Using Agriculture As A Tool For Better Health

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Why Does Agriculture Exist?

- To produce food and fiber and provide livelihoods to farmers and profits to the agricultural and food industries alone?
- Why do we need "food"? – Nutrients!
- Agriculture is the primary source of all essential minerals and vitamins required for human life!
- Farmers are nutrient providers!
- If food systems, based in agriculture, cannot provide all the essential nutrients in adequate quantities to sustain human life during all seasons, diseases ensue, societies suffer and development efforts stagnate.

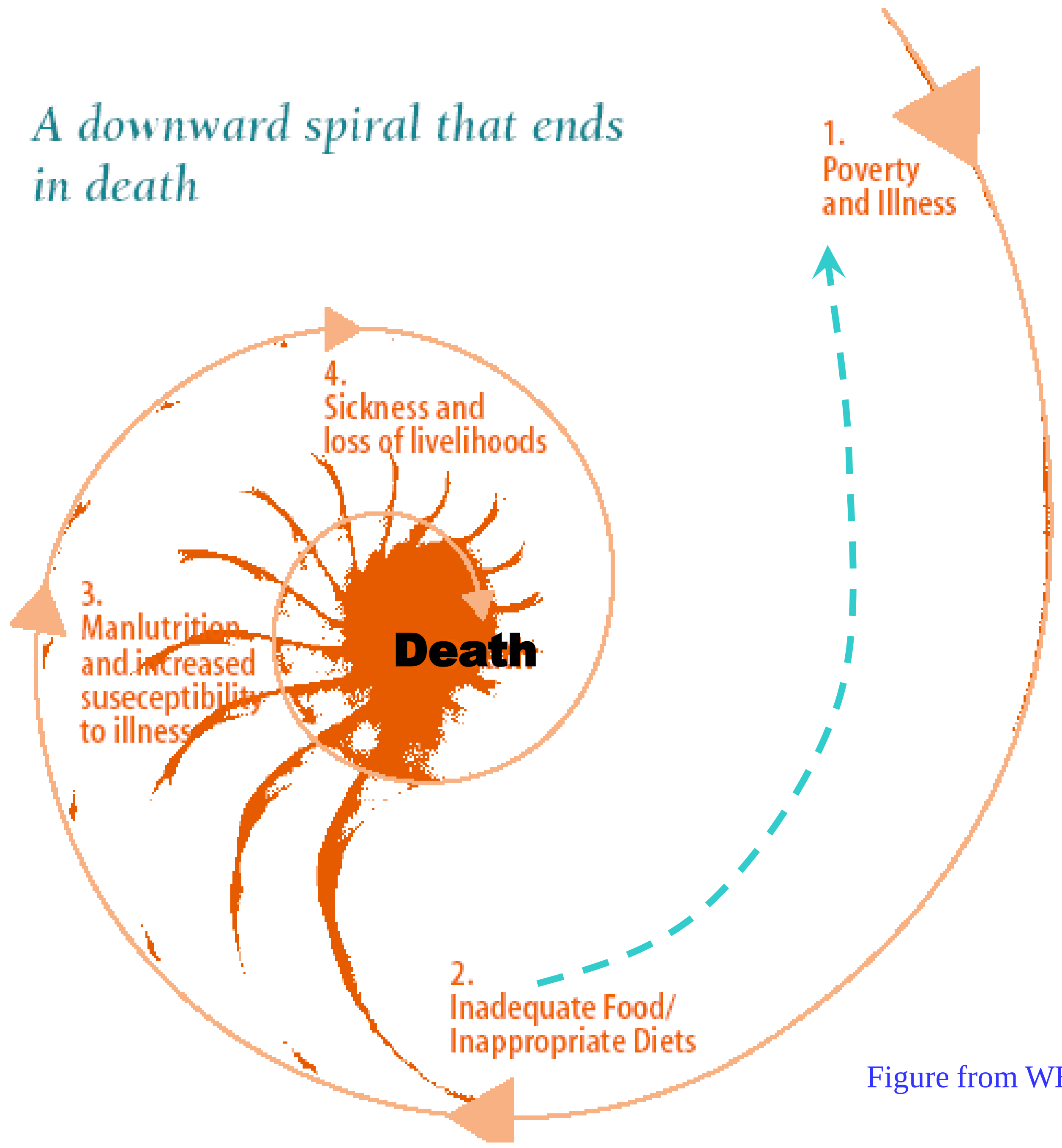
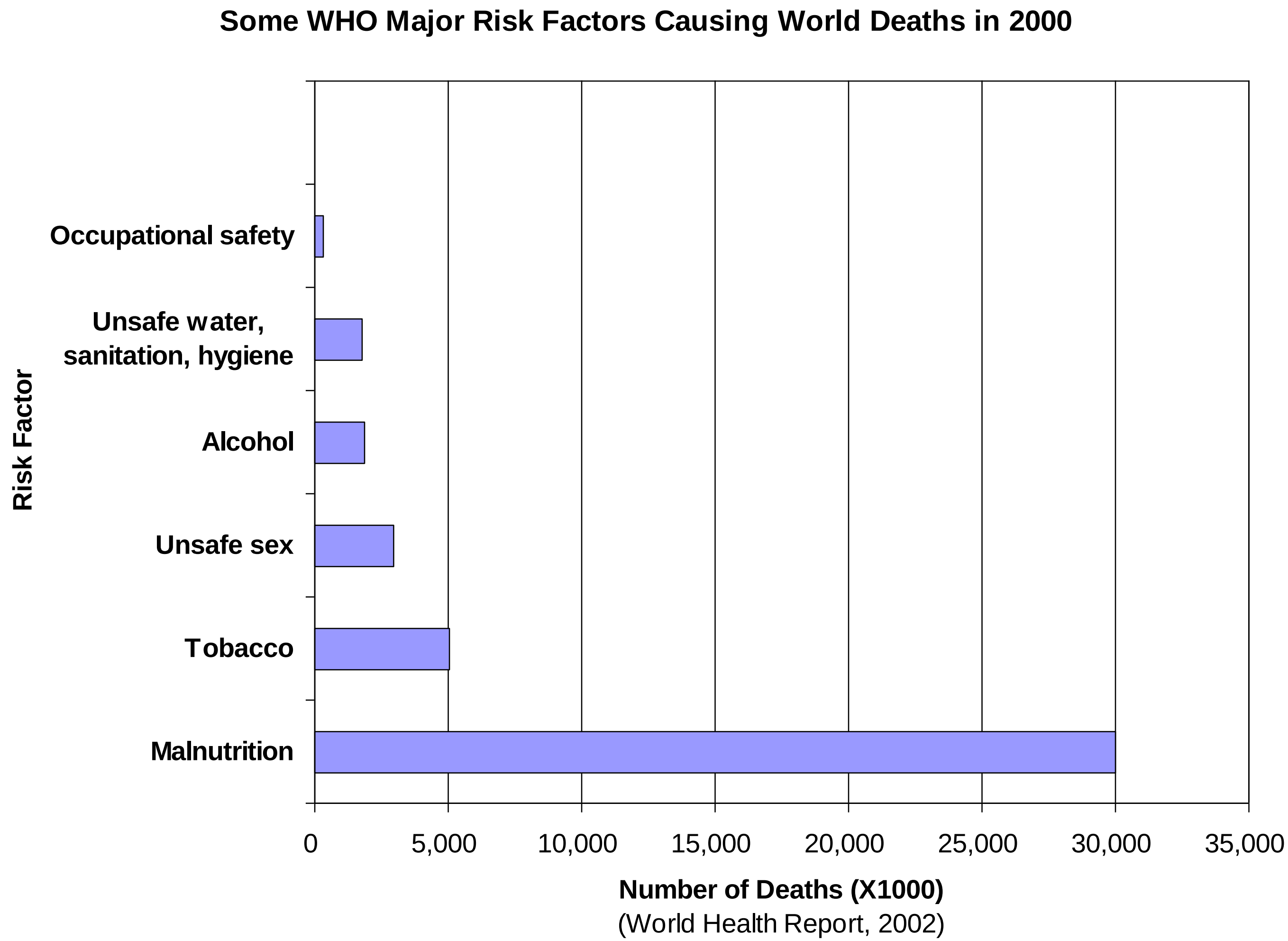


Figure from WHO, 2000

Some Major World Risk Factors Causing Deaths

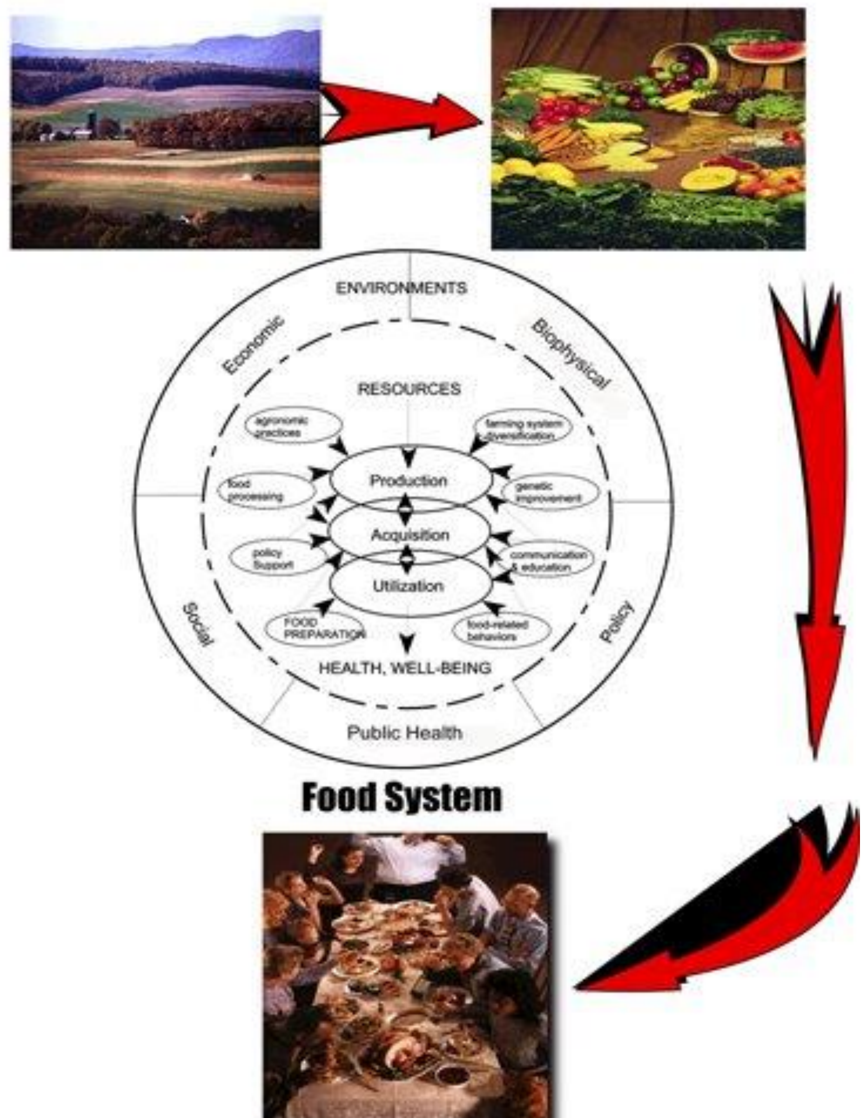


Malnutrition accounts of ≈ 30 million deaths per year (about 1 death per second)

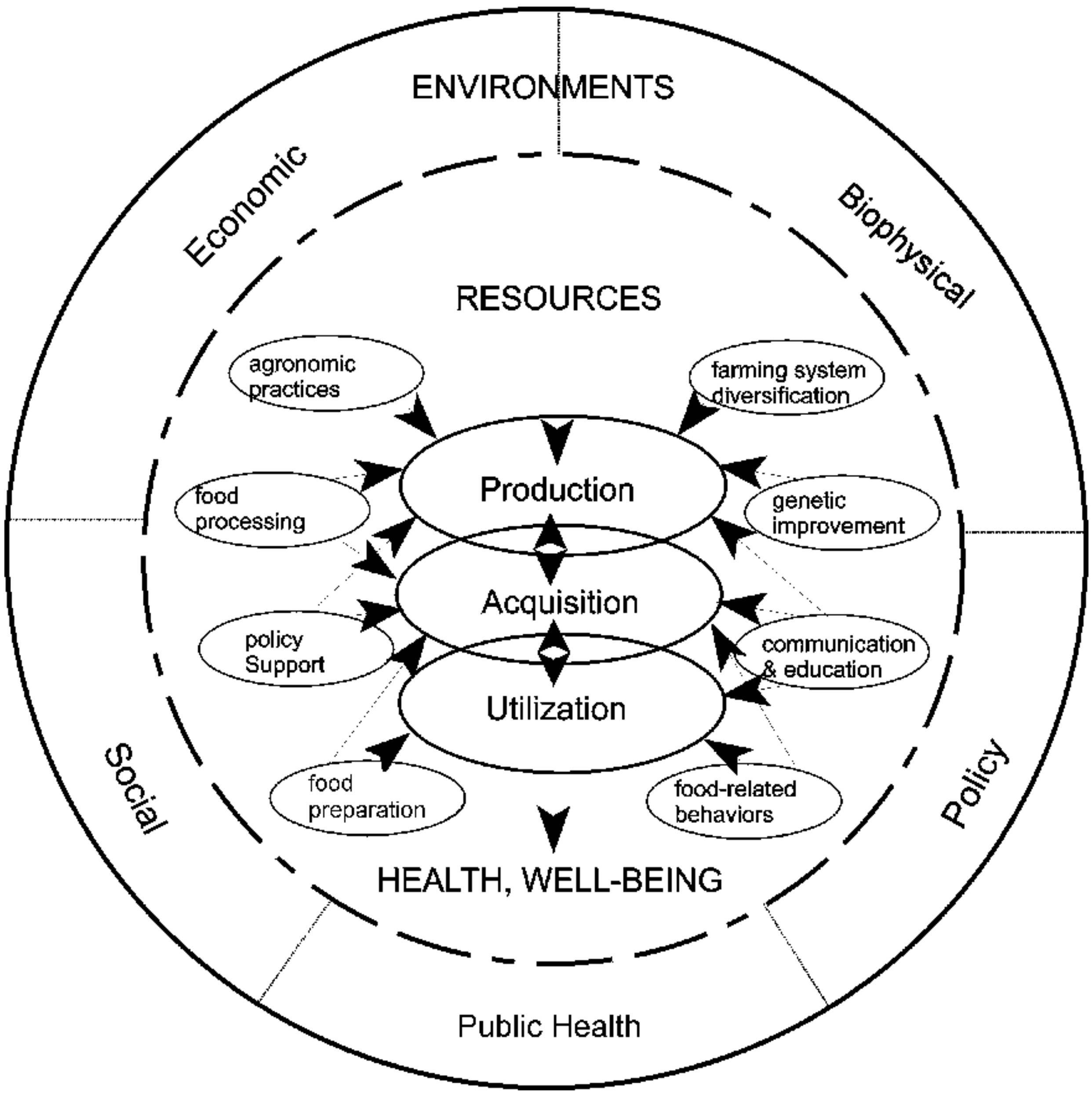


Agricultural technologies can be directed at improving the “healthiness” of foods to meet human needs, but this require the use of

