Plant and Crop Sciences Seminar

Farming for fitness:
the economics of putting vitamins and minerals into staple crops

Alexander J. Stein

5 May 2010, The University of Nottingham

---

fitness fit·ness (fĭt'nĭs)
n.

The state or condition of being physically sound and healthy, especially as the result of exercise and proper nutrition.

A state of general mental and physical well-being.

➔ This seminar is about the fitness of the poor and malnourished to simply live and work

---

Structure

- Introduction
- Vitamin and mineral deficiencies (VMDs)
- Health consequences of VMDs
- Quantifying the burden of disease of VMDs
- Socio-economic impacts of VMDs
- Causes of VMDs
- Micronutrient interventions
- Impact and cost-effectiveness of biofortification
- Conclusions

Introduction

- FAO (2009): 1,020,000,000 are hungry

Introduction

- Increasingly also “hidden hunger” falls under the definition of malnutrition
- Chronic lack of vitamins and minerals
- “Hidden" because people feel not hungry; often no immediately visible signs of VMDs

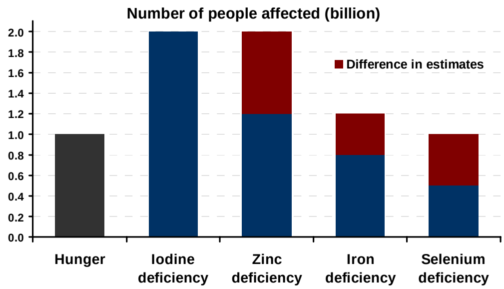
➔ Here the potential role of agriculture in addressing VMDs is discussed and evaluated from an economic viewpoint

---

Mineral deficiencies

- 20+ dietary minerals & trace elements essential for proper functioning of body
- Most are abundant in food or are only needed in very small amounts
- But for some minerals deficiencies occur:
  - globally: iron (*Fe*), zinc (*Zn*) and iodine (*I*)
  - regionally: calcium (*Ca*) and selenium (*Se*)
  - less: magnesium (*Mg*) and copper (*Cu*)

Mineral deficiencies



+ vitamin deficiencies = multiple deficiencies

Health consequences

- Iron deficiency leads to anaemia and
  - higher maternal mortality
  - lower mental development in children
  - impaired physical activity and fatigue
- Zinc deficiency in children contributes to
  - under-five mortality
  - pneumonia & diarrhoea
  - stunting

Health consequences

- Iodine deficiency causes goiter and mental retardation & cretinism
- Calcium deficiency causes bone problems (especially rickets in children) and may aggravate certain chronic diseases
- Selenium deficiency is associated with a heart disease that is often fatal (Keshan) and it increases a number of other health risks

Health consequences

➔ Impact of VMDs **not uniform**:

- They cause different functional outcomes, hit different target groups and impose different levels of suffering
- Magnitude of some health consequences intuitive, but impact of others difficult to grasp
- The deficiency that affects most people is not necessarily the one representing the biggest overall health loss

Burden of disease

- How to **measure "health loss"** consistently?
- World Bank and WHO introduced "disability-adjusted life years" (DALYs)
- Single index taking into account the <u>duration</u> and <u>severity</u> of each health outcome
- Severity captured through a disability-weight ranging from 0 (no health loss) to 1 (death)

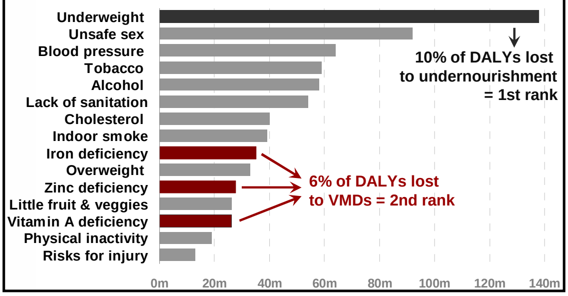
Burden of disease

- Adding up DALYs gives "burden" of disease
  - Premature death is counted in Years of Life Lost (YLL)
  - Disease is counted in Years Lived with Disability (YLD)
- Burden = $\text{DALYs}_{\text{lost}}$ = YLL + $\text{YLD}_{\text{weighted}}$
- More formally:

$$DALYs_{lost} = \sum_j T_j M_{ij} \left(\frac{1 - e^{-rL_j}}{r} \right) + \sum_i \sum_j T_j I_{ij} D_{ij} \left(\frac{1 - e^{-rd_{ij}}}{r} \right)$$

