Role of agronomy in enhancing nutritional quality of cereals

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CGIAR

CIMMYT

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  - ✓ Agronomy practices for increasing micro-nutrients
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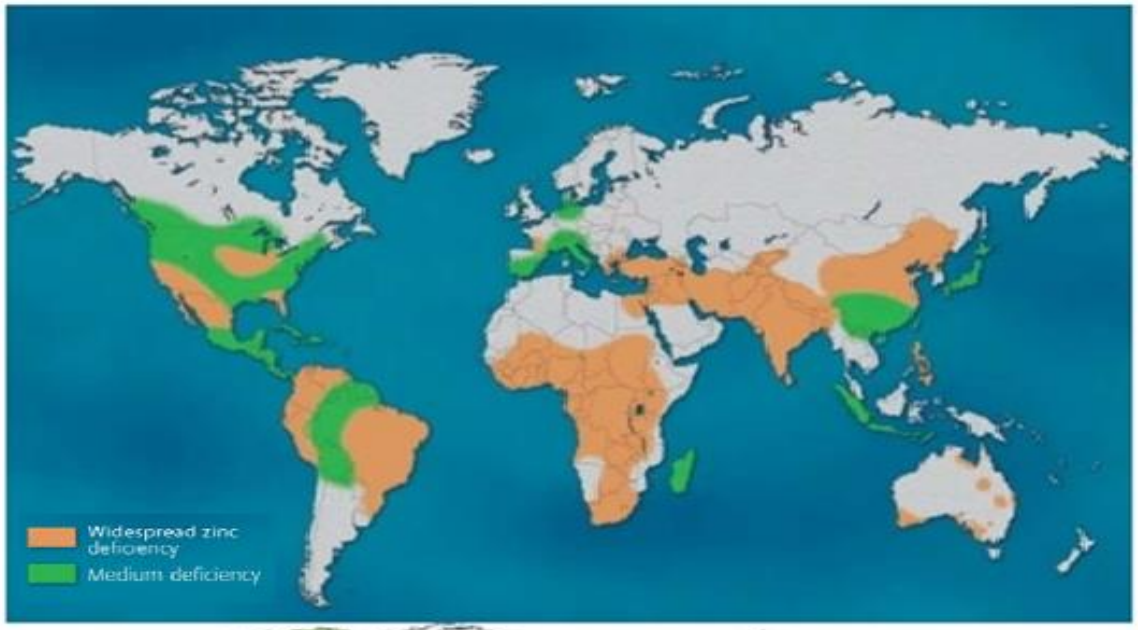
Human nutrition status

- Micronutrients play a vital role in human health and immune systems
- One billion people undernourished worldwide
- > 2 billion people suffer from malnutrition of micronutrients
- Vitamin A, Fe and Zn deficiency prevalence among 40% of world populations
- South Asia: 50 % are anemic and 30% Zn deficient

Constraints for nutritional quality

- Last 50 years, more emphasis on quantity than quality
- 70 % of Indian rural population diet is from cereals
- Cereals are inherently low in micronutrients
  - 13-15 mg Zn/kg of rice grain
  - 38-47 mg Zn/kg of wheat grain
- A diet of 300-400 g cereal day^{-1} will supply only
  - 4-6 mg Zn day^{-1} in case of rice
  - 11-18 mg Zn day^{-1} in case of wheat
- All India Coordinated Research Project on Micronutrients:
  - 48 % of soil deficit in Zn and 11% in Fe.
  - Constraint to crop production and public health issue

Positive correlation of Zn Deficiency in soil & Humans



Soils

Humans

BIOFORTIFICATION

- Increasing the bio-available concentrations of micronutrients in edible portions of plants through crop management and genotype improvement (WHO 2002).
- Agronomic biofortification is a strategy, along with breeding, for increasing micronutrient concentrations to reduce dietary deficiencies (HarvestPlus).