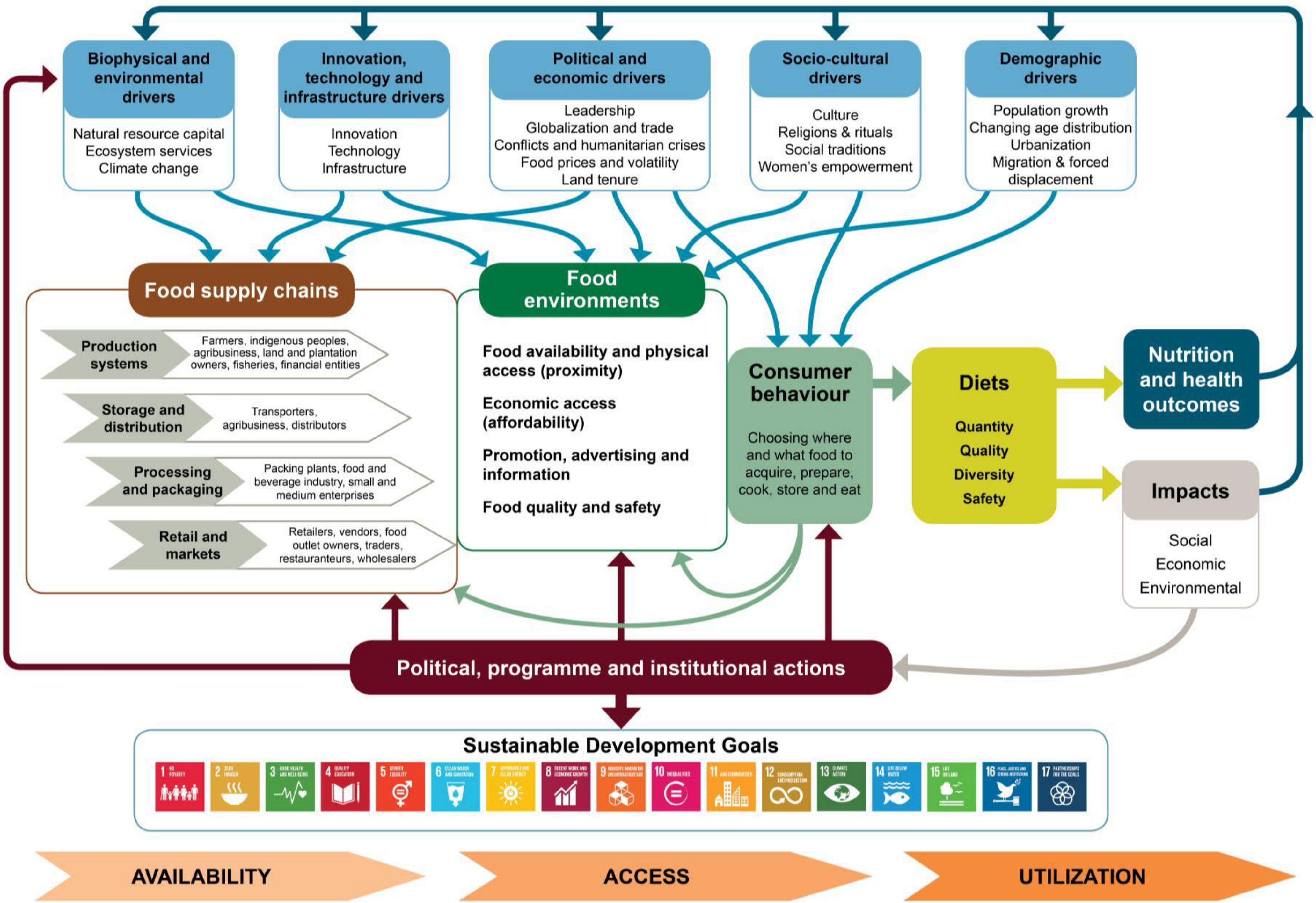
Holistic Food System Perspectives to Assure Sustainable Impact



Complexities of Food Systems



Conceptual Framework for Food Systems (HLPE, 2017)

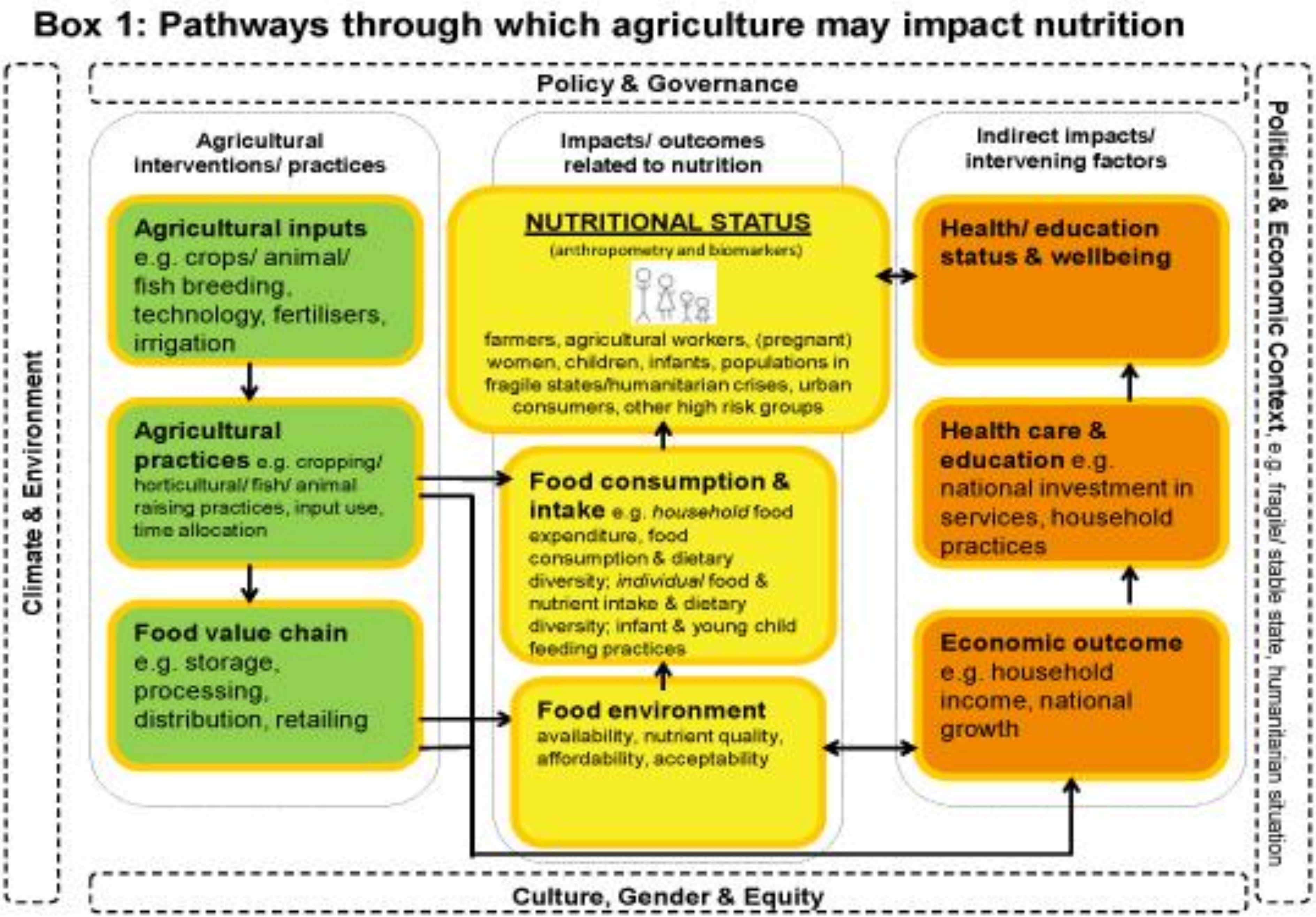


Food Systems, Diet and Disease

- **Global food systems are failing to provide adequate quantities of essential nutrients and other factors needed for good health, productivity and well being for vast numbers of people in many developing nations.**
- ***Green revolution* cropping systems have resulted in reduced food-crop diversity and decreased availability of many micronutrients.**
- **Nutrition transitions (double burden of malnutrition) are causing increased rates of chronic diseases (e.g., obesity, cancer, heart disease, stroke, diabetes, osteoporosis) in many nations.**
- **Holistic, sustainable improvements in the entire food system are required to solve the massive problem of malnutrition and increasing chronic disease rates in developed and developing countries.**
- **Agricultural systems are a major factor affecting human health**

Global Food Systems' Problems

- Agriculture's primary focus has been on production alone, with little concern for nutritional or health-promoting qualities of products
- Nutritionists tend to emphasize unsustainable medical approaches to solve malnutrition problems
  - supplements
  - food fortificants
- These strategies do not address the underlying causes of malnutrition - dysfunctional food systems based in agricultural systems that do not have a goal of promoting human health
- Simplistic views are the norm – looking for "silver bullet" approaches for solutions
- Agriculture and human health have never been generally recognized as closely linked disciplines



Rachel Turner blog, 2012

Early History of Agriculture-Human Nutrition Linkages in USA

- **Henry Wallace** (Sec. Agriculture, 1933-1940) & Bank Jones Act 1935
  - **E.C. Auchter** (Chief of Bureau of Plant Industry) – *Science* article 1939. "Interrelationship of Soils & Plant, Animal & Human Nutrition"
  - U.S. Plant, Soil & Nutrition Laboratory (USPSNL) built in 1938 on Cornell University Campus
    - Charter - to understand the movement of nutrients from soils to plants to animals to humans to enhance the nutritional quality of agricultural products and human health
    - **Leonard Maynard** – first Director of USPSNL and Director of the School of Nutrition at Cornell University
- **Sir Albert Howard** (father of organic agriculture) - 1945

Sir Albert Howard

• • • "related subjects as agriculture, food, nutrition and health have become split up into innumerable rigid and self-contained little units, each in the hands of some group of specialists. The experts, as their studies become concentrated on smaller and smaller fragments, soon find themselves wasting their lives in learning more and more about less and less. The result is the confusion and chaos now such a feature of the work of experiment stations and teaching centers devoted to agriculture and gardening. Everywhere knowledge increases at the expense of understanding.
The remedy is to look at the whole field covered by crop production, animal husbandry, food, nutrition, and health as one related subject, and then to realize the great principle that the birthright of every crop, every animal, and every human being is health." – March, 1945
In: Rodale, J.I. 1945. Pay Dirt, Farming & Gardening with Composts. Rodale Books, Inc., Emmaus, Penn. p. vii.

"Western civilisation is suffering from a subtle form of famine – a famine of quality."– November, 1947

The Known 43 (51) Essential Nutrients for Sustaining Human Life*

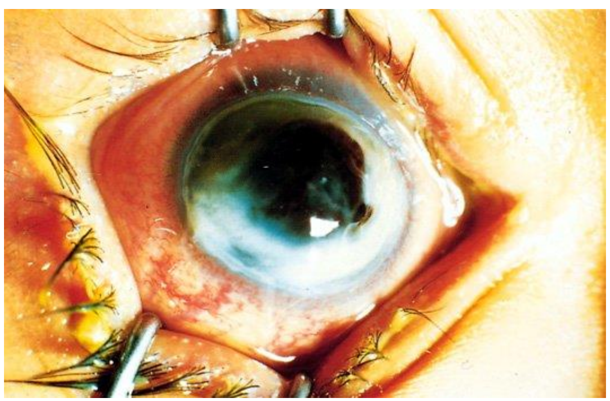
Air, Water & Energy (3)	Protein (amino acids) (9)	Lipids-Fat (fatty acids) (2)	Macro-Minerals (7)	Trace Elements (9) (17)	Vitamins (13)
Oxygen	Histidine	Linoleic acid	Na	Fe	A
Water	Isoleucine	Linolenic acid	K	Zn	D
Carbohydrates	Leucine		Ca	Cu	E
	Lysine		Mg	Mn	K
	Methionine		S	I	C (Ascorbic acid)
	Phenylalanine		P	F	B_1 (Thiamin)
	Threonine		Cl	Se	B_2 (Riboflavin)
	Tryptophan			Mo	B_3 (Niacin)
	Valine			Co (in B_{12})	B_5 (Pantothenic acid)
				Cr	B_6 (Pyroxidine)
				Si	B_7/H (Biotin)
				B	B_9 (Folic acid, folacin)
				Ni	B_{12} (Cobalamin)
				V	
				As	
				Li	
				Sn	

*Numerous other beneficial substances in foods are also known to contribute to good health.

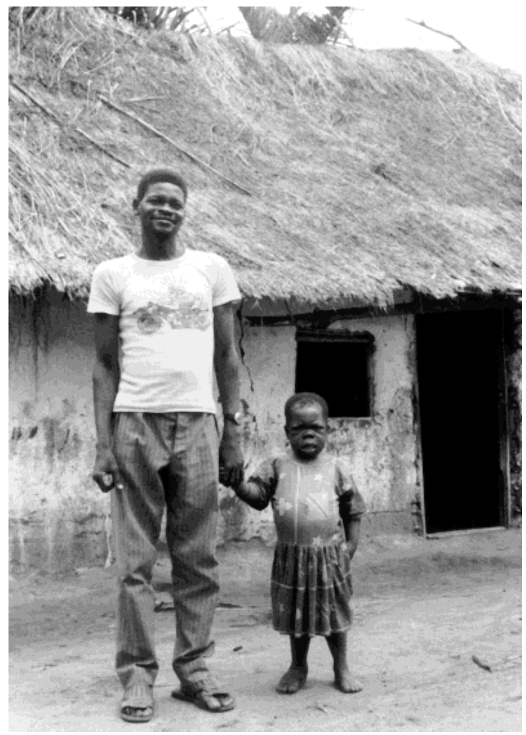
The Ugly Face of Micronutrient Malnutrition

Zinc Deficiency

Iron Deficiency



Vitamin A Deficiency



Iodine Deficiency

Ca Deficiency
Rickets

Micronutrient Malnutrition Causes….

