Contributions of Fertilizers to Human Health

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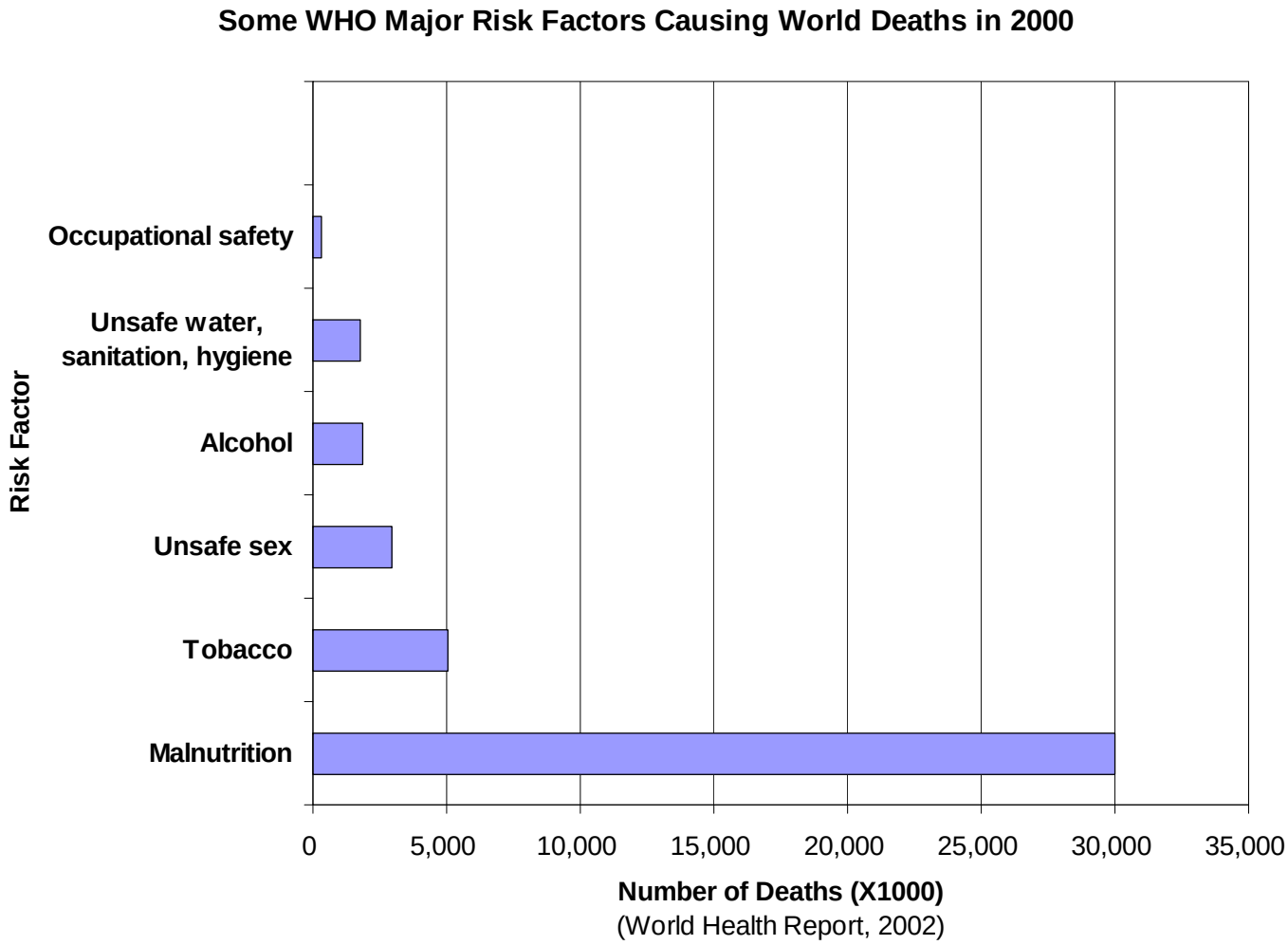
Annually, What Global Risk Factor is Responsible for Causing the Most Human Deaths?

A. Unsafe sex (HIV-AIDs, etc.)
B. Smoking
C. Unsafe water, sanitation, hygiene
D. Alcohol
E. War and genocide
F. Terrorism
G. Malnutrition

Some Major World Risk Factors Causing Deaths



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

Malnutrition -

will be responsible for 3,000 deaths globally, mostly women, infants and children, during this presentation!

- **This global crisis is happening now!**
- **These deaths are preventable.**
- **What is the root cause of these deaths?**
- **What can we do to prevent them from happening in a sustainable way?**

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!
- "Nutrient" security not "food" security should be the focus of agriculture
- 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.

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 developed and 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

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 Water Carbohydrates	Histidine Isoleucine Leucine Lysine Methionine Phenylalanine Threonine Tryptophan Valine	Linoleic acid Linolenic acid	Na K Ca Mg S P Cl	Fe Zn Cu Mn I F Se Mo Co (in B_{12}) Cr Si B Ni V As Li Sn	A D E K C (Ascorbic acid) B_1 (Thiamin) B_2 (Riboflavin) B_3 (Niacin) B_5 (Pantothenic acid) B_6 (Pyroxidine) B_7/H (Biotin) B_9 (Folic acid, folacin) B_{12} (Cobalamin)

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

From Quantity to Quality

- Agriculture is no longer driven only by supply-side forces and stimulus of support policies (commodity agriculture)
- Now becoming demand-driven controlled by consumer food preferences
- These demands seek distinctive elements of food value
- Quality characteristics of foods can be fostered by farmers
- Profitable farms will shift form raw material producers to become genuine producers of "food" capturing some of the final value of the products consumed
- "Quality agriculture" is the future of sustainable farms from an economic prospective
  - e.g., high Se durum wheat grain
  - packaged lettuce (1989 - $18 million; 2003 - $2.1 billion at the same production level).

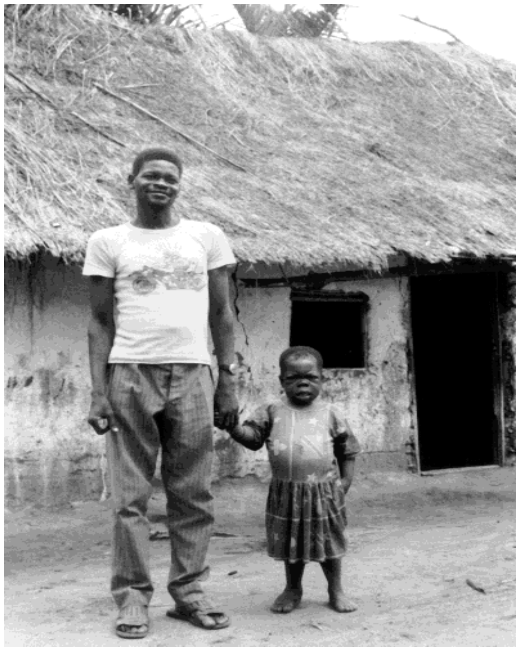
(J. McInerney. 2002. The production of food: from quantity to quality. Proc. Nutr. Soc. 61: 273-279)