Burden of disease

- Ranking of major health risks (WHO 2002)



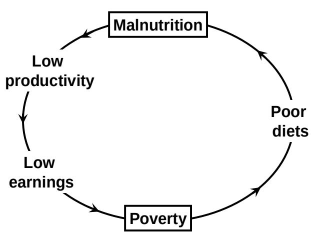
Socio-economic impact

- VMDs affect billions of people, cause ill health and suffering, and contribute to the global burden of disease
- They also impose tangible economic costs by hampering both individual productivity and overall economic growth

➔ Apart from a moral obligation, there is a purely **economic rationale** for fighting them

Socio-economic impact

- Controlling malnutrition (inclusive VMDs) helps break the malnutrition-poverty trap



Socio-economic impact

- In the aggregate the mechanism is similar:
  - Malnutrition reduces overall productivity, economic growth and national income
  - This keeps labor demand down, suppresses wages and thus perpetuates poverty...
  - ... and it limits public resources that can be used for nutrition and health interventions

Socio-economic impact

- VMDs also affect cognitive abilities, hence they even reduce *future* productivity by lowering the success of schooling
- Malnourished mothers have smaller babies that are more sickly later on in life, thus again reducing future productivity

➔ VMDs not only affect health but also economic outcomes in many ways

Socio-economic impact

- Fogel (2004): **30%** of growth in British per capita income **over the last 200 years** due to better nutrition (incl. vitamins & minerals)
- World Bank (1994): deficiencies of vitamin A (VA), iodine & iron can cost up to **5%** of GDP
- Horton & Ross (2003): iron deficiency costs developing countries **4%** of GDP
- MI/UNICEF (2004): Fe, I, VA & folate deficiency can cost over **2%** of GDP

Socio-economic impact

- But economic productivity is no end in itself
- Ultimate goal is human happiness and development (Millennium Development Goals)
  - ➔ Less hunger, less poverty, more education, more gender equality, less mortality, more health, more environmental sustainability, more participation: often **vitamins & minerals can help!**

Causes of VMDs

- No **availability** of micronutrient-rich food: disasters, shortages, seasonality
- Lack of **access** to food & health care:
  - poverty = low overall food intakes
  - poverty = monotonous diets poor in micronut.
  - intra-household distribution (individual level)

Causes of VMDs

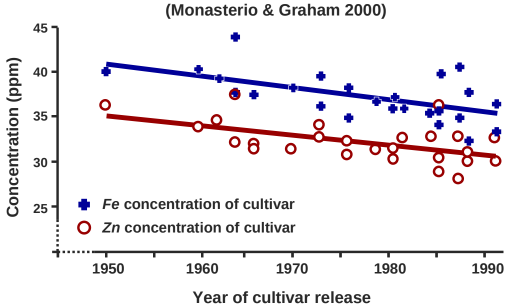
- Poor **utilisation** of available food:
  - low bioavailability of micronutrients (monotonous, cereal-based diets)
  - micronutrient content irrelevant for people's food preferences (even if affordable)
  - poor food choices due to a lack of nutrition knowledge
- **Loss** of nutrients due to disease, e.g. diarrhoea or bleeding

Causes of VMDs

- No or low **micronutrient content** in crops:
  - no beta-carotene in white crops (rice, sweet potato, cassava, maize)
  - cultivation of crops on mineral deficient soils
  - depletion of soils through higher crop production per unit area
  - increased yields in cultivars associated with reduced mineral concentrations in crops