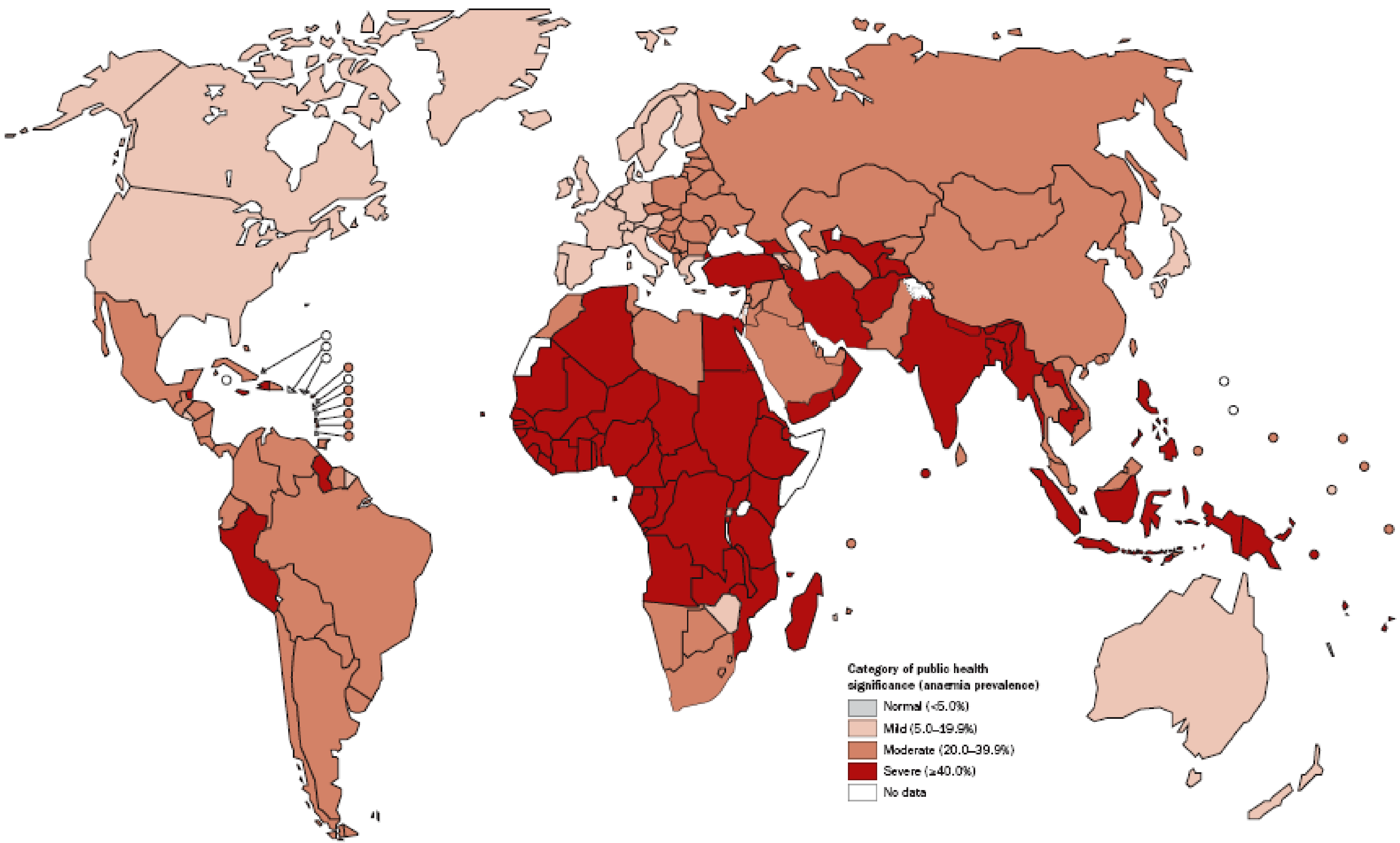
- More severe illness
- More infant and maternal deaths
- Lower cognitive development
- Stunted growth
- Lower work productivity

And ultimately -

- Lower GDP (e.g. an estimated >5% annual loss in Pakistan)
- Higher population growth rates

Worldwide Prevalence of Anemia (i.e., Fe Deficiency) in Pregnant Women

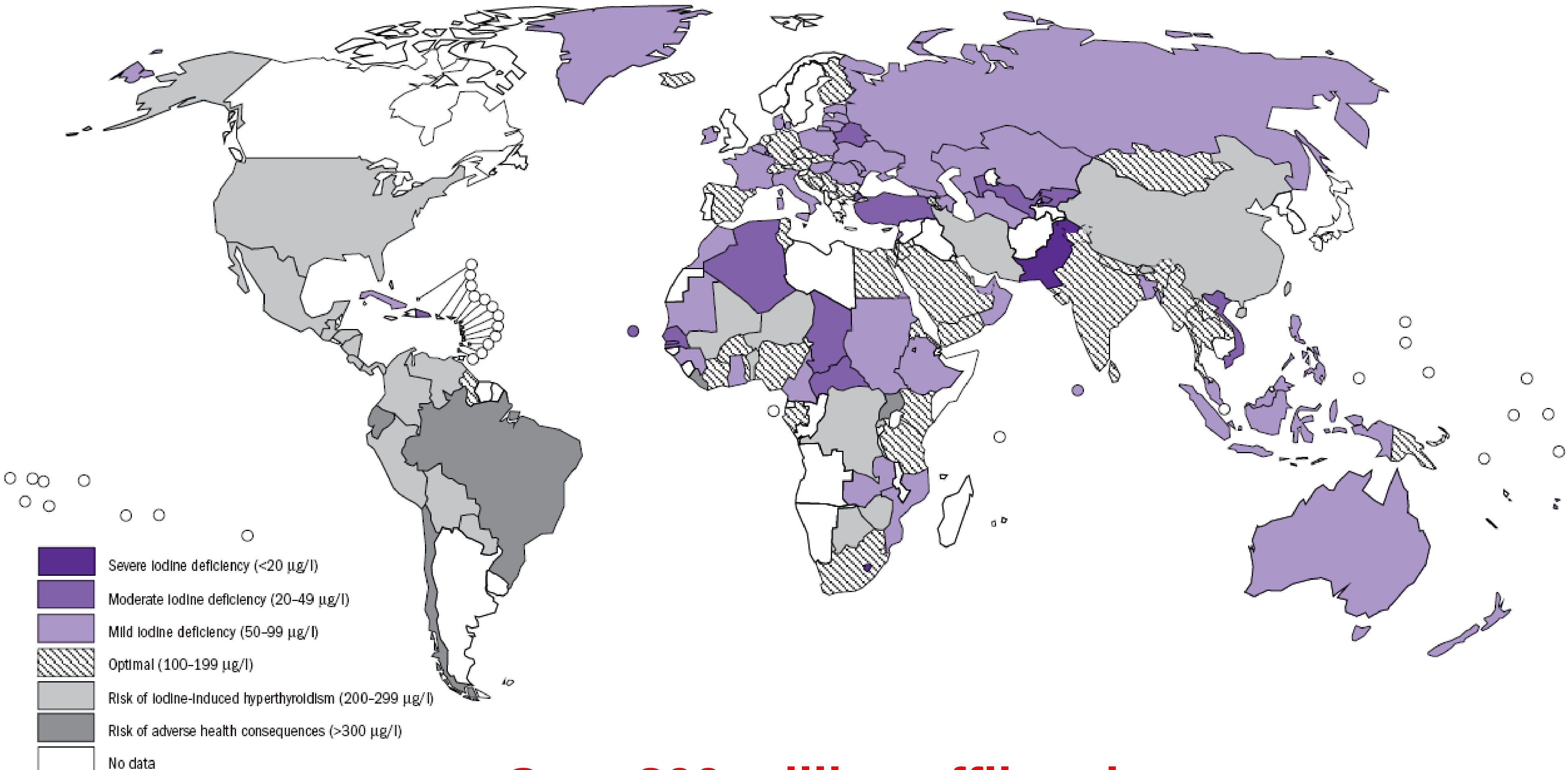
Figure 3.1b   Anaemia as a public health problem by country: Pregnant women



Over 2 billion iron deficient people

(WHO, 2008)

Degree of Public Health Significance of Iodine Nutrition Based on Median Urine Iodine

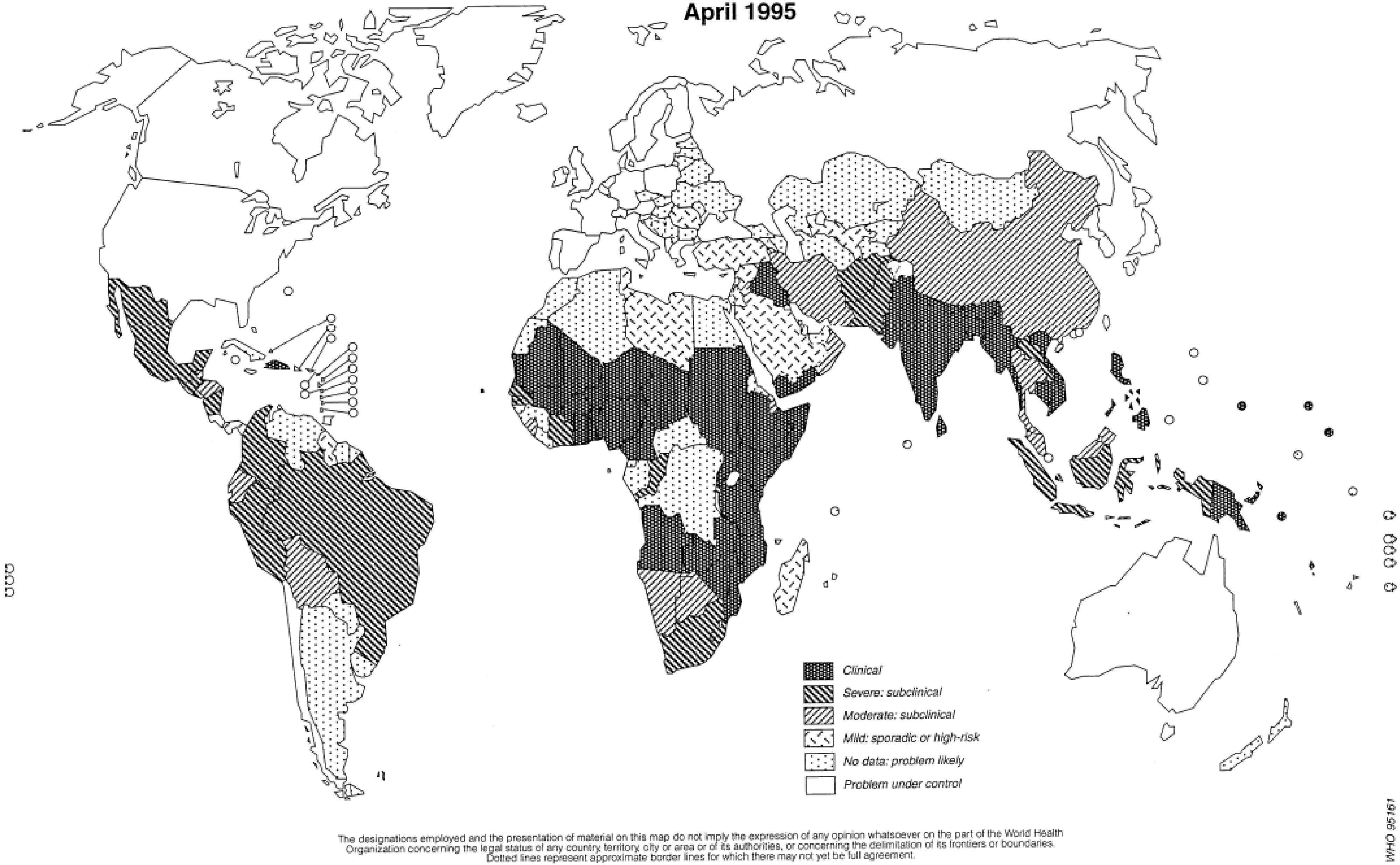


Over 800 million afflicted

WHO (2004)

Countries categorized by degree of public health importance of vitamin A deficiency

April 1995

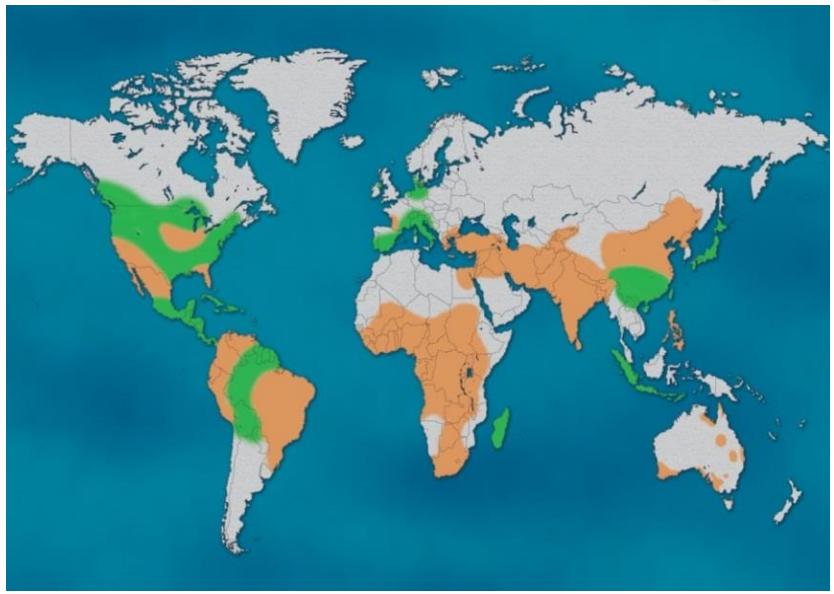


The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines represent approximate border lines for which there may not yet be full agreement.

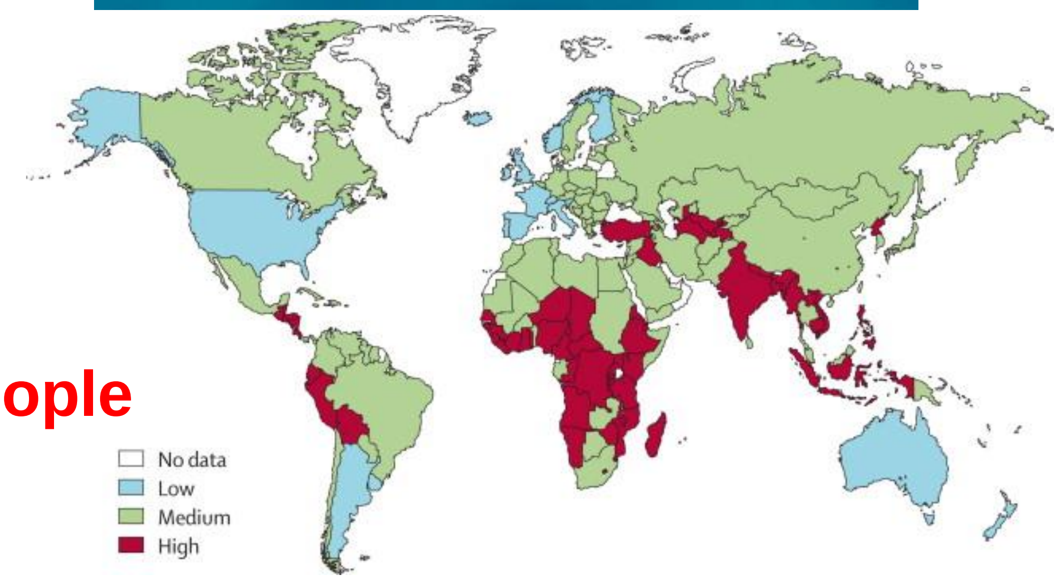
> 200 million children afflicted

Link Between Zn-Deficient Soils (Crops) & Zn Deficiency in Humans

Wide Deficiency –
Medium deficiency –



Zn-Deficient Crops



Zn-Deficient Humans

> 1 billion people

Figure from A. Green, 2009

Some Other Known Human Micronutrient Deficiency Problems

Selenium deficiency

Scurvy (vitamin C deficiency)