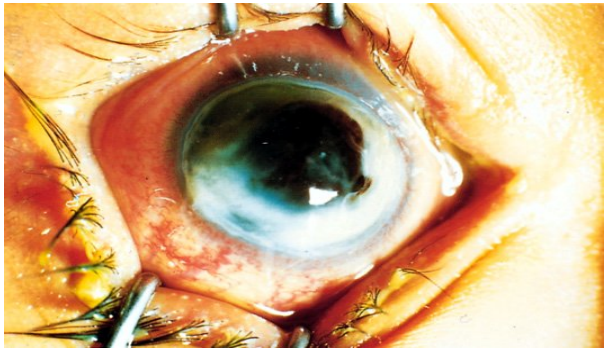
The Ugly Face of Micronutrient Malnutrition

Zinc Deficiency

> 3 Billion People Afflicted

Iron Deficiency





Vitamin A Deficiency

Iodine Deficiency

Ca Deficiency
Rickets

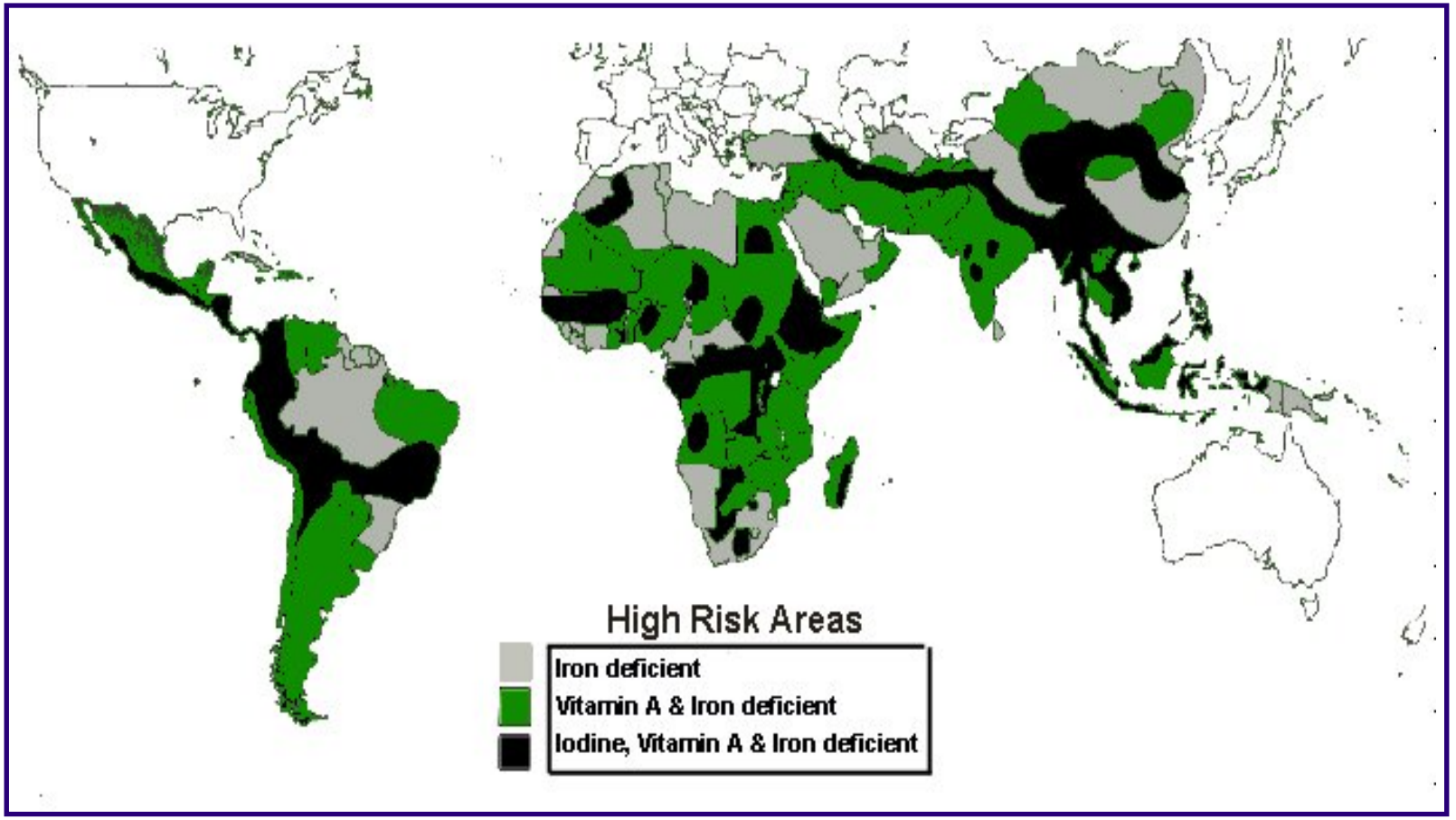
Micronutrient Malnutrition Causes….

