Occurrence and management of soil micronutrient deficiencies in smallholder agriculture in SSA

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Outline

- The Context
- ISFM Concept
- Soil fertility & micronutrient deficiency nexus
  - Case Study – NE Zimbabwe
- Fertilizer fortification
  - Case Study – SSA Lit Review
- Future research and development priorities

The context of soil and human micronutrient deficiencies

- Agriculture is closely linked to human nutrition and health in developing countries
- Biofortification technologies effective in improving human nutrition
  - Genetic biofortification
    - Focus mainly on Fe, Zn and vitamin A
    - Challenges of stability, density, yield penalty, public acceptance, and regulation of transgenic crops
  - **Agronomic biofortification**
    - **Micronutrient fertilization**
    - **Most effective for Zn, *Se* and *I***
  - Crop diversification

The context of soil and human micronutrient deficiencies

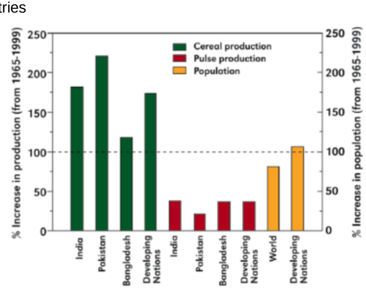
- Deficiencies of macronutrients and micronutrients in global soils

Deficiency	N	P	K	B	Cu	Fe	Mn	Mo	Zn
Acute	71	55	36	10	4	0	1	3	25
Latent	14	18	19	21	10	3	9	12	24
Total	5	73	55	31	14	3	10	15	49

- Micronutrient deficiencies mostly expressed as latent deficiencies.

The context of soil and human micronutrient deficiencies

- Impact of crop production intensification on human nutrition in developing countries

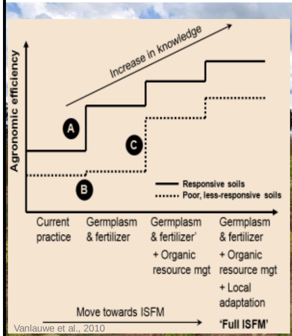


Graham et al., 2007

The context of soil and human micronutrient deficiencies in SSA

- Current fertilizer recommendations mainly cover N and P
- Soil micronutrient deficiencies are part of a set of interrelated biophysical and agronomic factors underlying low crop productivity
- Smallholder farming systems are highly heterogeneous
- Cereal crops dominate cropping systems and contribute largest proportion of dietary micronutrients
- Soil and crop micronutrient linked to human micronutrient deficiencies

Integrated Soil Fertility Management



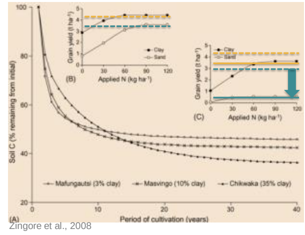
Vanlauwe et al., 2010

- Complex constraints to crop productivity in smallholder farming systems in SSA
- ISFM systematic conceptualization of management intervention for sustainable crop production intensification:
  - Fertilizer as the entry point
  - Soil fertility variability
  - Appropriate varieties
  - The role of organic resources
  - Local adaptation

Soil fertility & micronutrient deficiency nexus

Case Example: Micronutrient fertilizer yield responses in SSA

Kihara, Zingore et al., 2016, in prep.



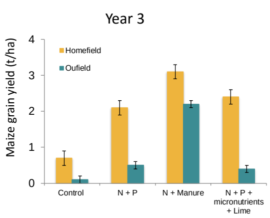
Zingore et al., 2008

- Inherent low soil fertility
- Continuous crop cultivation with low inorganic or organic inputs
- Crop systems dominated by cereal crops
- Unbalanced fertilizer application

Prolonged poor soil fertility management is associated with increasing complexity of nutrient deficiencies and other constraints ➔ degraded soils 'non-responsive soils'

Soil fertility & micronutrient deficiency nexus

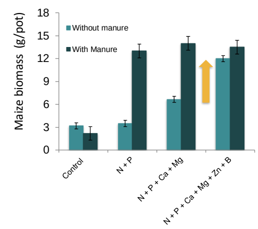
Influence of soil fertility management on Zn deficiency and grain Zn content on granitic sands in Zimbabwe



- Homefields receive large additions of manure and outfields receive non
- Maize yields and yield responses higher on homefields
- Zn deficiency a major limiting factor in outfields
- Lack of Zn fertilizer response under field conditions due to fixing by P and lime application and other constraints
- Multiple seasons of manure application required to substantially increase productivity

Soil fertility & micronutrient deficiency nexus

Influence of soil fertility management on Zn deficiency and grain Zn content on granitic sands in Zimbabwe



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- Multiple seasons of manure application required to substantially increase productivity
- Micronutrient responses strong under controlled conditions

Soil fertility & micronutrient deficiency nexus

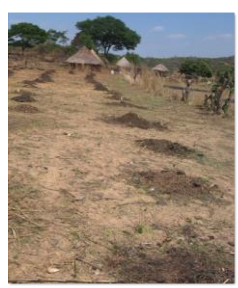
Influence of soil fertility management on Zn deficiency and grain Zn content on granitic sands in Zimbabwe