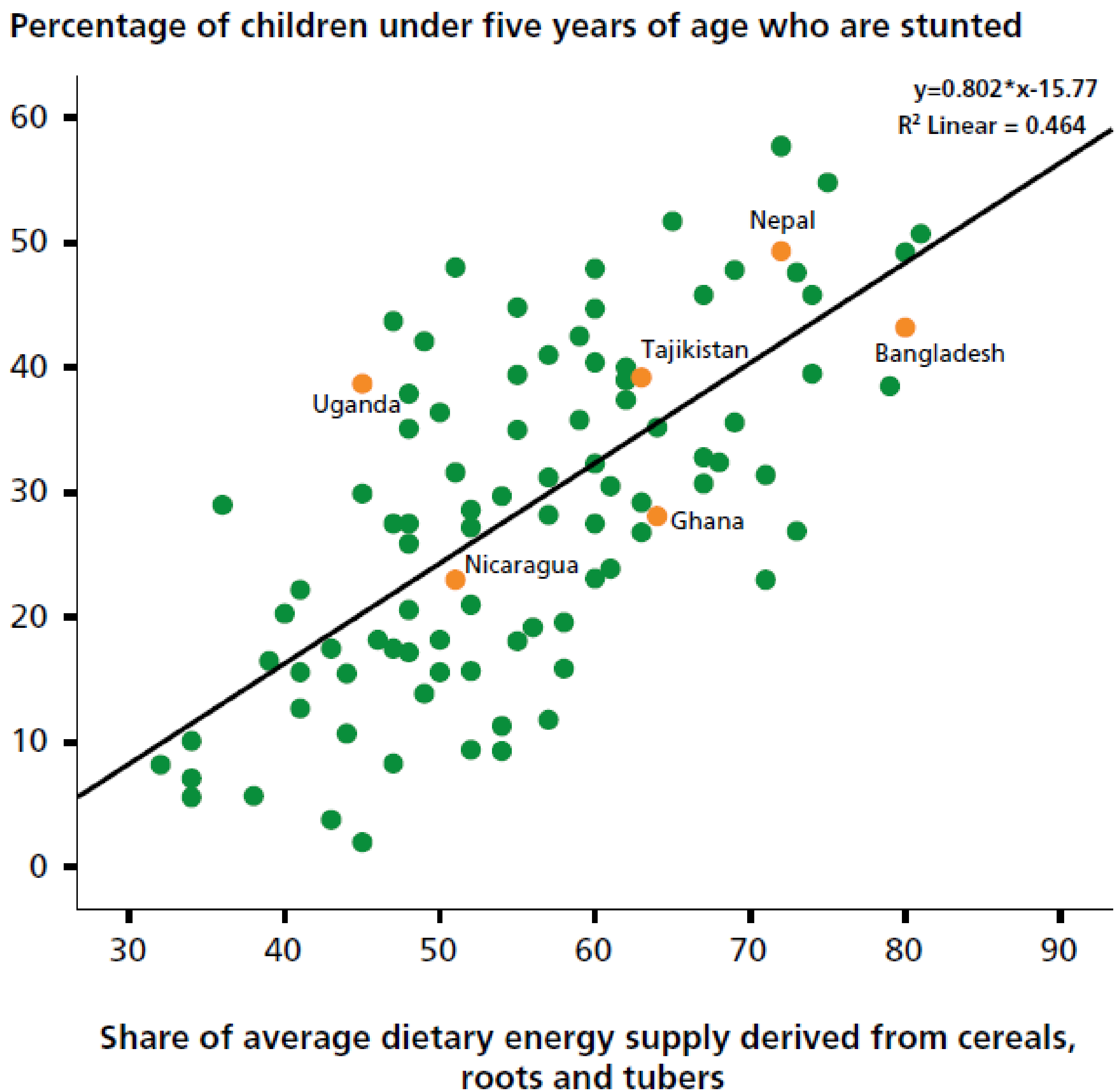
Beriberi (thiamine/B_1 deficiency)

Rickets (both vitamin D & Ca deficiencies)

Pernicious Anemia (cobalamine/B_{12} deficiency)

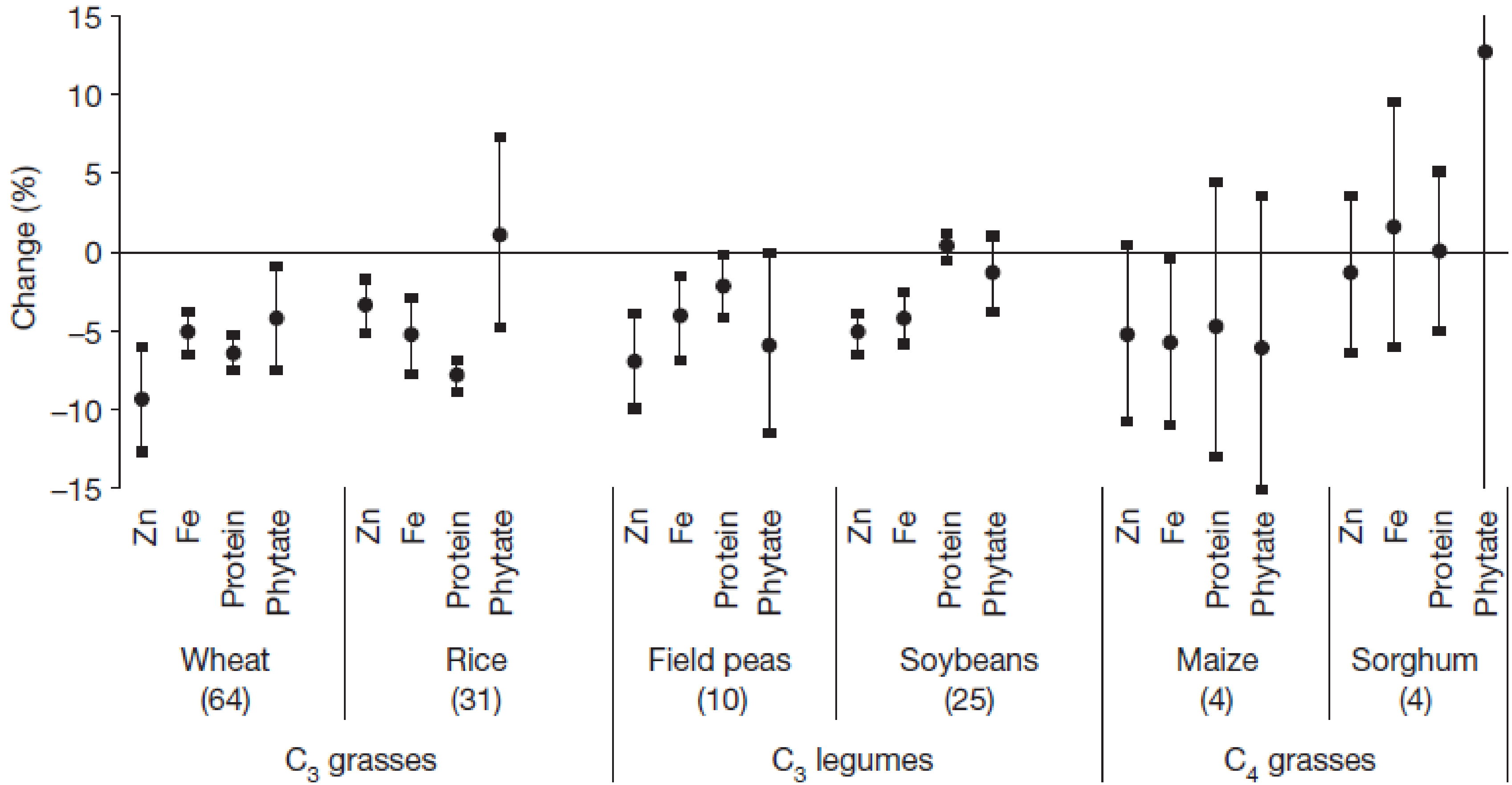
Folic acid deficiency

Effects of Eating Starchy Staple Crops on Stunting in Children



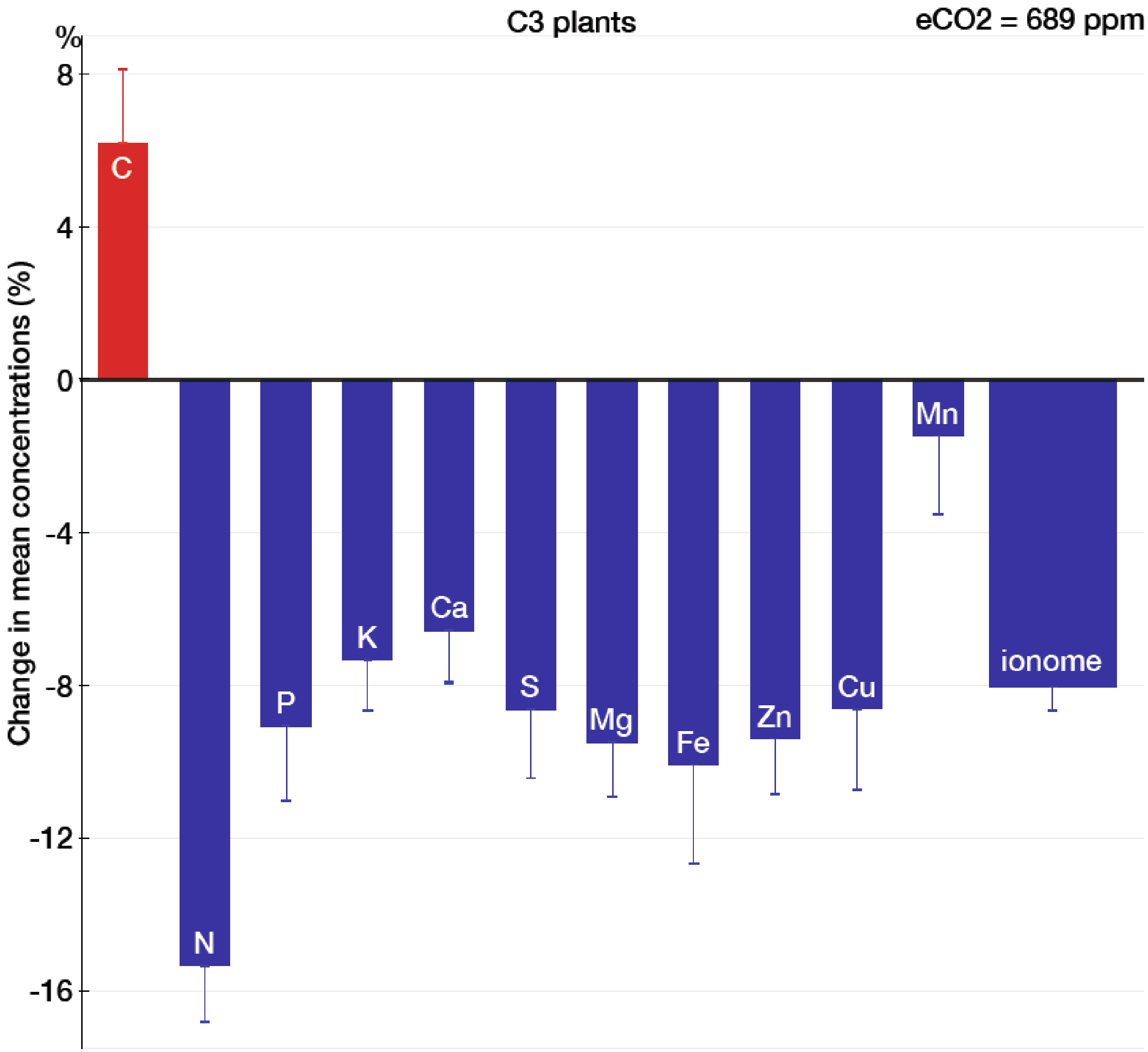
FAO, 2013

Percentage Change in Crop Nutrients at Elevated [CO_2] Relative to Ambient [CO_2]