Causes of VMDs

Wheat cultivars released by CIMMYT from 1950 to 1992 (Monasterio & Graham 2000)



Micronutrient interventions

- Various interventions to control VMDs:
  1. supplementation (e.g. iron pills)
  2. fortification (e.g. iodised salt)
  3. dietary diversification (production & promotion of micronutrient-rich crops)

  \+ complementary interventions (infant feeding, nutrition education, public health, WASH, poverty reduction)

Slide 25

Micronutrient interventions

- What is the role of agriculture?
- Provision of (wholesome) food is the key function of agriculture
- So far food was fortified industrially, i.e. during food processing (e.g. salt with iodine, flour with iron, juices with vitamins, etc.)
- Now interest in agricultural approaches: (i) breeding for micronutrient content and (ii) mineral fertilisation

Slide 26

Micronutrient interventions

- **Biofortification** (breeding)
  - target populations eat plenty of staple crops, i.e. biofortification is self-targeting
  - poor & rural populations difficult to reach otherwise (eat little processed food)
  - economies of scale: once developed, germ-plasm can be shared & seeds can be saved
  - mineral biofortification my be synergetic by improving plant vigour in parallel

Slide 27

Micronutrient interventions

- **Mineral fertilisation** (agronomic biofortificat.)
  - \+ targeting of staple crops also possible
  - \- access for poor farmers & in remote areas? (fertiliser subsidies & infrastructure develop't)
  - \- no economies of scale as fertiliser needs to be applied regularly
  - \+ synergetic by improving plant nutrition
  - \+ where infrastructure quick impact possible
  - \- no impact or cost-effectiveness studies yet

Slide 28

Micronutrient interventions

- Toolbox of interventions with different strengths and weaknesses:
  - time horizon
  - dose adjustment
  - infrastructure needs
  - resource use
  - cooperation of beneficiaries
  - long-term sustainability, etc.

Slide 29

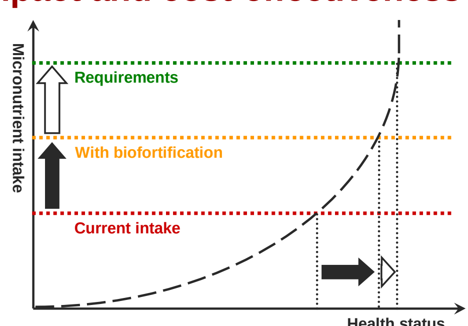
Impact and cost-effectiveness

- Interventions may complement each other
- But what is the impact of each?
- And given that resources are scarce, what is an efficient use of a given budget?
- Calculating the impact:

$$DALYs_{lost} = \sum_j T_j M_{ij} \left(\frac{1-e^{-rL_j}}{r} \right) + \sum_i \sum_j T_j I_{ij} D_{ij} \left(\frac{1-e^{-rd_{ij}}}{r} \right)$$

Slide 30

Impact and cost-effectiveness



Various feeding trials promising

Impact and cost-effectiveness

- Impact of biofortification =
  DALYs lost in status quo minus
  DALYs lost in a "with biofortification" scenario
- Impact can be expressed in indicators like
  - percent reduction of the burden of VMDs
  - number of DALYs saved per 1m population
- The direct benefit of biofortification consists in the health gain (DALYs saved)

Impact and cost-effectiveness

- Determining the costs of biofortification is more straightforward:
  - Costs for the international R&D of the biofortified crops (or of the mineral fertiliser)
  - In-country costs for adaptive breeding
  - Costs for extension (adoption by farmers) and social marketing (acceptance by consumers)
  - Costs for seed distribution, subsidies, etc.
  - Costs for maintenance breeding

Impact and cost-effectiveness

- Having quantified (health) benefits and costs, simply economic analysis is possible:
- Dividing total costs by the number of DALYs saved gives as indicator "$/DALY"
  – the "price" of saving one healthy life year
- With this, the cost-effectiveness of different interventions can be compared...
- ... or more colloquially: Which intervention gives more bang for the buck?