- 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

Global Micronutrient Deficiencies

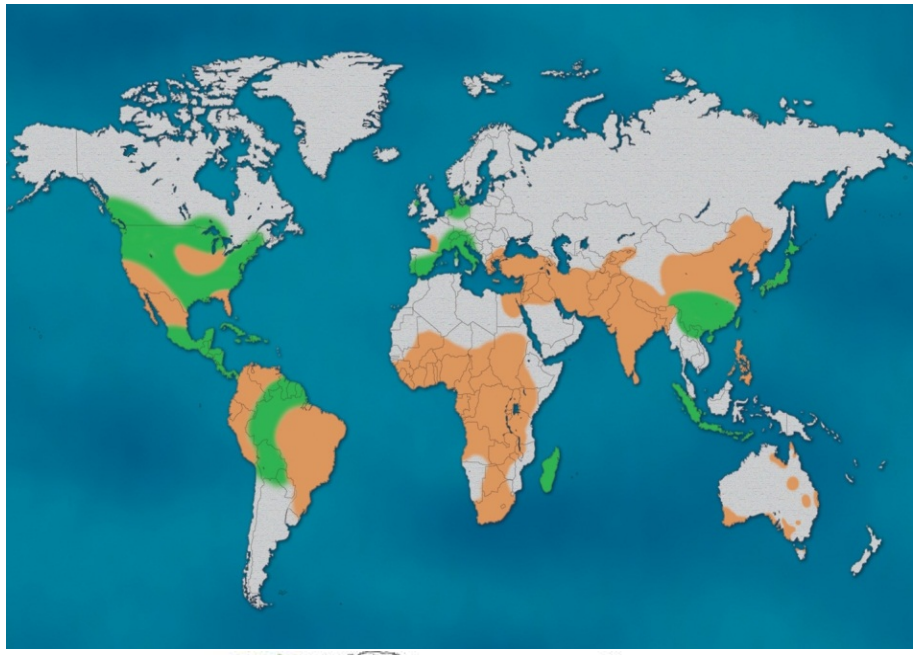


> 3 billion people afflicted

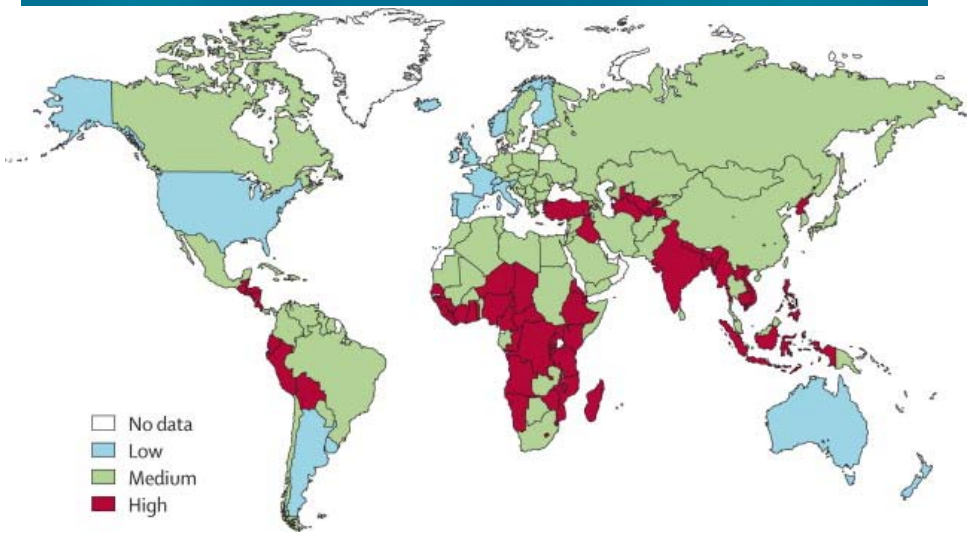
(Map from USAID)