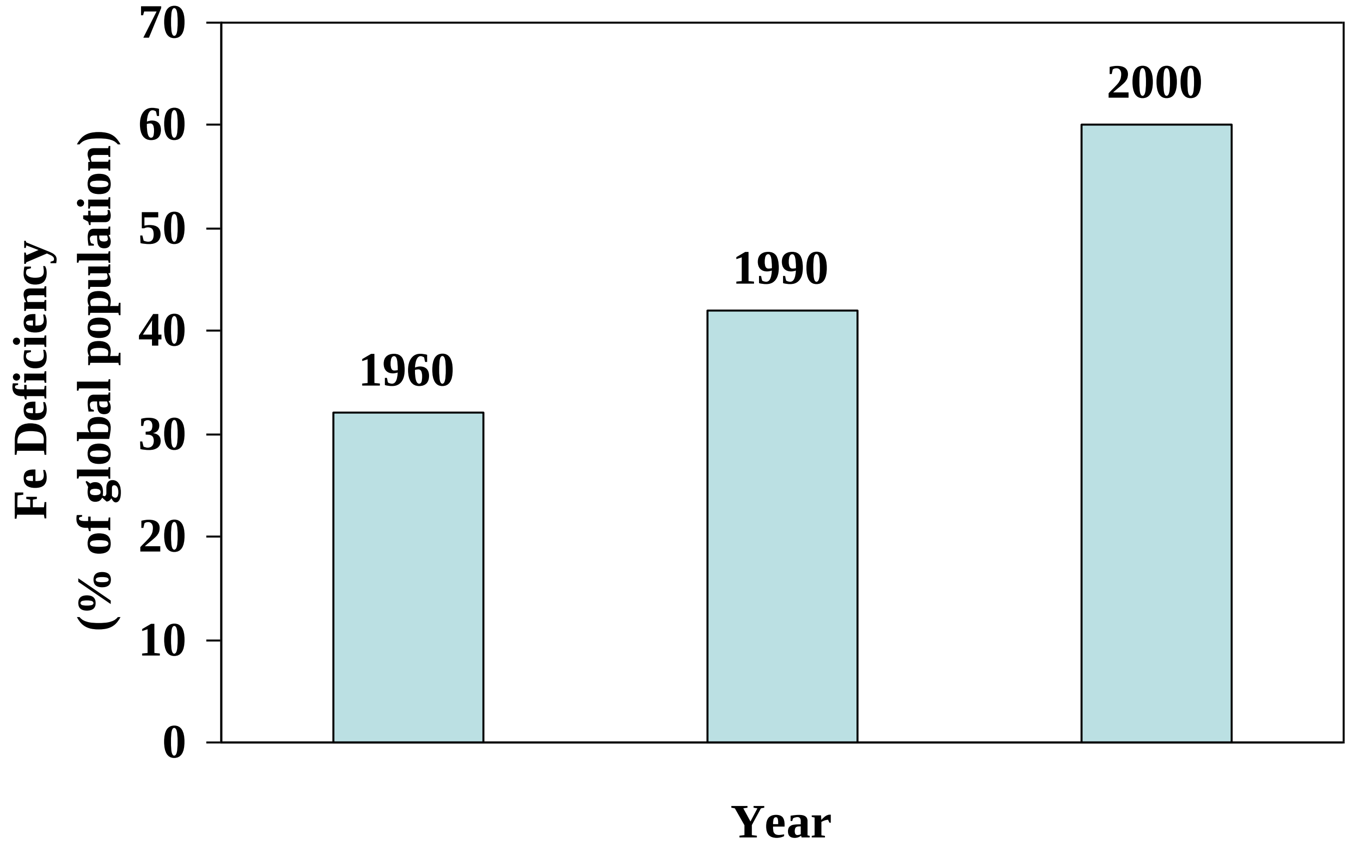
Myers et al., *Nature* 2014

Effects of Elevated CO_2 on Elements in C3 plants



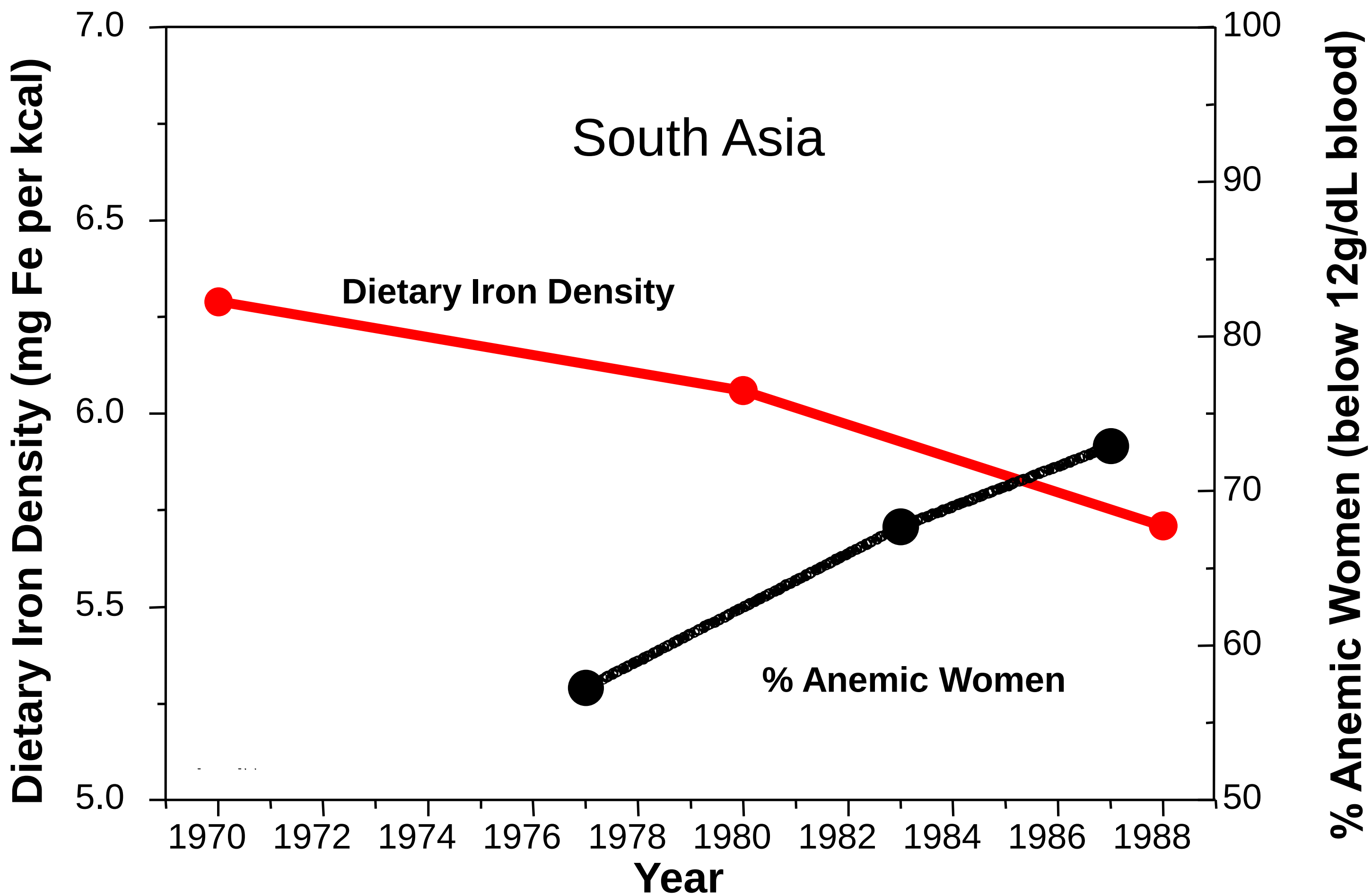
Loladze, *eLife* 2014

Change in The Prevalence of Iron Deficiency Globally

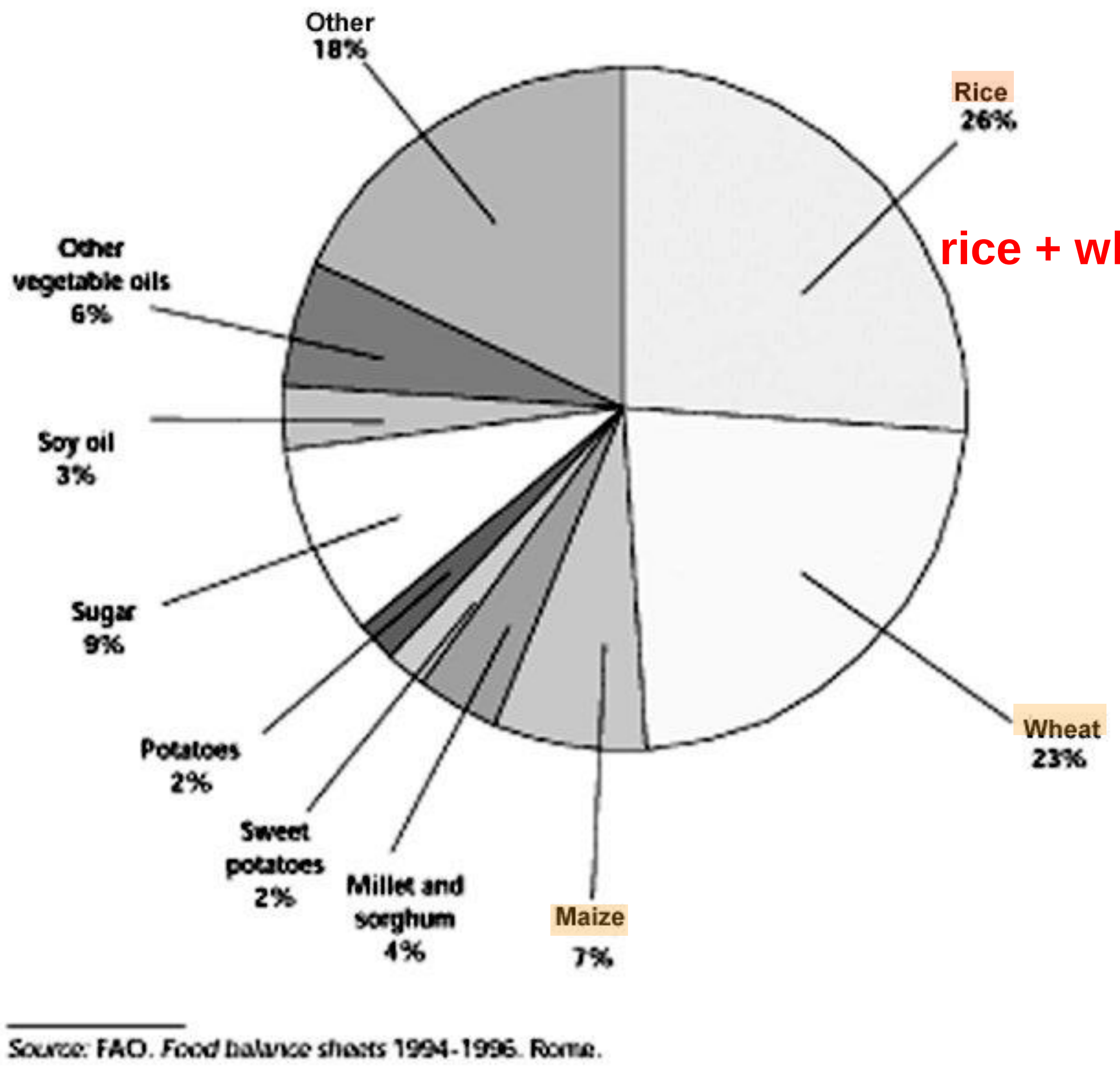


Data from WHO, 2002

Dietary Iron Density and % Anemic Women in S. Asia



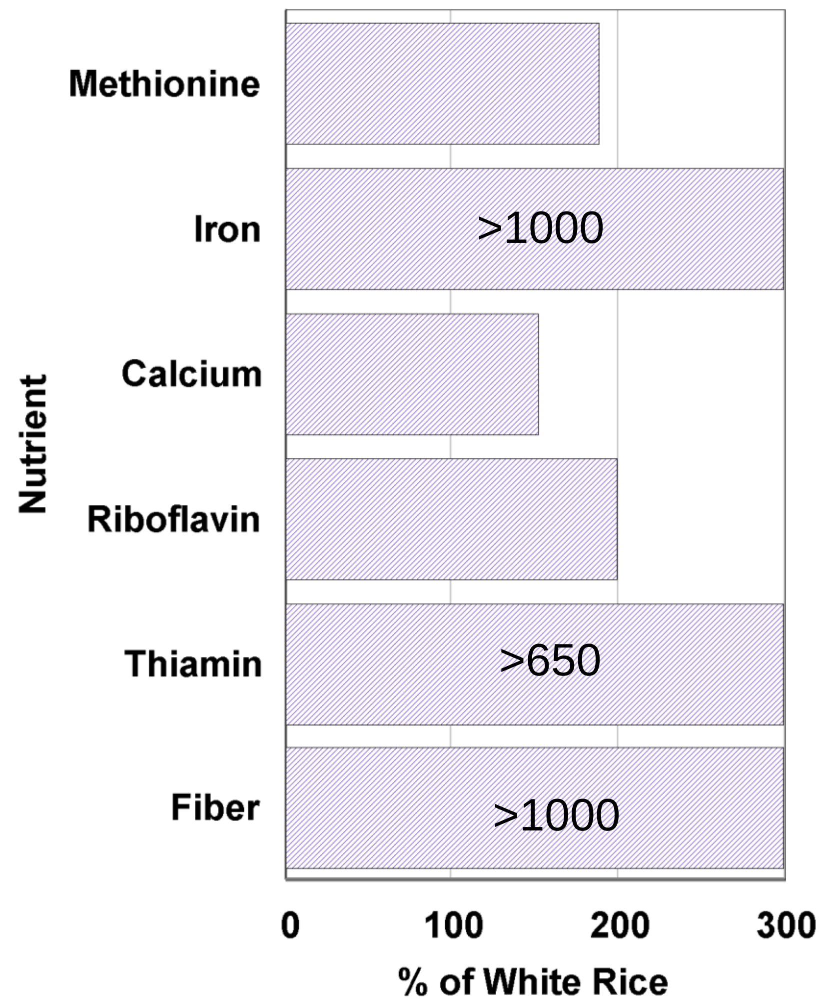
Most Important Food Crops Globally



rice + wheat + maize = 56%

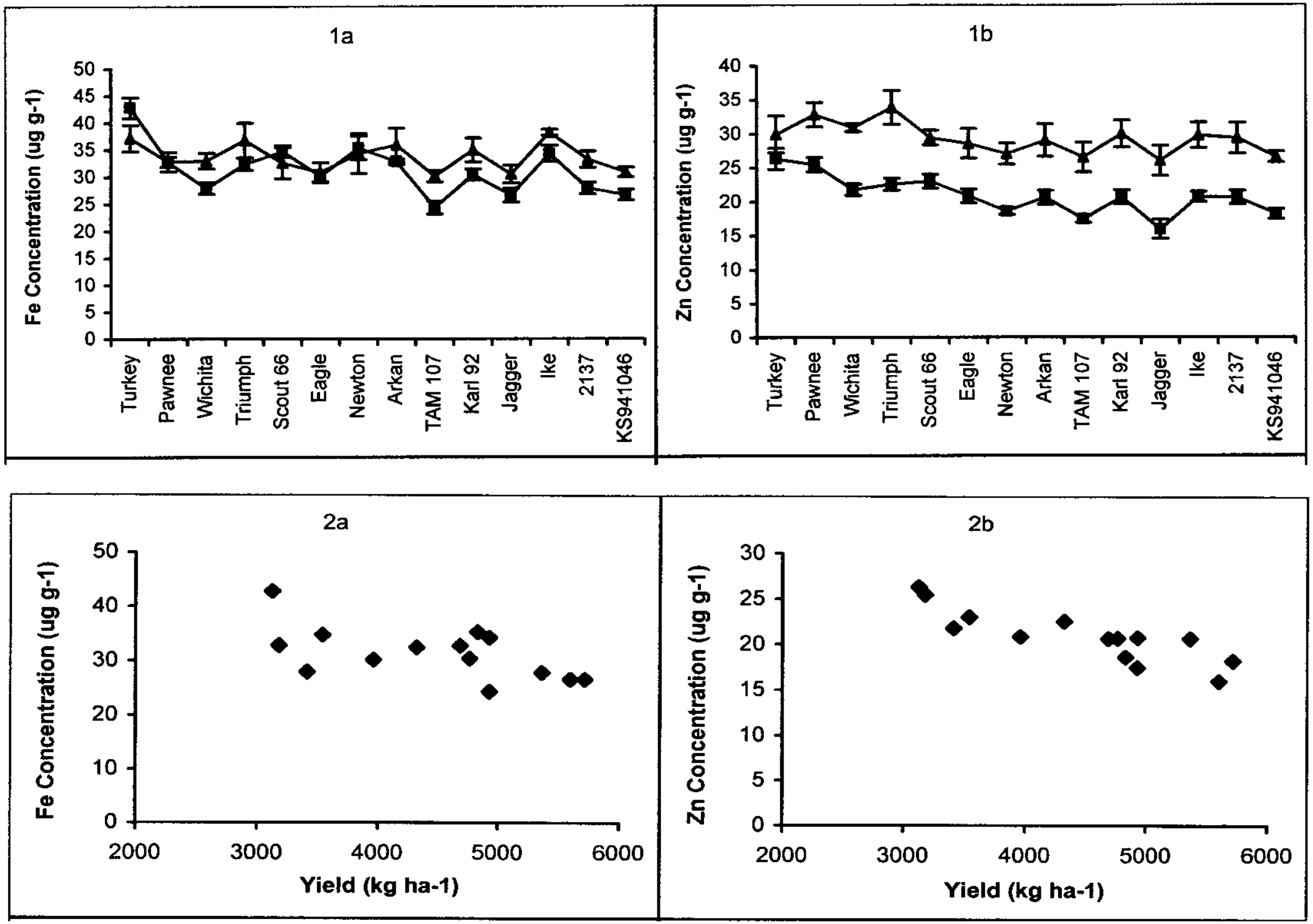
Comparative Nutritional Quality of Fonio to White Rice

- Very high biological value of protein; rich in methionine and cystine
- Rich in minerals
- One of the world's best tasting cereals
- World's fastest maturing cereal



