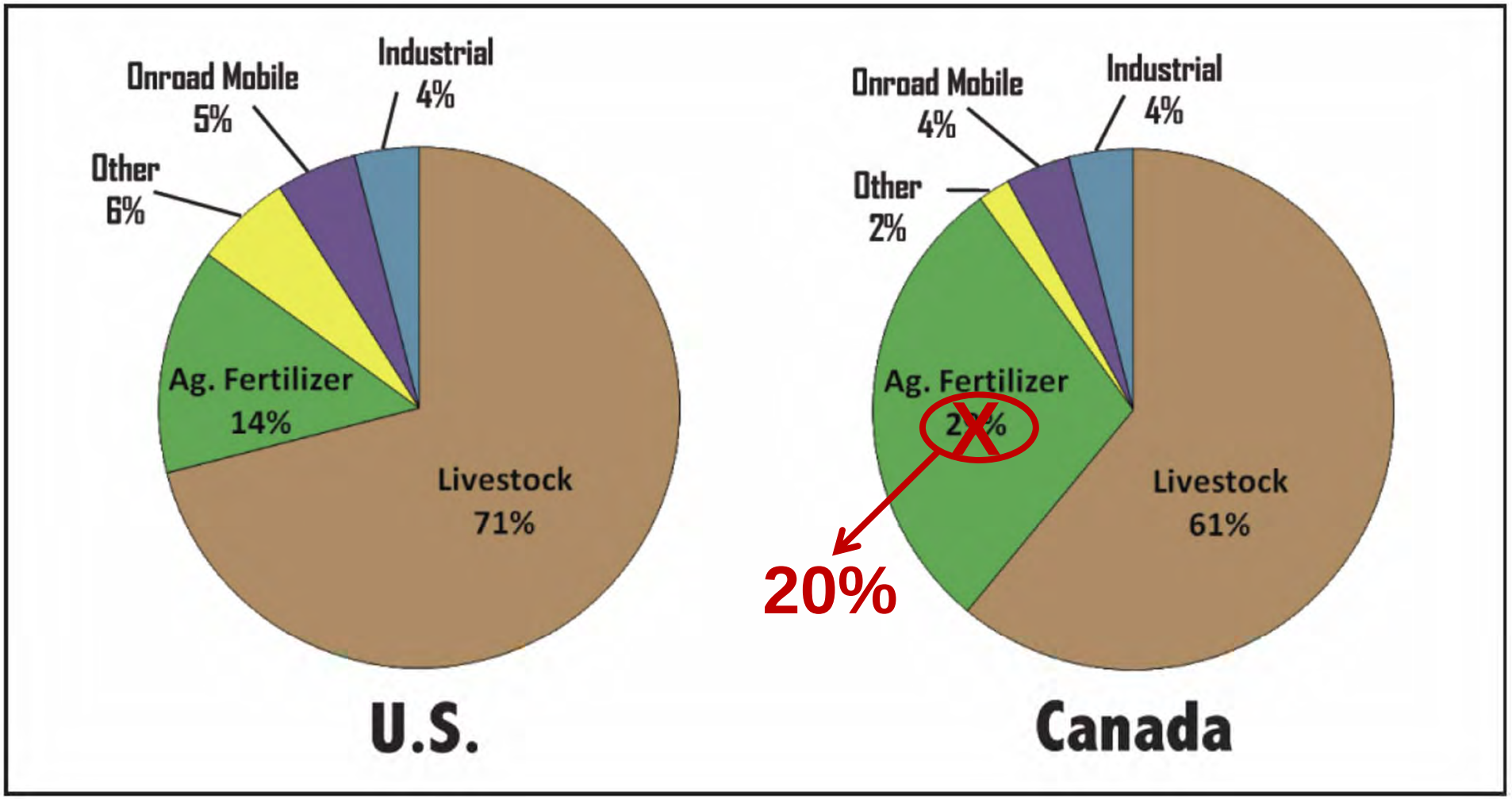


Figure 2. Primary sources of NH_3 emission from the USA and Canada. (USEPA, 2005; Environ. Canada 2006.)