Link Between Zn-Deficient Soils & Zn Deficiency in Humans

Wide Deficiency –
Medium deficiency –



Zn-Deficient Soils



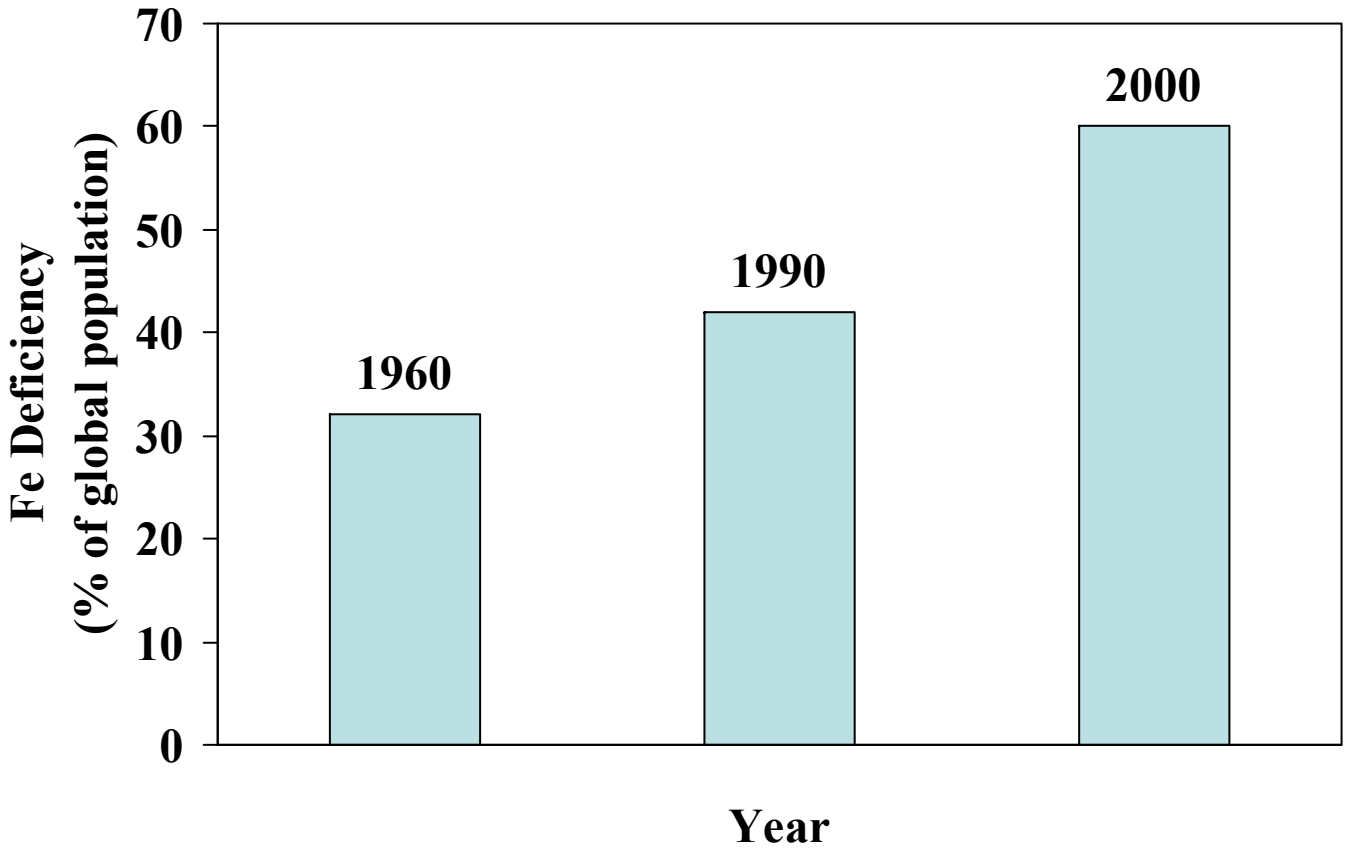
Zn-Deficient Humans

Figure from A. Green, 2009

Other Nutrient Deficiency Problems

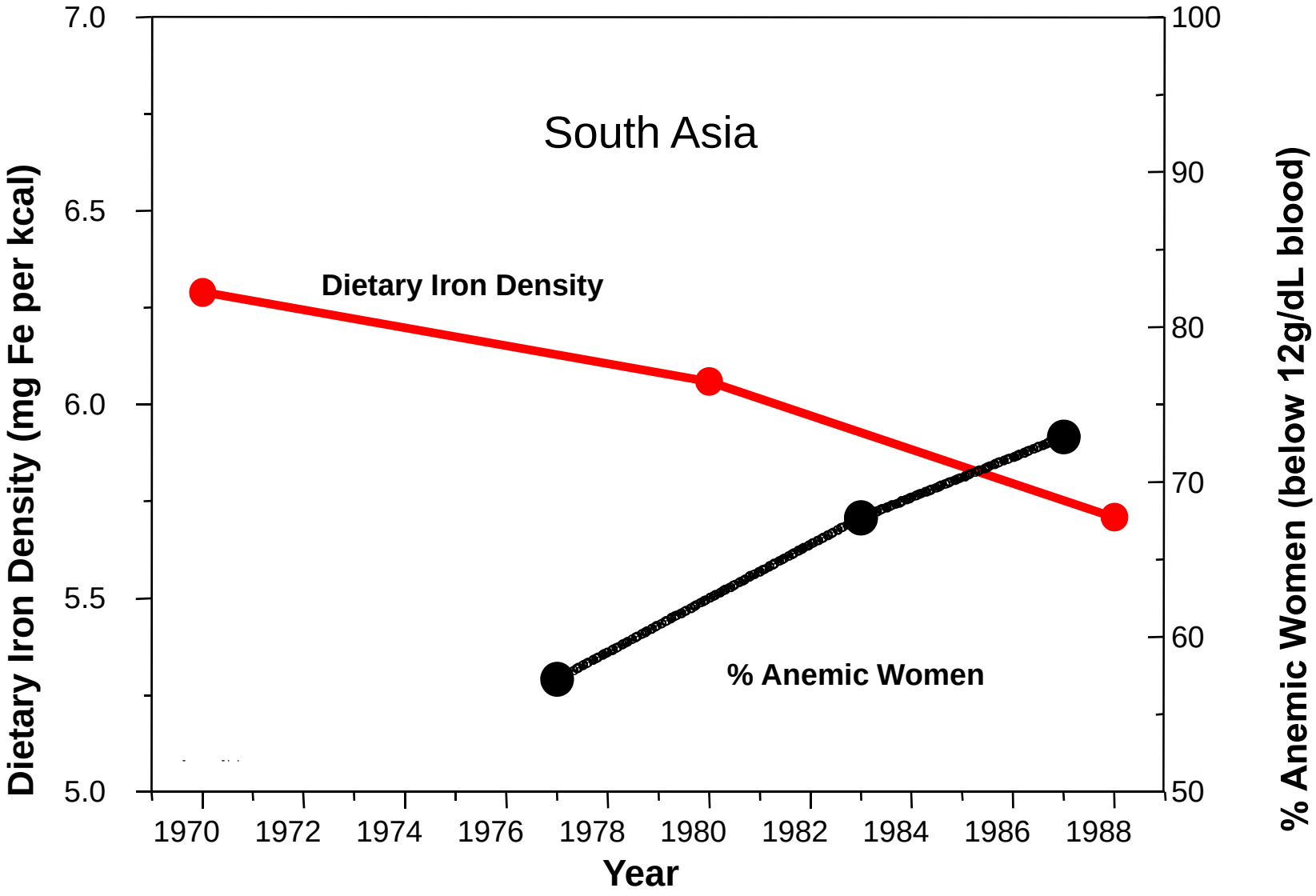
- Se deficiency
- Scurvy (vitamin C)
- Beriberi (thiamine/B_1)
- Rickets (both vitamin D & Ca deficiencies)
- Pernicious Anemia (cobalamine/vitamin B_{12})
- Folate
- Riboflavin