Manzeke et al., 2012

Farmer management practice	OR Zn content (mg/kg)	Soil avail. Zn (mg/kg)	Maize yield (t/ha)	Maize grain Zn (mg/kg)
Unfertilized maize	-	0.7	0.4	14
Maize after legume	-	2.1	1.2	19
Mineral NPK only	-	0.9	1.7	16
Leaf litter + NPK	86.0	2.4	1.8	23
Manure + NPK	22.5	1.5	2.1	21

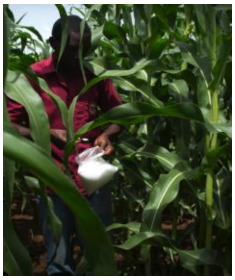
- Farmer management practices affect soil Zn, maize yields and Zn content
- Unfertilized maize ➔ low yields and low soil and grain Zn contents
- Sole application of macronutrient fertilizers increased yields but have insignificant effects of grain Zn content
- Integrated application of organic resources and fertilizer increased yields and Zn content

Soil fertility & micronutrient deficiency nexus



- Organic resources are an essential component of soil fertility management and micronutrient supply
  - Limited quantities are available (<25% of croplands receive substantial amounts of manure)
  - Quality low and variable
  - High labour demands
- Micronutrient fortification through fertilizers is a necessary strategy
- NPK fertilizer in Zimbabwe were required to contain min. 0.5% Zn by law, but no longer enforced.

Fertilizer micronutrient fortification

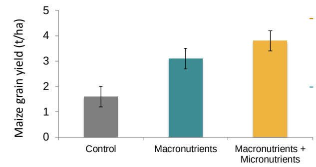


- Wide scale for the recognition for the need to for fertilizer recommendations that include micronutrients.
- Progress in revising fertilizer recommendation in several countries
- Micronutrient fertilizer blends remain the most practical supply methods
- Fertilizer formulas containing micronutrient becoming increasing available
  - Focus on Zn, B, Mn, Mo, Cu
  - Inconsistent methods to map soil micronutrient deficiencies ➔ soil analysis and fertilizer trial based approaches
  - Yield is often the sole output indicator

Fertilizer micronutrient fortification

Case Example: Micronutrient fertilizer yield responses in SSA

Kihara, Zingore et al., 2016, in prep.



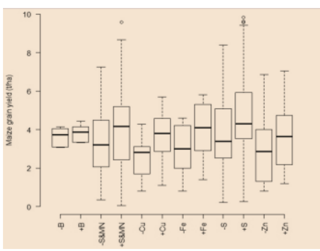
- Positive yield responses to micronutrients across soil and climate zones
- What are the effects of individual nutrients, soil types and crops on micronutrient yield responses?

Fertilizer micronutrient fortification

Micronutrient fertilizer yield responses in SSA

Kihara, Zingore et al., 2016, in press.

- What are the effects of individual nutrients?



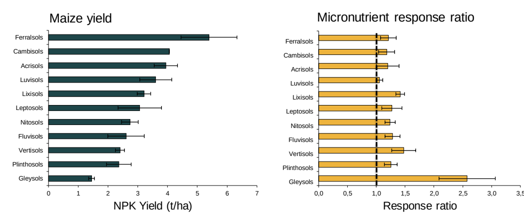
- Positive but highly variable

Fertilizer micronutrient fortification

Micronutrient fertilizer yield responses in SSA

Kihara, Zingore et al., 2016, in press.

- What are the effects of soil types?



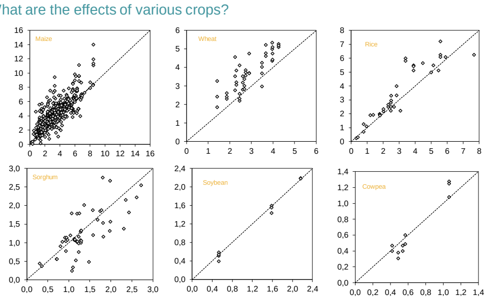
- Highest response ratios for gleysols
- Lowest responses for Luvisols
- No clear correlation with NPK fertilizer yields

Fertilizer micronutrient fortification

Micronutrient fertilizer yield responses in SSA

Kihara, Zingore et al., 2016, in press.

- What are the effects of various crops?



Further research and development priorities

- Holistic assessment of agronomic biofortification in context of smallholder farming systems considering the economic, social and environment output indicators
  - Sustainable intensification taking into account human requirements
  - Closer connection between industry, R&D, policy stakeholders

- Integrated analysis of genetic and agronomic biofortifcation strategies along food system value chain and their interaction with with environmental factors
- Managing complexity: Rapid and costs-effective diagnosis approaches at different scales and decision support tools for agronomic practices

Concluding remarks

- Micronutrient intake in smallholder farming systems strongly related to soil fertility and soil fertility management
- Micronutrient responses not only limited to poor soils, but evident across wide yield ranges
- Efforts to increase fertilizer without addressing micronutrient deficiencies will exacerbate human micronutrient deficiencies
- Focus on yield response as a basis for fertilizer recommendation obscure the importance of yield quality
- Integrated agronomic solutions are required to address the challenge of low productivity and low nutritional values of crops:
  - Crop varieties
  - Crop diversification
  - Organic resources
  - Appropriate fertilizer formulas and management practices
  - Socio-economic determinants and outcome indicators