Health Risks Associated With Plant Diseases – Huber

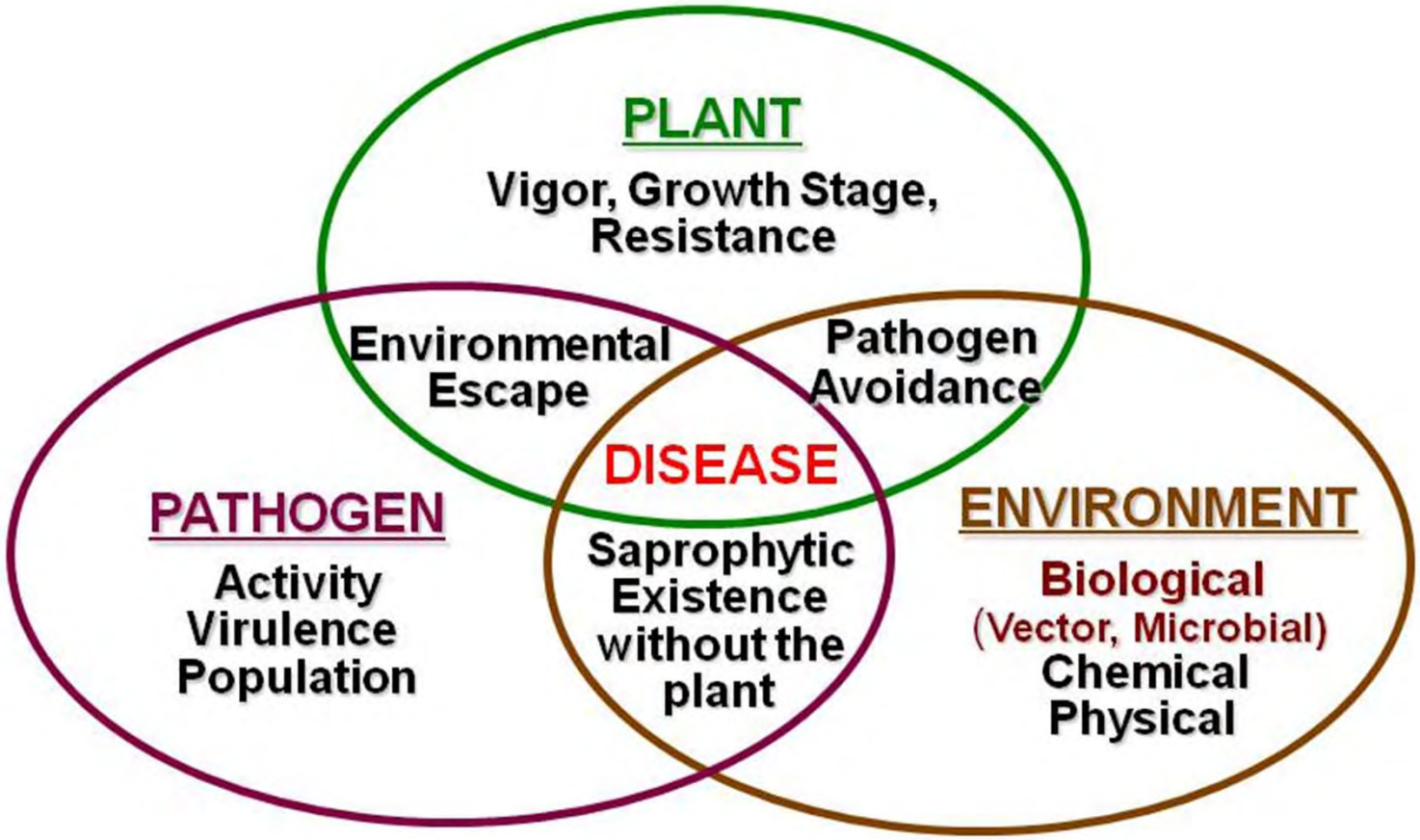


FIGURE 1. INTERACTING COMPONENTS OF PLANT, ENVIRONMENT, AND PATHOGEN AFFECTING DISEASE AND NUTRIENT QUALITY

Plant Diseases – Huber

- By immobilizing and competing for mineral nutrients, plant pathogens reduce mineral content, nutritional quality and safety of food products from plants.
- Managing nutrition influences diseases and their control
- Strategies to reduce disease through nutrition:
  1. **Nutrient-efficient cultivars –** Mn uptake ability in cereals
  2. **Balanced nutrition:** optimum levels
  3. **Form & Source:** NH_4 versus NO_3, KCl versus K_2SO_4
  4. **Timing:** apply N during conditions favoring plant growth
  5. **Integration:** tillage, crop rotation, soil microbes

Mycotoxins – food safety

Crop	Disease	Toxin	Nutrient
Cereals	Ergot (*Claviceps sp*)	Ergotamine (alkaloid)	Cu
Grain, peanuts	*Aspergillus*	aflatoxin	Mn + ?
Cereals	*Fusarium graminearum* (*Gibberella zeae*)	deoxynivalenol zearalenone trichothecene	Mn + ?

Knowledge Gap: nutritional control of the plant diseases most relevant to food safety

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Human Health Issues Associated with Organic and Conventional Crop Production
– Kirchmann & Bergström

- No truth to the perception that organic food products are better from a health perspective
- Organic crop production cannot provide sufficient food for the growing world population, since yields are 20-60% lower in organic agriculture

Summary

- Managing plant nutrition impacts the health of humanity in myriad ways, not all of which are fully understood.
- A thorough scientific review of the impacts of fertilizer use on human health will benefit the industry, helping to find solutions that resolve the harmful while enhancing the beneficial.
- The relationship of fertilizer use to human health needs full consideration in sustainability initiatives (e.g. Wal-Mart, PepsiCo, Loblaw, 4R Nutrient Stewardship).
- Next step: identify priorities among the many opportunities and challenges outlined.

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Reviewers Welcome

http://nane.ipni.net