Change in Prevalence of Iron Deficiency Globally

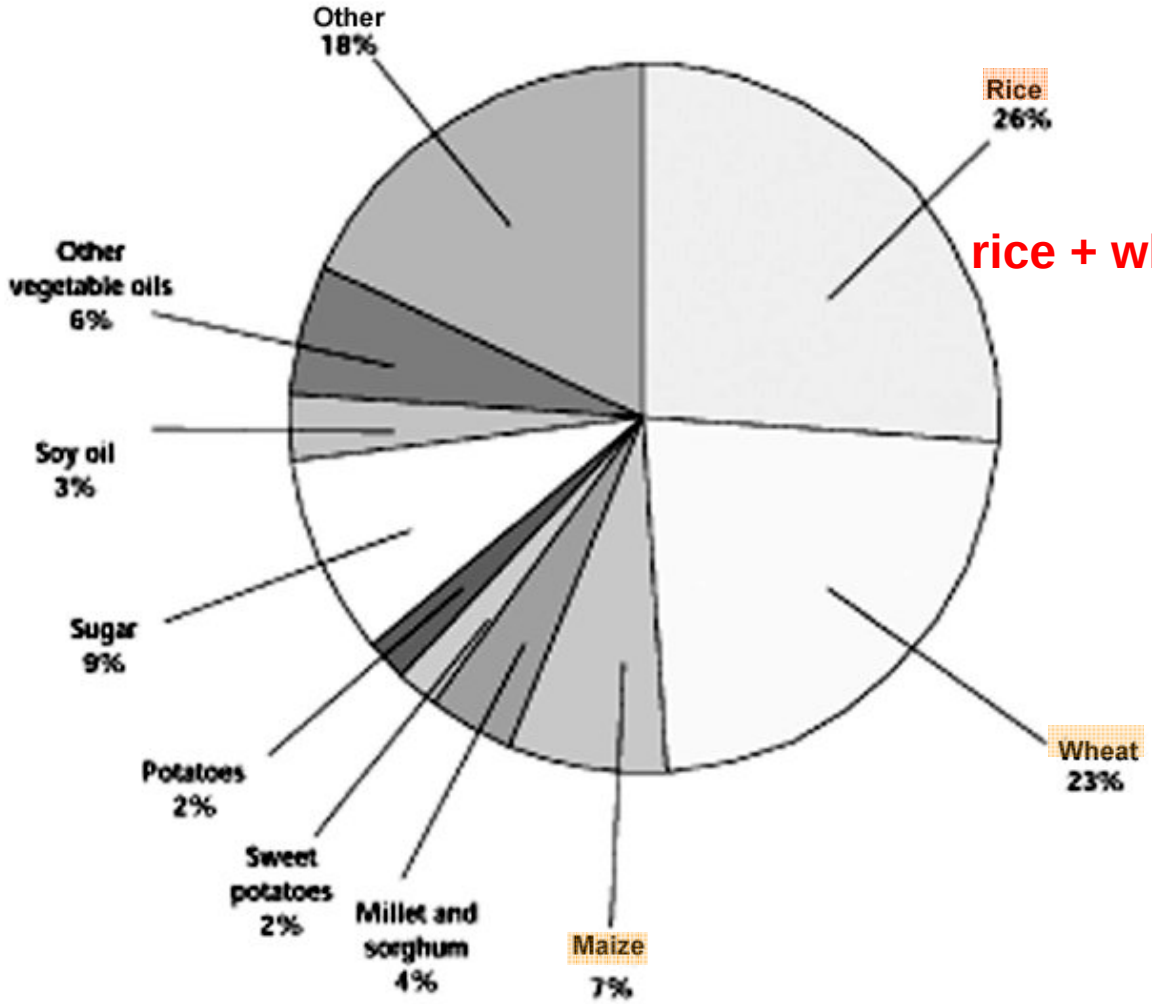


Data from WHO, 2002

Dietary Iron Density and % Anemic Women in S. Asia



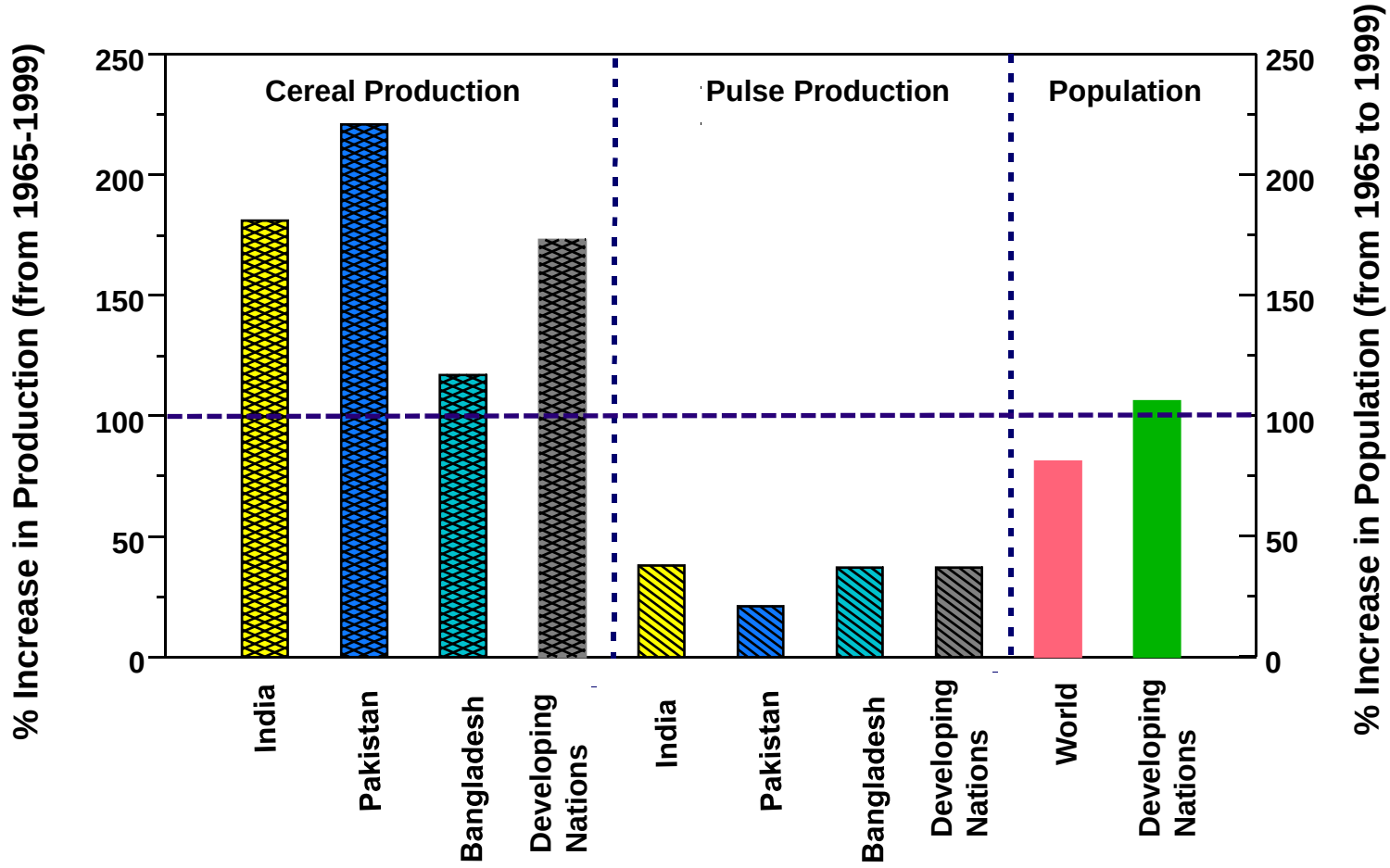
Most Important Food Crops Globally



rice + wheat + maize = 56%

Source: FAO. *Food balance sheets* 1994-1996. Rome.

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



(FAO data, 1999)

An increase in proportion of starchy staple foods in the diet can lead to increased stunting in children