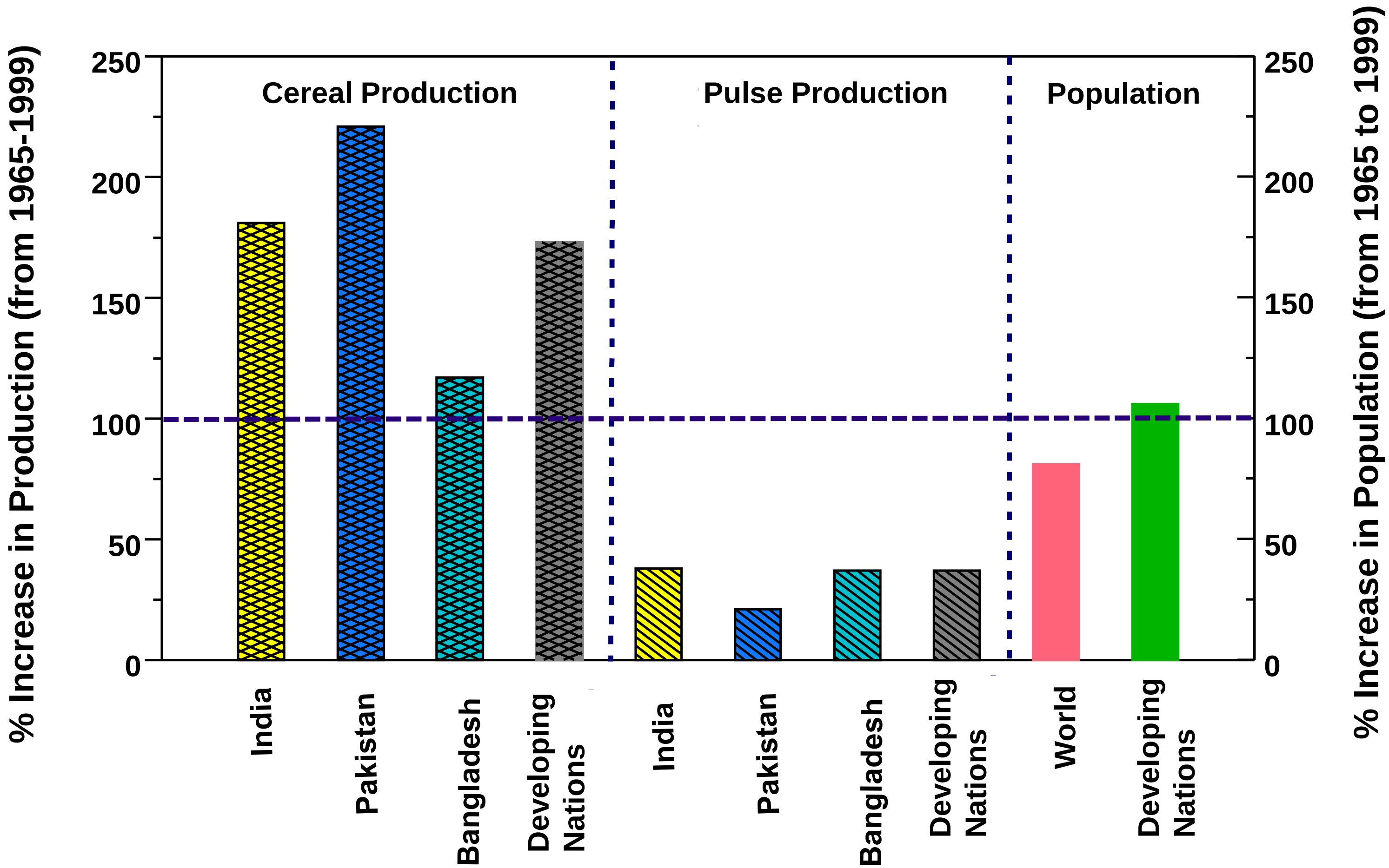
Data from National Research Council, NAS, 1996

Historical Trends in Fe & Zn in Grain of Hard Red Winter Wheat Varieties in USA (1873 to 2000)



(From Garvin et al., J. Sci. Food Agr. 2006)

% Changes in Cereal & Pulse Production & in Populations Between 1965 & 1999



(FAO data, 1999)

Micronutrients in Whole Cereal Grains and Legume Seeds (Pulses)

	Plant Food	Fe	Zn	Mn	Cu	Mo	Cr	Ni
					($\mu g\ g^{-1}$ dry weight)			
Cereals	Brown rice	20	14	11	2.4	0.78	0.088	-
	Whole soft wheat	39	22	35	4.5	-	0.370	0.31
Legumes	Mung bean	87	41	14	13.0	3.20	0.251	2.04
	Black gram	139	36	19	7.9	0.16	0.530	3.43
	Cowpea	67	45	16	6.3	1.47	0.272	3.44
	Soybean	97	43	26	15.5	-	-	-
	Red kidney bean	64	30	12	6.8	-	-	-

Effects of Polishing and Milling on Rice Grain Micronutrient Concentrations[a]

Micronutrient	Brown Rice	Polished Rice	% Removed
Iron ($mg\ kg^{-1}$)	20	5	75
Copper ($mg\ kg^{-1}$)	3.3	2.9	12
Manganese ($mg\ kg^{-1}$)	17.6	10.9	62
Zinc ($mg\ kg^{-1}$)	18	13	30
Biotin ($\mu g\ kg^{-1}$)	120	50	58
Folic Acid ($\mu g\ kg^{-1}$)	200	160	20
Niacin ($mg\ kg^{-1}$)	47	16	66
Pantothenic Acid ($mg\ kg^{-1}$)	20	10	50
Riboflavin ($mg\ kg^{-1}$)	0.5	0.3	40
Thiamin ($mg\ kg^{-1}$)	3.4	0.7	80
Vitamin B_6 ($mg\ kg^{-1}$)	6.2	0.4	94
Vitamin E ($IU\ kg^{-1}$)[b]	20	10	50

[a]Dry weight basis.
[b]IU = International Unit.

Copenhagen Consensus 2008 Global Challenges

Ranked Top Five World Challenges

	SOLUTION	CHALLENGE
1	Micronutrient supplements for children (vitamin A and zinc)	Malnutrition
2	The Doha development agenda	Trade
3	Micronutrient fortification (iron and salt iodization)	Malnutrition
4	Expanded immunization coverage for children	Diseases
5	Biofortification	Malnutrition

Malnutrition and Hunger

The expert panel examined the following solutions to this challenge: micronutrient supplementation (Vitamin A and Zinc), micronutrient fortification (iron and salt iodization), biofortification (agricultural improvements through research and development), de-worming (which also improves education), and nutritional education campaigns.

The panel ranked solutions to this challenge very highly, because of the exceptionally high ratio of benefits to costs. Micronutrient supplements were the top-ranked and fortification was the third-ranked solution, with tremendously high benefits compared to costs.

G-8 Action on Food Security and Nutrition
($3 billion pledged; May 18, 2012)

- To improve nutritional outcomes and reduce child stunting, the G-8 will:
- Actively support the Scaling Up Nutrition movement and welcome the commitment of African partners to improve the nutritional well-being of their populations, especially during the critical 1,000 days window from pregnancy to a child's second birthday.
- We pledge that the G-8 members will maintain robust programs to further reduce child stunting.
- Commit to improve tracking and disbursements for nutrition across sectors and ensure coordination of nutrition activities across sectors.
- Support the accelerated release, adoption and consumption of bio-fortified crop varieties, crop diversification, and related technologies to improve the nutritional quality of food in Africa.
- Develop a nutrition policy research agenda and support the efforts of African institutions, civil society and private sector partners to establish regional nutritional learning centers.

What Farmers Require to Grow More Nutritious Crops

Provide them the knowledge and tools needed to grow more nutrient-dense crops allowing increased nutrient output of farming systems

Provide the tools needed to prove their crops are more nutritious and healthy such as analytical services for testing crops for nutrients (e.g., minerals, vitamins) and health promoting substances (e.g. antioxidants)

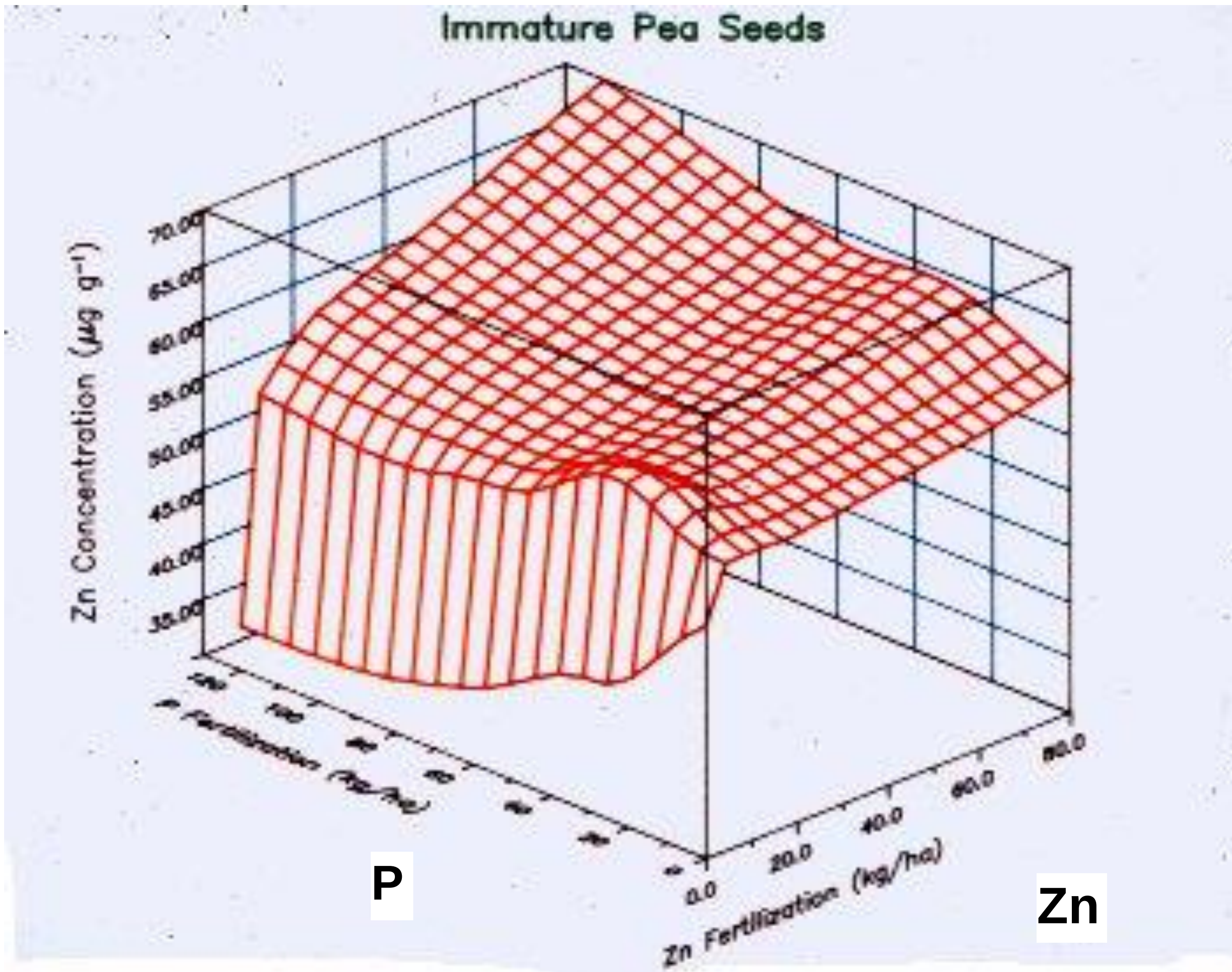
Provide incentives to attract more farmers into growing "health" promoting crops (e.g., Norway)

Make it profitable

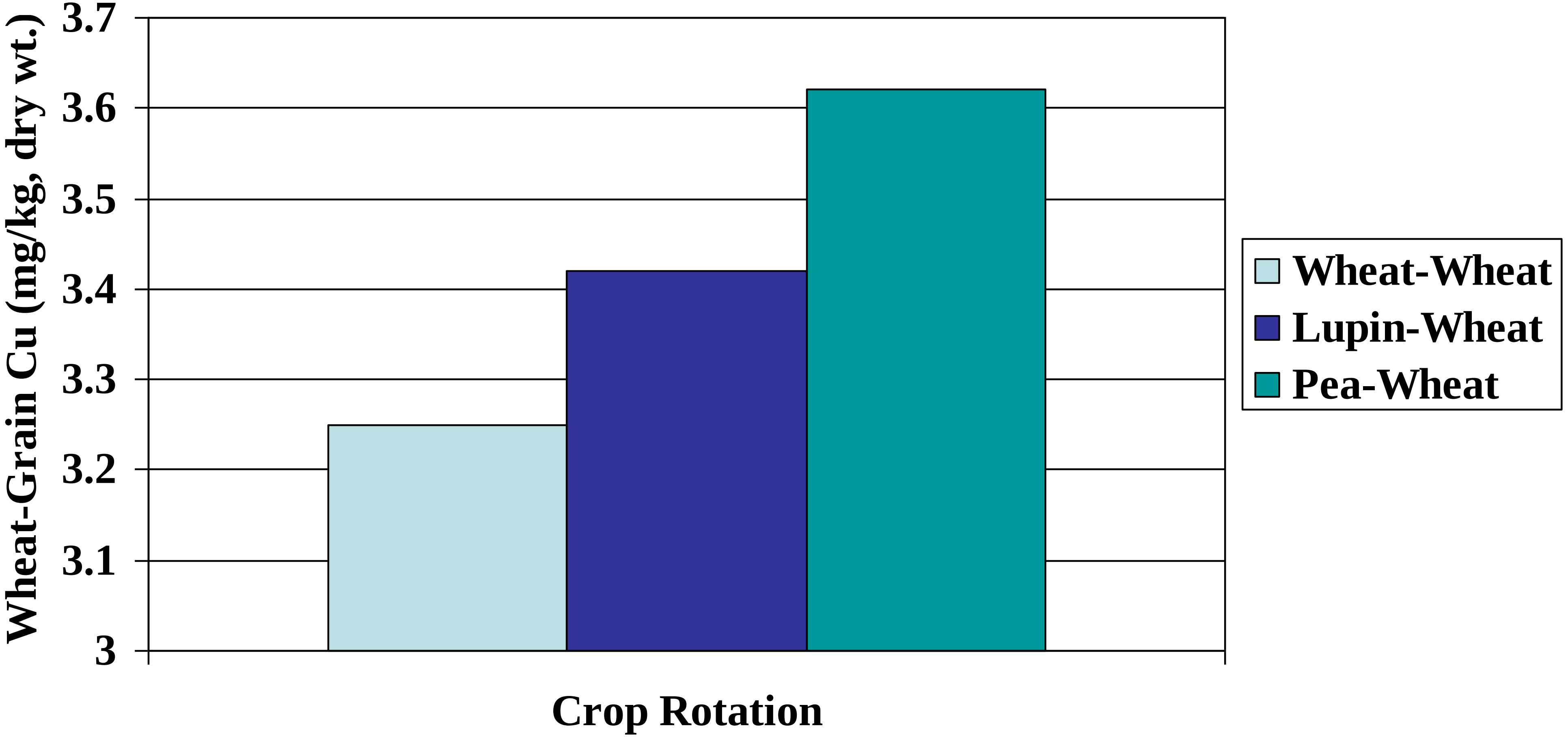
Agricultural Approaches to "Healthier" Food Crops