Impact and cost-effectiveness

- Ex-ante analyses confirm potential impact:
  - *Fe* biofortified rice & wheat could reduce **20-60%** of the Indian burden of iron deficiency and save **1-2m DALYs** (Stein et al. 2008a)
  - *Zn* biofortified rice & wheat could reduce **20-50%** of the Indian burden of zinc deficiency and save **0.5-1.5m DALYs** (Stein et al. 2007)
  - Golden Rice could reduce **9-60%** of the Indian burden of vitamin A deficiency and save **0.2-1.4m DALYs** (Stein et al. 2008b)

Impact and cost-effectiveness

- The analyses also show cost-effectiveness:
  - With *Fe* biofortification of rice & wheat, saving a DALY in India could cost **50¢ to $5.40**
  - With *Zn* biofortification of rice & wheat, saving a DALY in India could cost **70¢ to $7.30**
  - With Golden Rice it could cost **$3 to $19**

    → cost drivers: genetic engineering, biosafety regulation, social marketing (colour change)

    → VA interventions generally more expensive

Impact and cost-effectiveness

- Estimates for vitamin A interventions in India:
  $134 - 599 per DALY saved (supplements)
  $ 84 - 98 per DALY saved (fortification)
- Estimates for biofortification in India:
  $0.5 - 19 per DALY saved
- World Bank threshold for cost-effective interventions: $200 per DALY saved
- Others use a country's per capita income or proxies like $1,000 per DALY saved

Impact and cost-effectiveness

		High impact scenario			Low impact scenario		
		DALYs saved ('000)	**Cost per DALY (USD)**	Cost per capita (USD cents)	DALYs saved ('000)	**Cost per DALY (USD)**	Cost per capita (USD cents)
NE-Brazil	Fe-rich rice & beans	99	**3.7**	0.2	99	**6.9**	0.2
Honduras	Zn-rich rice, beans & maize	15	**21**	1.1	15	**43**	1.3
Nicaragua	Zn-rich rice, beans & maize	9.0	**44**	1.9	9.0	**89**	2.3
Mexico	bC-rich maize	6.7	**18**	0.0	0.2	**1,399**	0.1
Haiti	bC-rich cassava	7.0	**9.6**	0.2	1.7	**86**	0.2
All	all	136	**9.6**	0.2	124	**21**	0.2
Latin America	Fe fortification		**134**			**214**	
	Zn fortification		**18**			**28**	
	VA fortification		**155**			**169**	

In smaller countries biofortification may be less cost-effective, but overall still "competitive"

Biofortification

- Biofortification projects:
  HarvestPlus, Golden Rice, BioCassava Plus, African Biofortified Sorghum, BAGELS, HarvestZinc, INSTAPA, smaller projects
- Target crops:
  rice, wheat, maize, millet, sorghum, cassava, sweet potato, beans, bananas, vegetables
- Target minerals:
  iron, zinc, selenium, calcium, magnesium

Biofortification

- Adoption by farmers?
  - Accessibility and affordability (of fertiliser)
  - Agronomic properties (yield, drought, pests ...)
  - Locally adapted varieties, planting material
  - Income generation (market acceptance, price)
- Acceptance by consumers?
  - If no price premium
  - If similar in taste, consistency, storability, ...

➔ Collaboration, participation, education, etc.

Conclusions

- VMDs have a negative impact globally
- One direct cause are insufficient intakes
- Currently micronutrients are **added** to food or given as supplements
- Wholesome food should already **contain** them – this is a challenge for agriculture

➔ Agricultural approaches to control VMDs are potentially effective and economic

Thank you very much for your attention!

www.AJStein.de