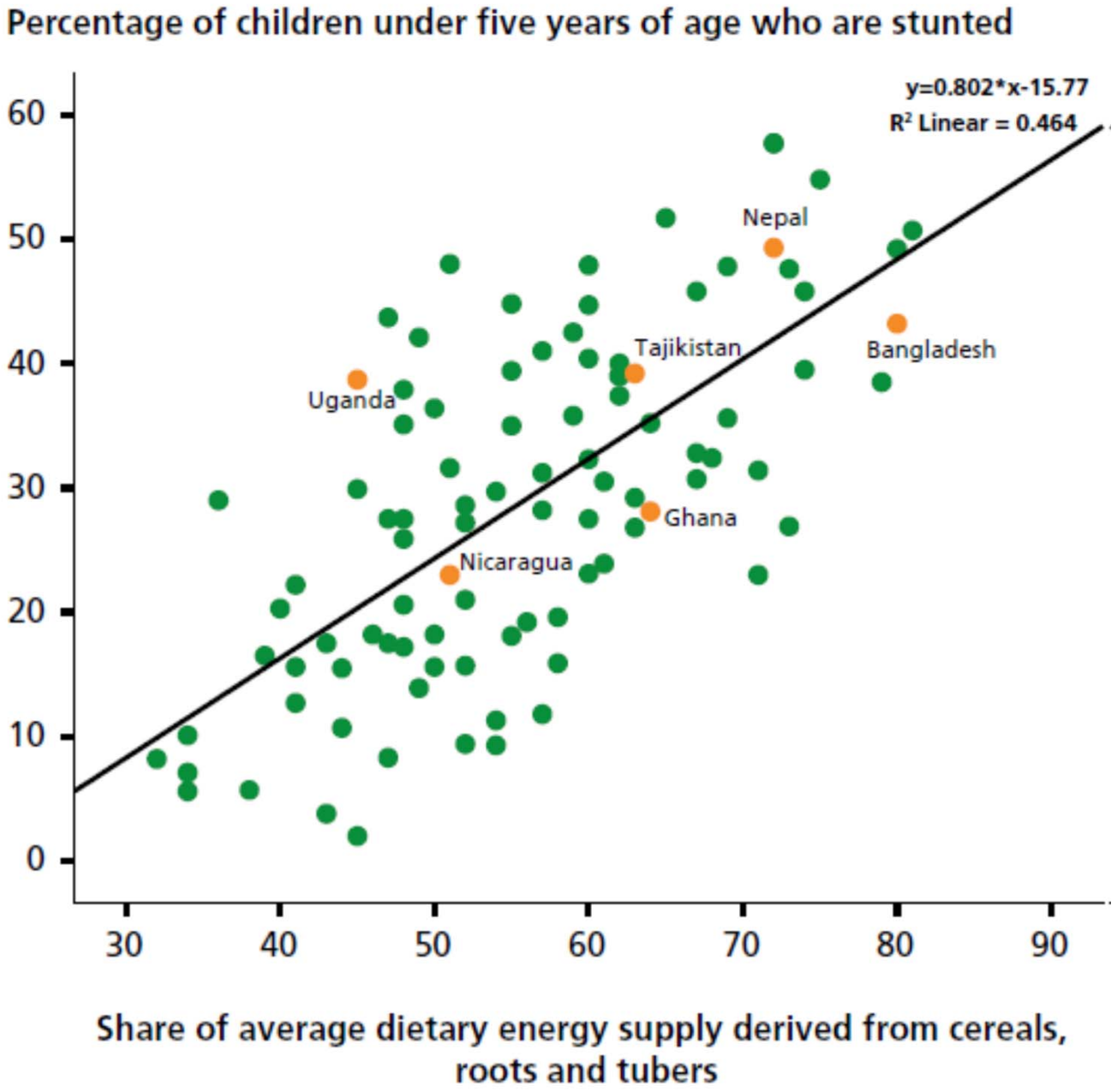


Figure from: FAO. State of Food Insecurity in the World (2013)

Typical Levels of Some Nutrients in Major Staple Food Crops

Crop	Ca	Fe	Zn	Riboflavin	Total folate
(dry weight)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(µg/kg)
Cereal Grains					
Polished Rice	123	18	13	0.61	78
Milled Wheat	170	13	8	0.45	295
Yellow Maize	78	30	25	2.24	212
Edible Legume Seeds					
Kidney Bean	1620	93	32	2.48	4465
Great N. Bean	1960	61	26	2.65	5398
Bengal Gram	1187	71	39	2.40	6296
Mung Bean	1451	74	30	2.56	6872
Cowpea	858	101	62	1.52	4686
Green Pea	1183	70	59	6.24	3075

Data from USDA Nutrient Composition Tables of Foods

Table 2. Effects of milling and polishing on micronutrients in rice grain (data from USDA Nutrient database at http://ndb.nal.usda.gov/).

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 (µg kg^{-1})	120	50	58
Folic Acid (µg 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 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.

Recent Programs to Link Agriculture to Nutrition

a U.S. Government initiative

SEE THE FUTURE
FEED CHANGE

http://www.thousanddays.org/news-media/

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.

Soil-Plant Factors Effecting the Health Promoting Quality of Plant Foods

- **Factors effecting available essential element supplies in soils**
  - **Soil type (pH, organic matter, parent material, etc.)**
  - **Root-soil interactions & rhizosphere effects**
  - **Agronomic practices (fertilizers, amendments, organic matter, cropping systems, variety selection, etc.)**
- **The available soil supplies of essential minerals (as influenced by genetic & environmental variables) also affect the accumulation of numerous nutrients (e.g., vitamins) and other health promoting substances accumulated in edible portions of food crops**

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

- Better seed viability
- Greater seedling vigor
- Denser stands (less soil irrosion)
- 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

Table 1. Proportion of agricultural soils deficient in mineral elements (based on a survey of 190 soils worldwide – Sillanpaa, 1990).