- Field Site Selection – (e.g., soils high in Se, Zn, etc.)
- Agronomic Practices
  - macronutrient fertilizers
    - nitrogen, phosphorus, potassium, sulfur, calcium, magnesium
    - effects protein, fats, vitamins, antinutrients, etc.
  - micronutrient & trace element fertilizers
    - Zn, Se, Co, Ni, I, Mo, Li, Cl - effective in increasing amount in plant seeds and grains
    - Fe, Cu, Mn, B, Cr, V, Si - not very effective in increasing seed or grain levels
  - farming system (no-till, organic matter, soil amendments)
- Cropping systems – design to maximize nutrient output
  - crop rotations - effects micronutrient content
  - use nutrient-dense varieties of food crops (HarvestPlus)
  - diversification – soil health and human health
- Utilize indigenous plant foods and diversify food systems
- Genetically modify food crops to improve nutrient output and the "healthiness" of crops from farming systems

P & Zn Fertilizer Effects on Zn Levels in Pea Seeds



Effects of Crop Rotations on Wheat Grain-Cu



Data from King et al., J. Agron. & Crop Sci. 169: 37-48 (1992)

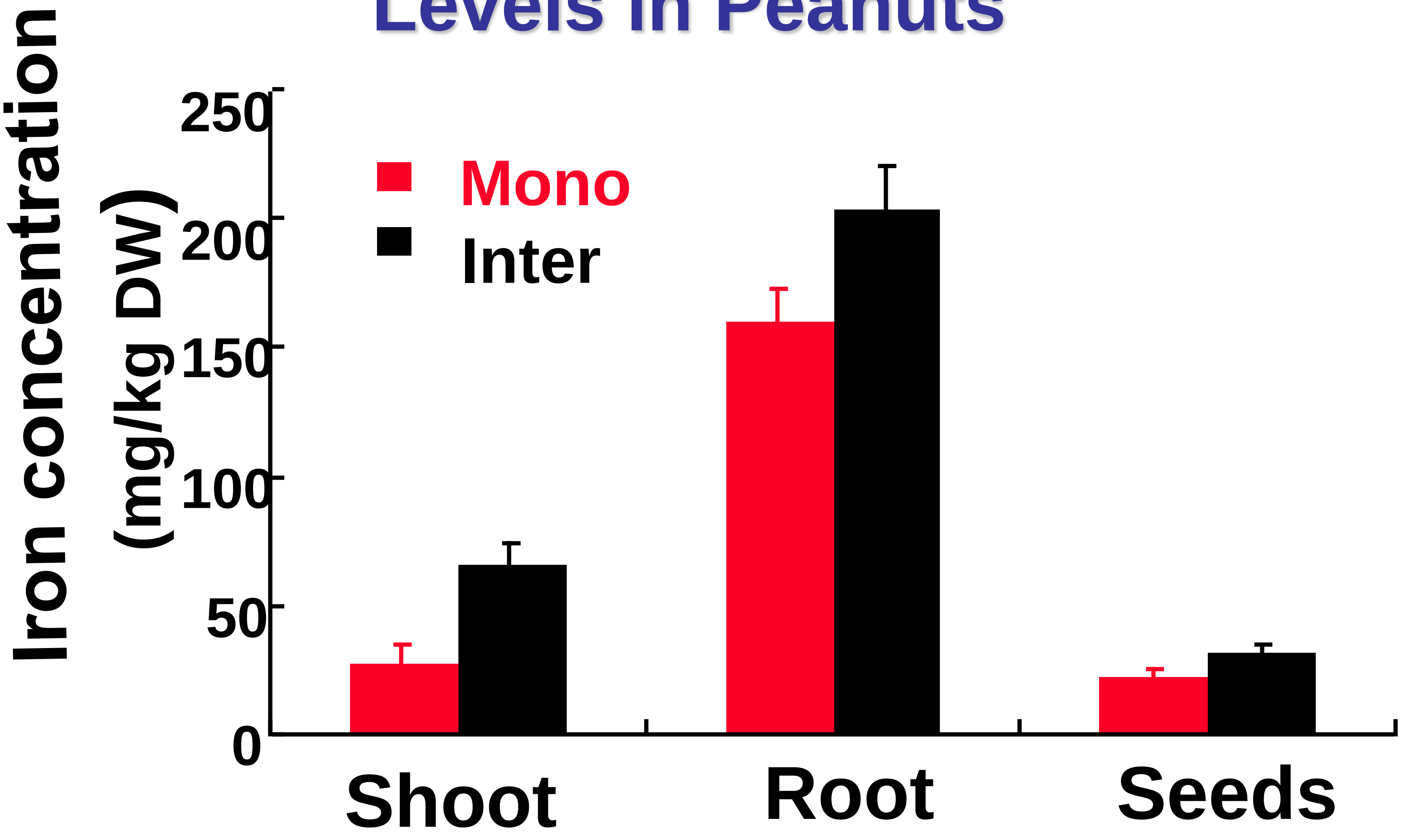
Effects of Maize Intercropping on Fe Deficiency in Peanuts

Mono-cropping

Intercropping

(Zuo et al., Plant and Soil, 2000)

Effect of Intercropping (Maize-Peanut) on Fe Levels in Peanuts



(Zuo et al., Plant and Soil, 2000)

Farming Benefits of Micronutrient Element-Enriched Seeds (e.g. Zn)

- Better seed viability
- Greater seedling vigor
- Denser stands (less soil erosion)
- Lower seeding rates (lower cost to farmers)
- Larger root absorptive surface (better water & nutrient use efficiency)
- Better resistance to disease
- Better plant survival
- Increased plant & seed yield
- Improved livestock health

Impact of Micronutrient Enriched Wheat Grain on Seedling Performance in 9 Farmers' Fields

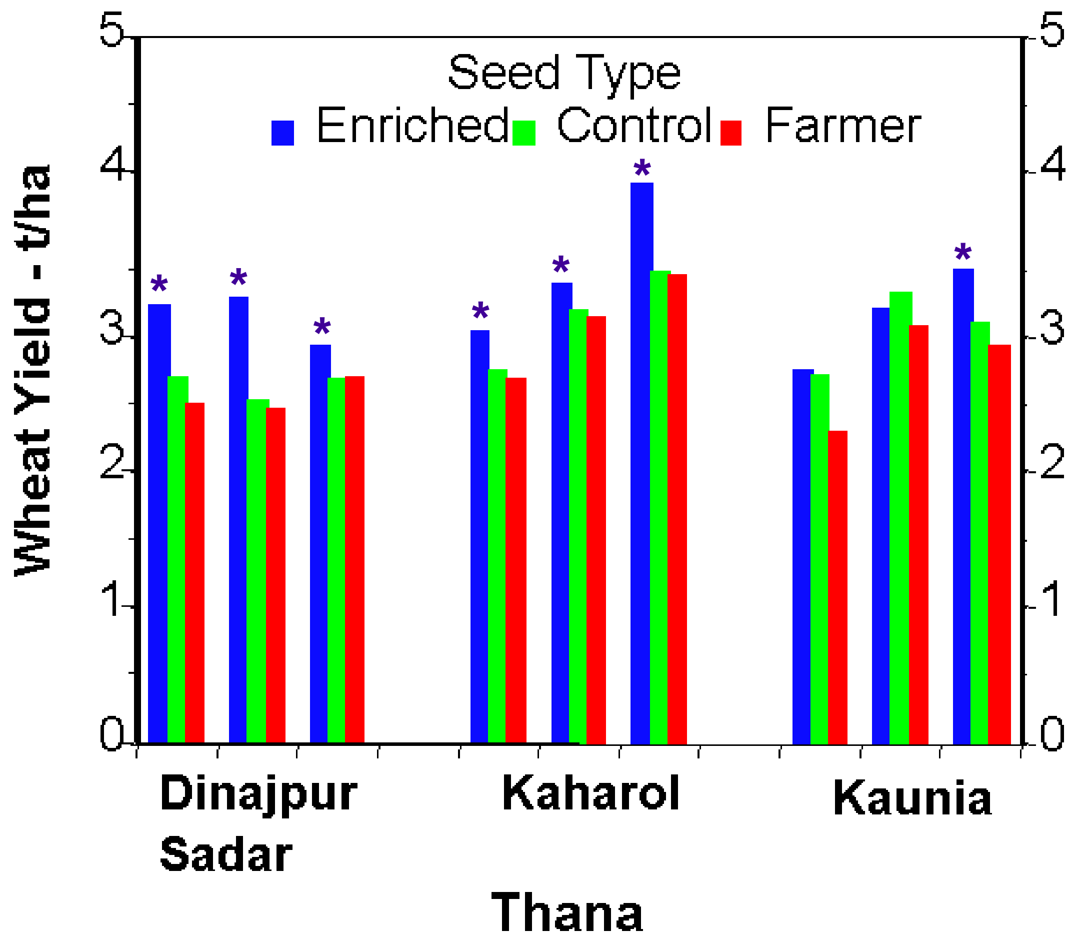
Parameter	Seed Type		
	Enriched	Control[a]	Farmer
Seedling Emergence-%	78	60	50
Biomass @ 30 days -mg	9.7	7.8	6.9
Root Health Grade[b]	2.8	3.9	4.3

[a]Unenriched seed grown at the same time as the enriched seed

[b]On a 1-9 scale, where 1 is best and 9 is worst

Data from John Duxbury

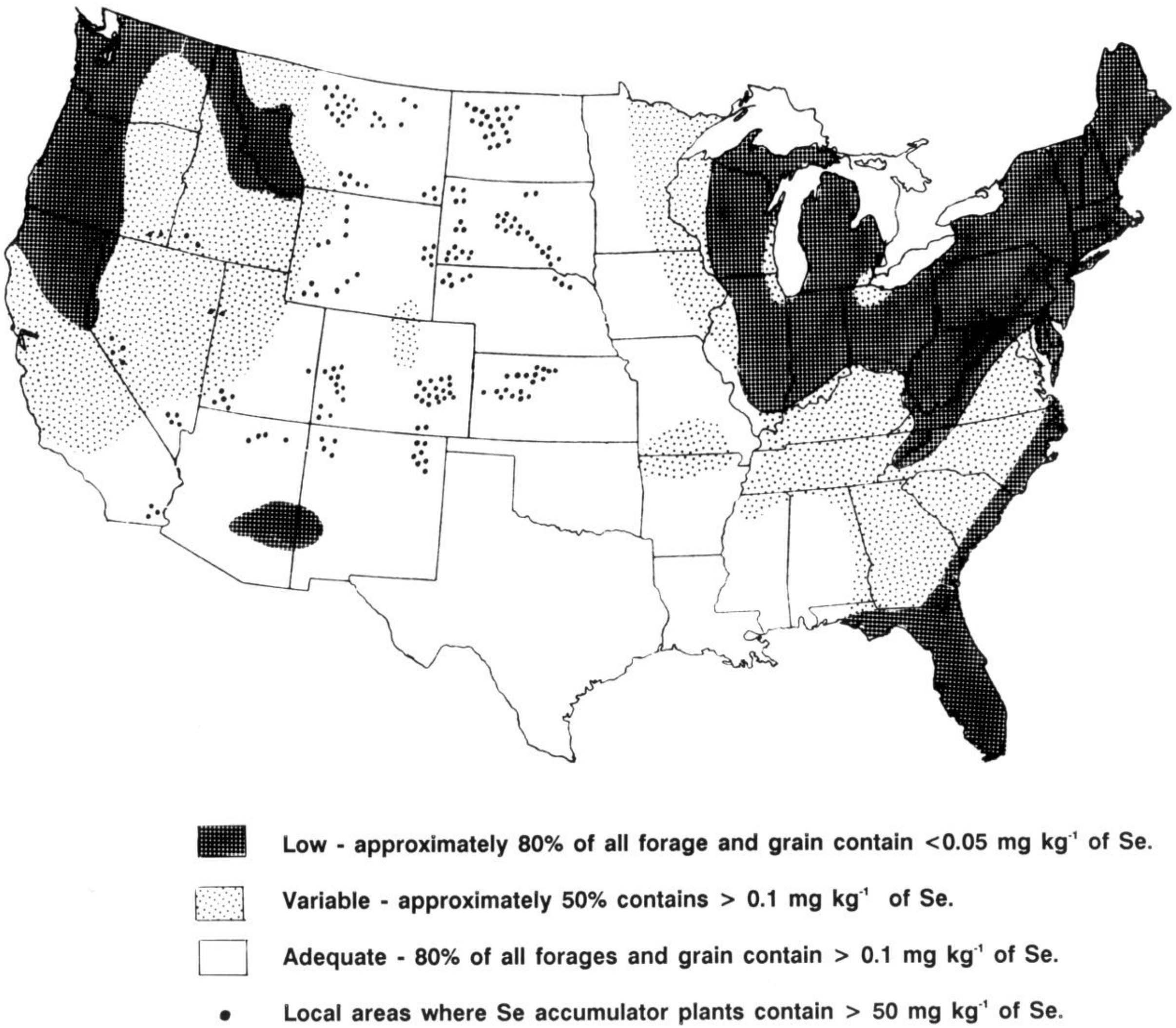
Effects of Micronutrient-Enriched Seed on Wheat (Kanchan) Grain Yields from Farms in Bangladesh



24% > in grain yield (0.69 t/ha) seen on 47 farms over 4 years.