Element	%
N	85
P	73
K	55
B	31
Cu	14
Mn	10
Mo	15
Zn	49

From: Bruulsema et al., 2012

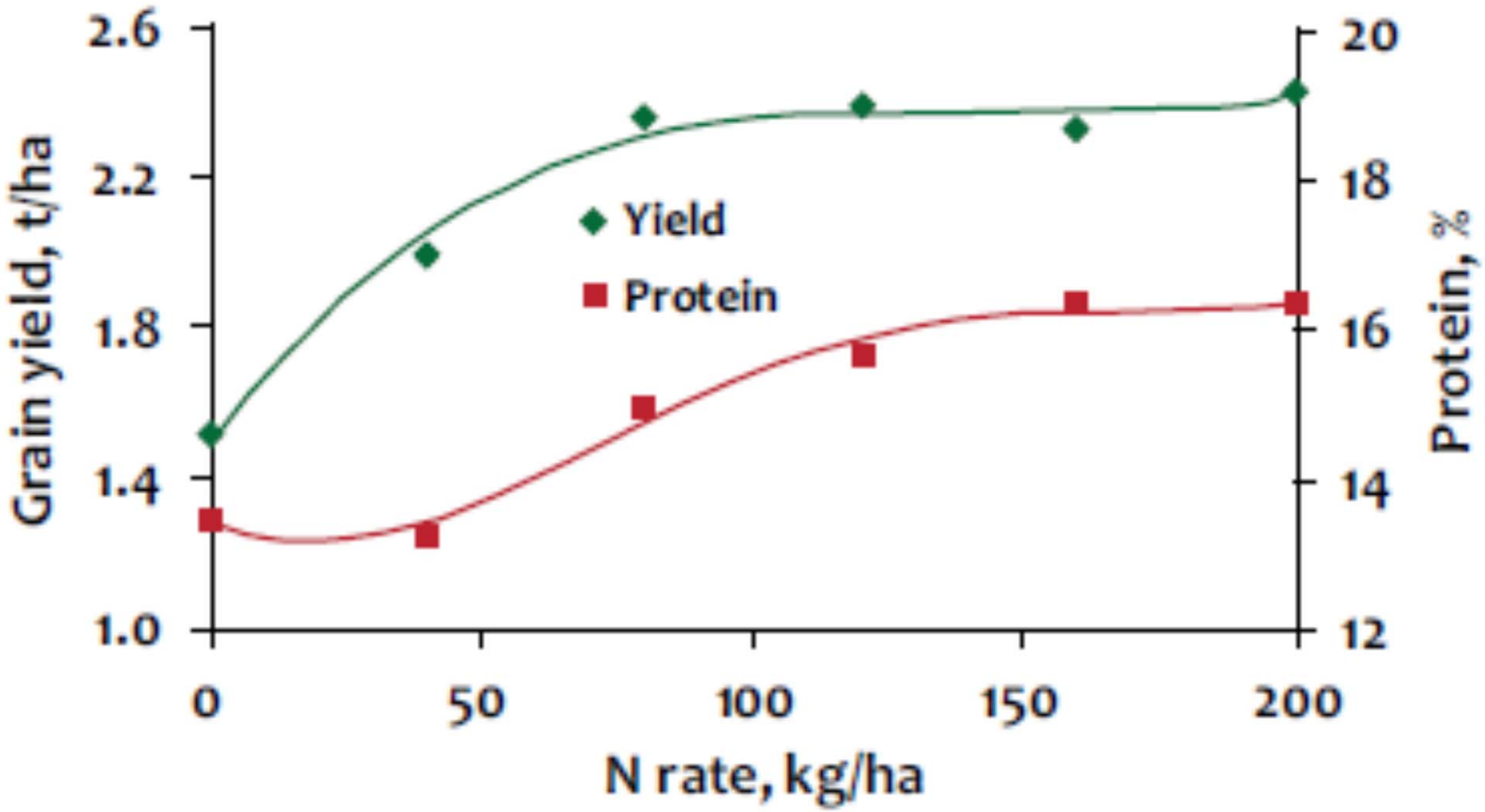
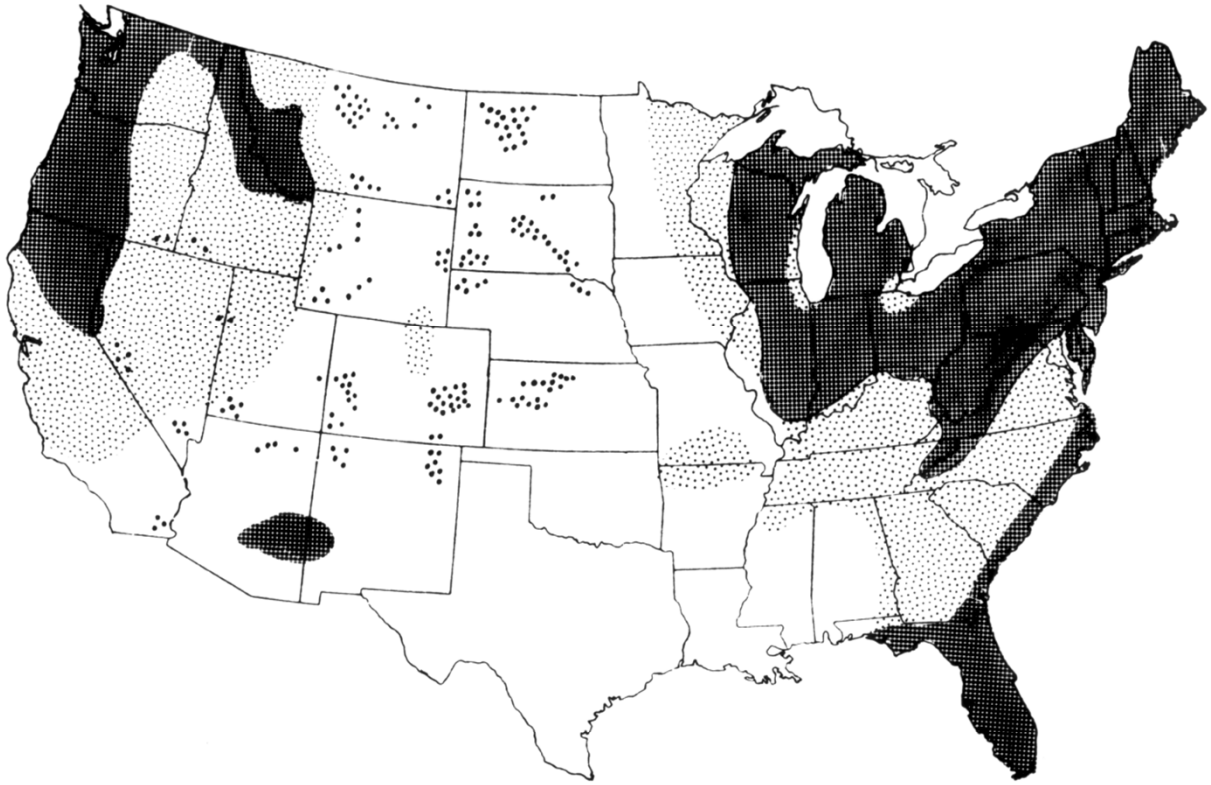


Figure 2. Yield and protein of wheat respond to applied N fertilizer.

From: Bruulsema et al., 2012

Se Map of 48 U.S. States



Low - approximately 80% of all forage and grain contain <0.05 mg kg^{-1} of Se.

Variable - approximately 50% contains > 0.1 mg kg^{-1} of Se.

Adequate - 80% of all forages and grain contain > 0.1 mg kg^{-1} of Se.

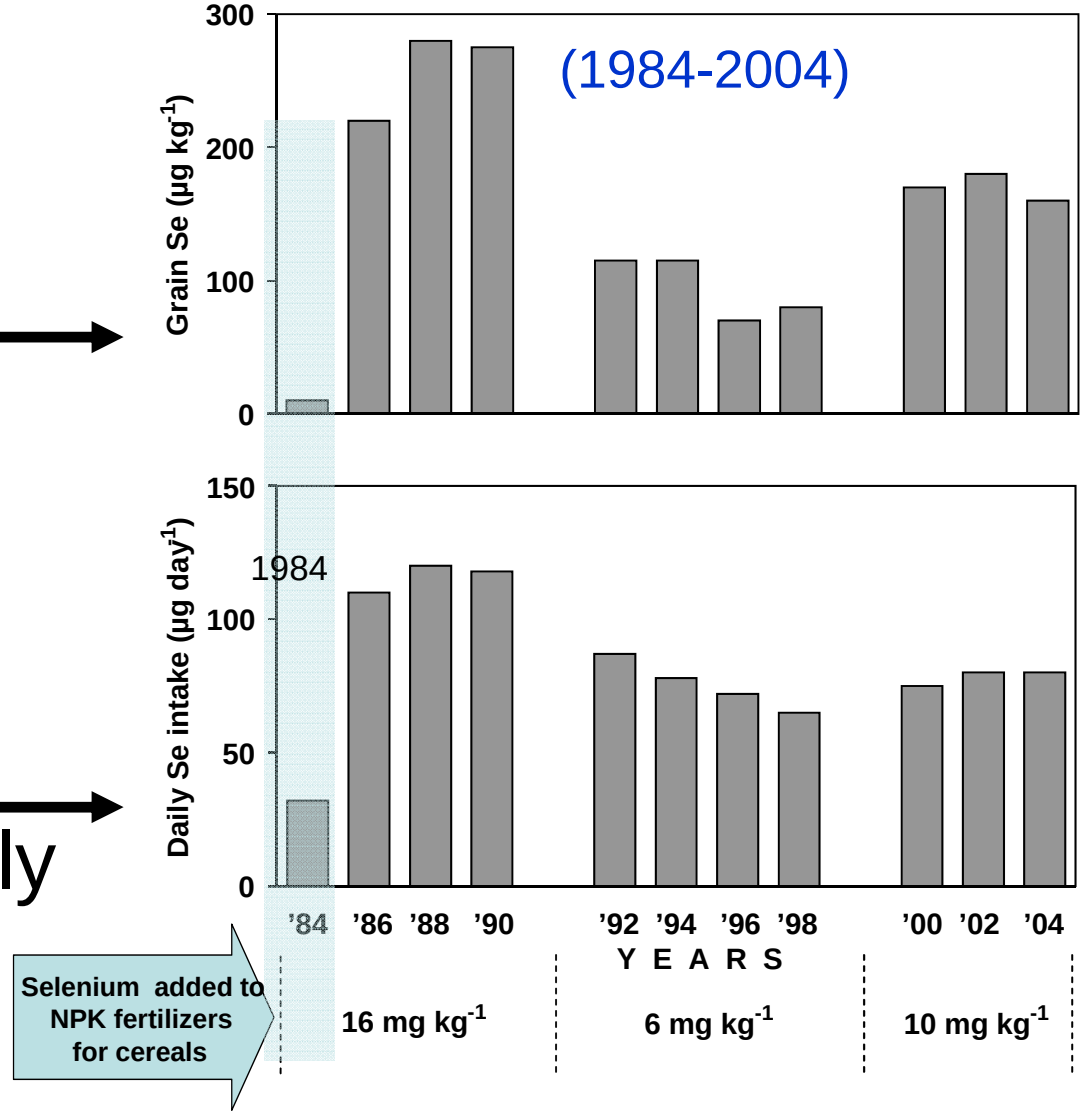
Local areas where Se accumulator plants contain > 50 mg kg^{-1} of Se.