(Data from Duxbury et al., unpublished data)

Se Map of 48 U.S. States

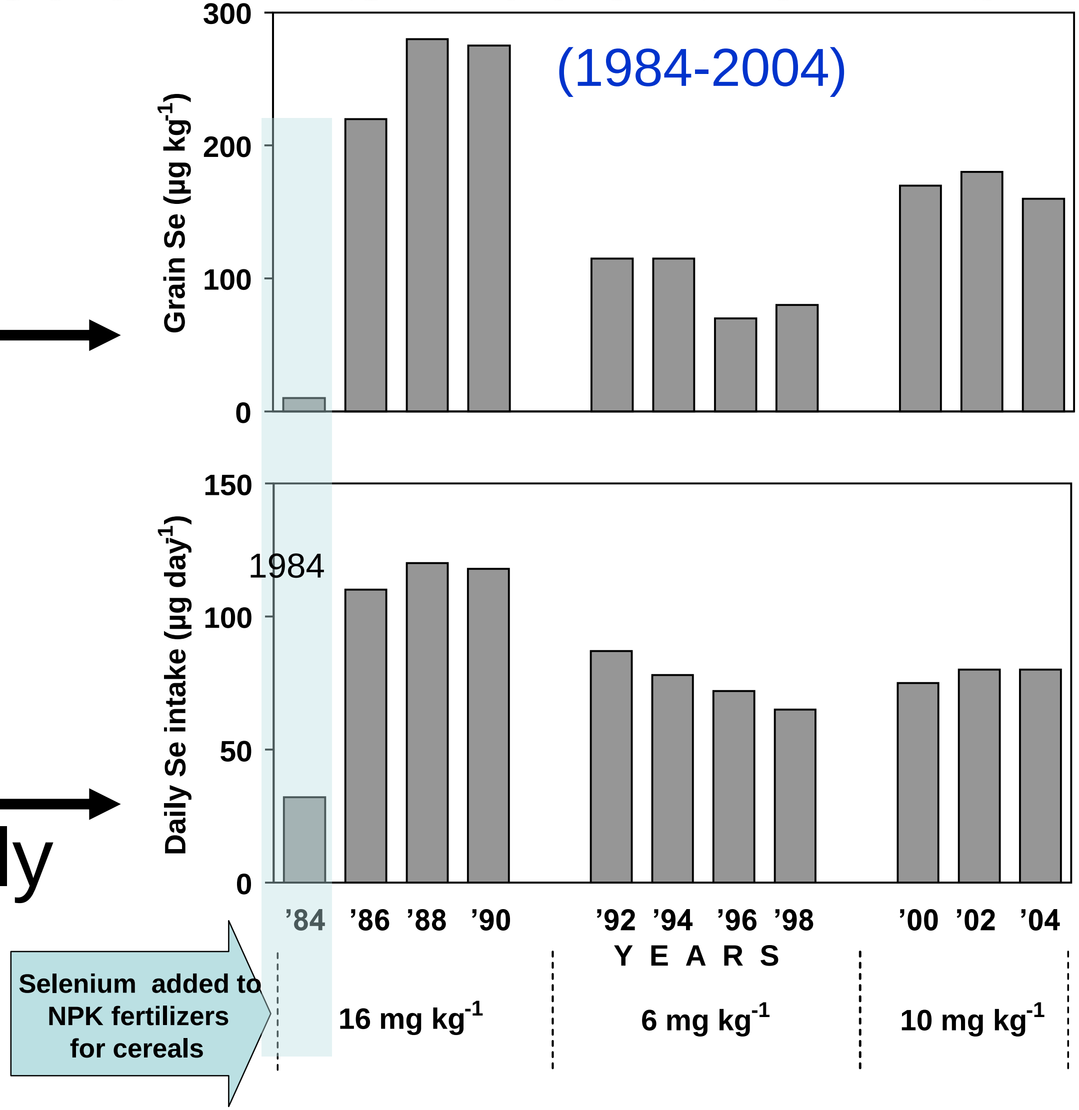


Map developed by Drs. Joe Kubota & William H. Allaway

Using the Selenium Fertilizer Tool to Improve Selenium Status of the Finish People

Grain-Se Level

Se Eaten Daily



Adding Se to fertilizers greatly > Se in cereal grain

Adding Se to fertilizers greatly > Se eaten each day

Resulted in a doubling of the blood-Se levels in the whole Finish population

From: Combs, 2005

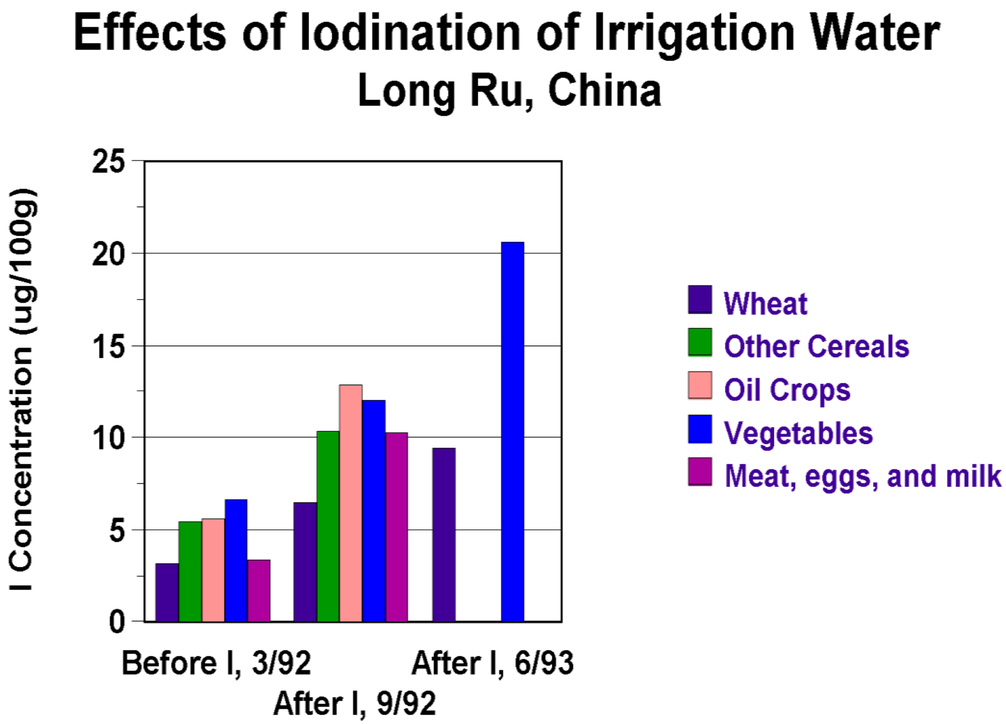
Effects of Zinc Fertilization on Wheat Yield & Grain Level

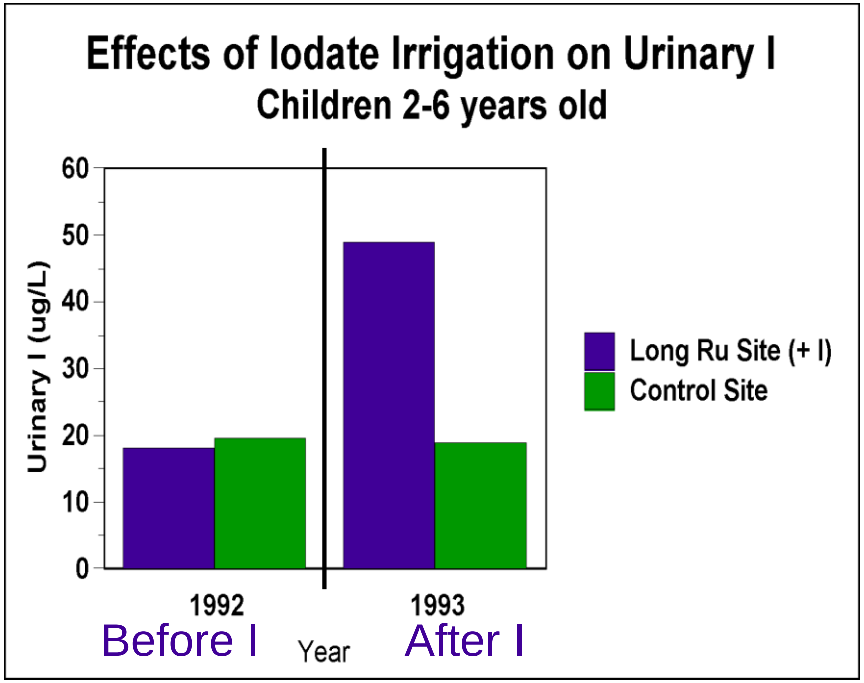
Zn application methods	Zn concentration		Increases in yield by Zn Fertilizer	
	Whole shoot	Grain	Wholeshoot	Grain
	(mg kg^{-1})		(%)	
Control	10	10	-	100
Soil	19	18	109	265
Seed	12	10	79	204
Foliar	60	27	40	124
Soil + foliar	69	35	92	250
Seed + foliar	73	29	83	268

Using both soil and foliar Zn fertilizers can maximize grain yields and grain-zinc

Yilmaz et al., 1997

Food Systems Approach to IDD





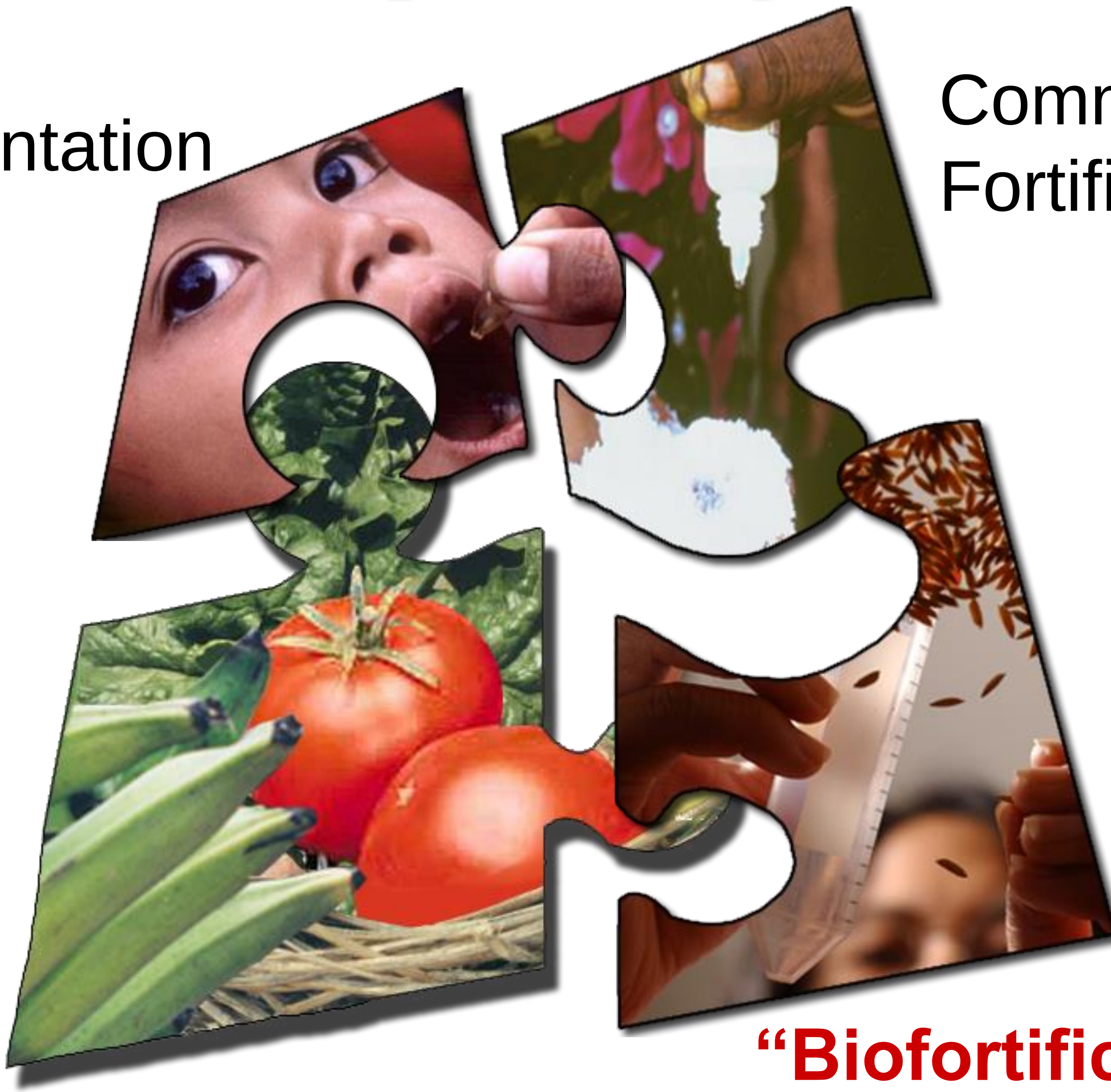
Importantly, also ≈ 30% increase in livestock productivity!
Using iodized salt can not achieve this benefit.
The root cause of I deficiency is not enough I in the soil!

Data from Cao, et al., 1994

Biofortification -
an Additional Weapon to Fight Malnutrition

Supplementation

Commercial
Fortification



Dietary
Diversity

"Biofortification"

HarvestPlus
Program Strategy

Develop micronutrient dense staple crops using the best traditional breeding practices and modern biotechnology to achieve provitamin A, iron, and zinc concentrations that can have <u>measurable</u> effects on nutritional status of target populations (i.e., the poorest of the poor)

HarvestPlus
Breeding Crops for Better Nutrition

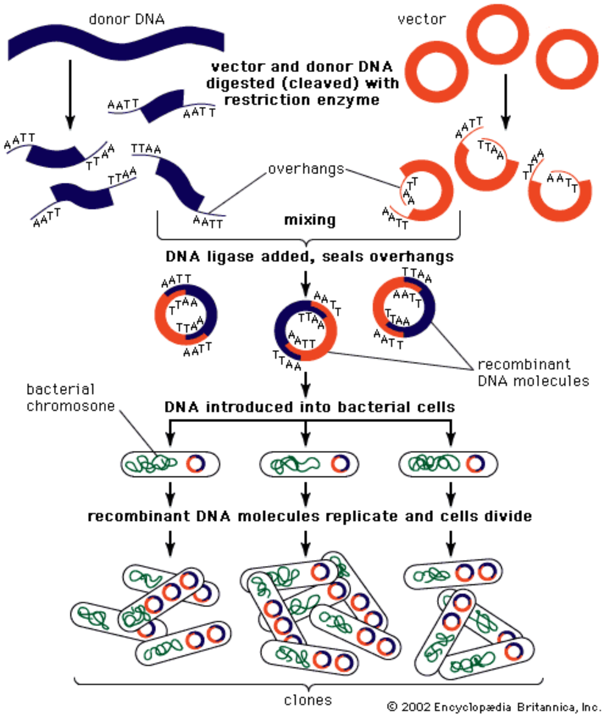

Congratulations to Dr. Howarth Bouis
2016 WORLD FOOD PRIZE LAUREATE
For his pioneering work to end global hunger and malnutrition by developing micronutrient-rich crops through biofortification.

Where Biofortification Started In 1993

Robin Graham, Ross Welch & Howdy Bouis
U.S. Plant, Soil & Nutrition Laboratory
Cornell University

Biofortification Strategies

- Plant Breeding
- Agronomic tools
- Genetic Engineering



Advantages of Biofortification

- **Targets the poor** who eat high levels of food staples
- **Rural-based**: where 75% of the malnourished populations live
- **Cost-effective**: research at a central location can be multiplied across countries and time
- **Sustainable**: investments are front-loaded, low recurrent costs

Questions for Success

- Can breeding increase nutrient levels to high enough levels to have health impacts?
- Will the extra nutrients be absorbed at sufficient levels to improve micronutrient status?
- Will farmers adopt and will consumers buy/eat in sufficient quantities?

Agriculture's Agenda For Better Health

Item 1: **Declare a goal of agriculture to produce high quality food that promotes human health and well-being in sustainable ways.**

Item 2: **Design seeds, cropping, livestock & aquiculture systems that help achieve primary goal—design for maximum bioavailable nutrient output of farming systems.**

Item 3: **Genetically modify food crops, increasing nutritional and health while promoting crop productivity**

Item 4: **Use agronomic practices (e.g., cropping systems and fertilizers) to improve nutrient output of farming systems.**

Item 5: **Define sustainable agriculture, as agriculture that yields "healthy foods" for healthy and productive people!**