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

Zinc concentrations of whole grain and the grain fractions bran, embryo, and endosperm of durum wheat cultivar Selcuklu grown in the field

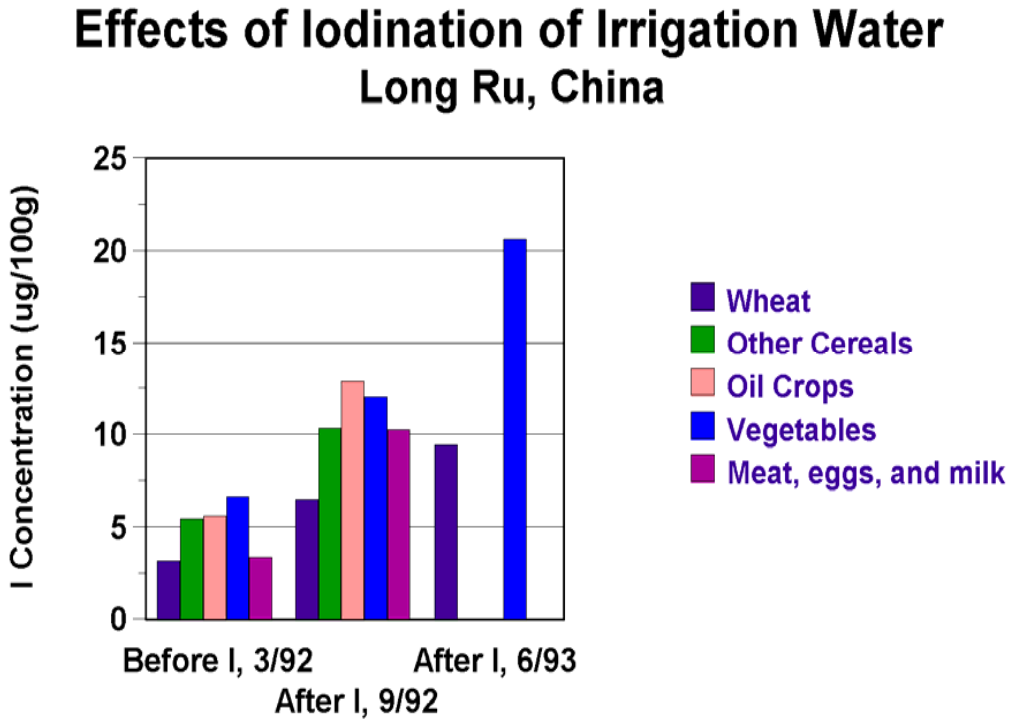
Soil Zn appl., kg/ha	Foliar Zn application stages	Zn concentration, mg/kg			
		Whole grain	Bran	Embryo	Endosperm
0	Control (no Zn)	11.7	20	38	8
	Stem + Booting	18.8	28	47	10
	Booting + Milk	26.9	35	62	15
	Milk + Dough	25.4	41	63	15
50	Control (no Zn)	21.7	33	52	11
	Stem + Booting	25.5	34	58	13
	Booting + Milk	29.3	45	69	16
	Milk + Dough	25.4	41	63	15
	$LSD_{0.05}$ for soil Zn application	1.8	3.0	3.4	1.0
	$LSD_{0.05}$ for foliar Zn application	2.6	4.8	4.2	4.8

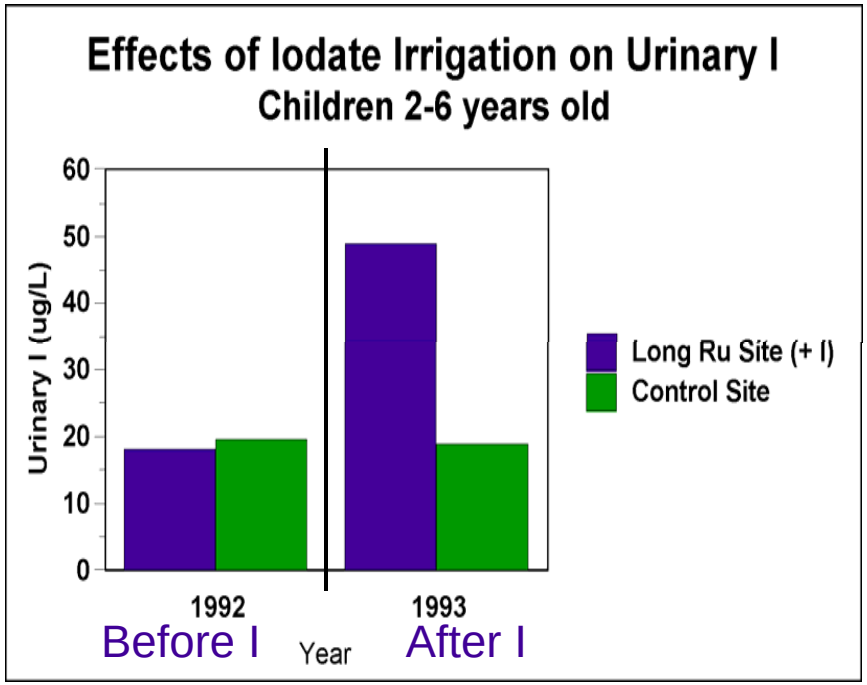
Cakmak et al., 2010

Table 6: Changes in grain yield and grain Zn concentrations of aromatic rice grown under field conditions in India as affected by use Zn-enriched urea (ZEU) at increasing Zn concentrations from 0 % to 3 % (Shivay et al., 2008).

Zincated Urea Application	Zn Applied	Grain Yield	Grain Zn Concentration
	kg ha $^{-1}$	ton ha $^{-1}$	mg kg $^{-1}$
Prilled Urea	-	3.87	27
0.5% ZEU	1.3	4.23	29
1.0% ZEU	2.6	4.39	33
2.0% ZEU	5.2	4.60	39
3.0% ZEU	7.8	4.76	42

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

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