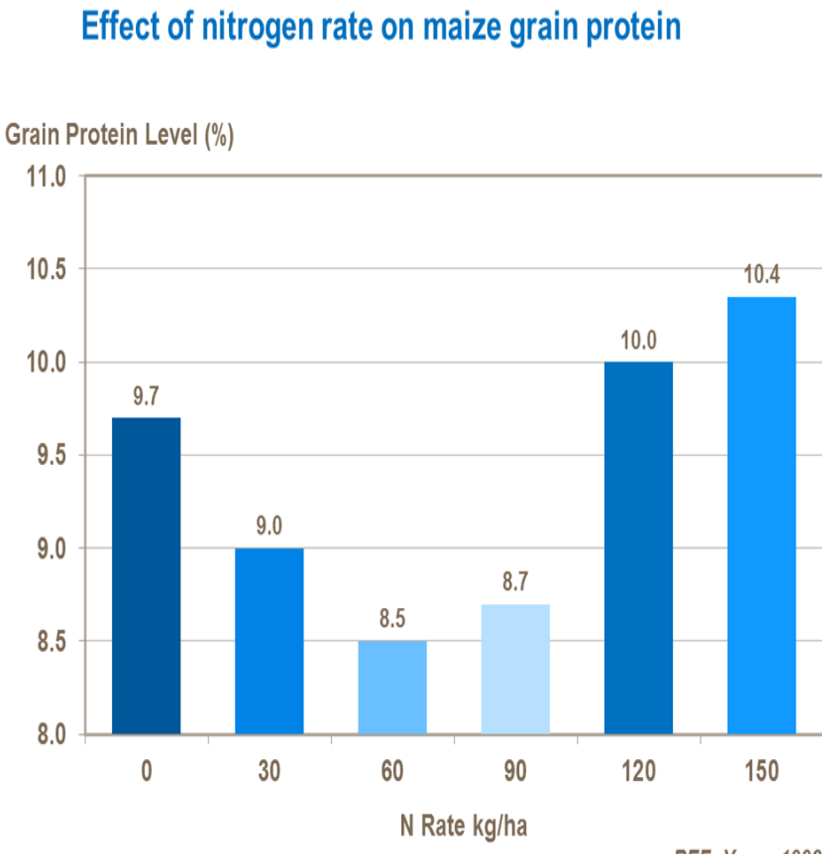
Agronomic biofortification

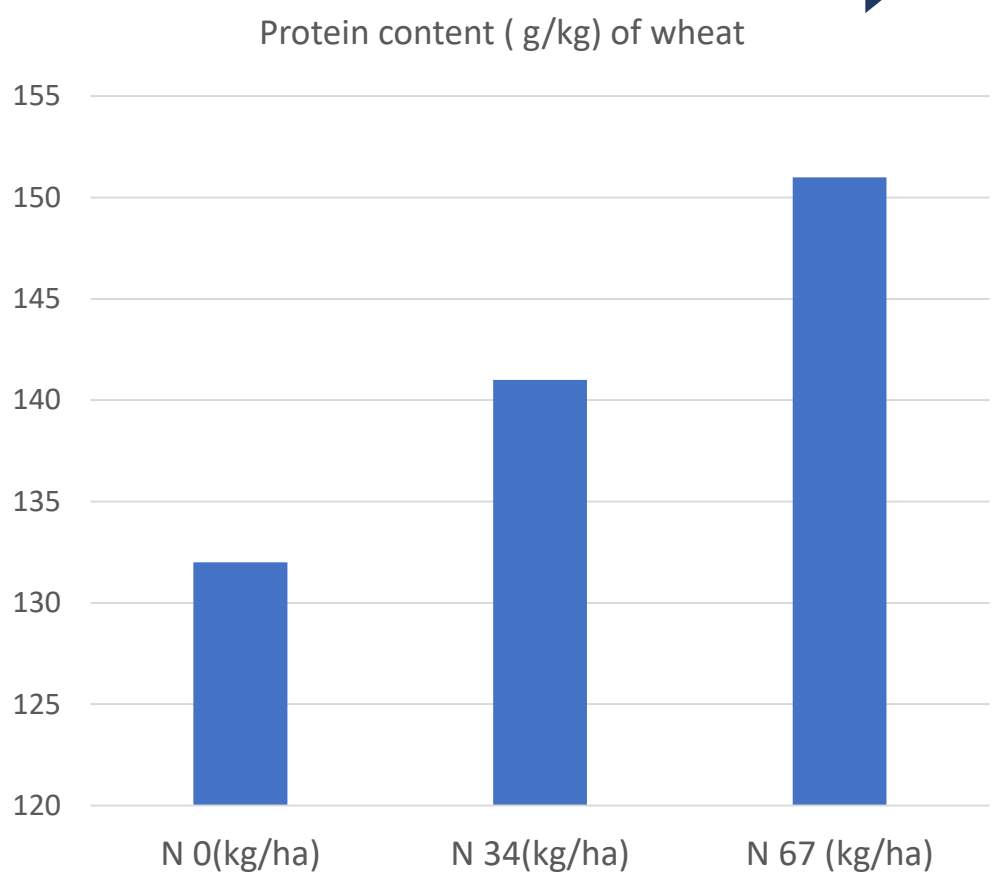
It is cost effective to enhance the micronutrients

1. Improving protein content (N, S, K)
2. Increasing Zn, Se & I content

- ✓ Fertilizers:
  - Adding Selenium fertilizer boosted Se intake among the Finnish populations
  - Adding Iodine fertilizer reduced infant mortality in China
- ✓ Other agronomic practices

Nitrogen application increases protein content of maize and wheat

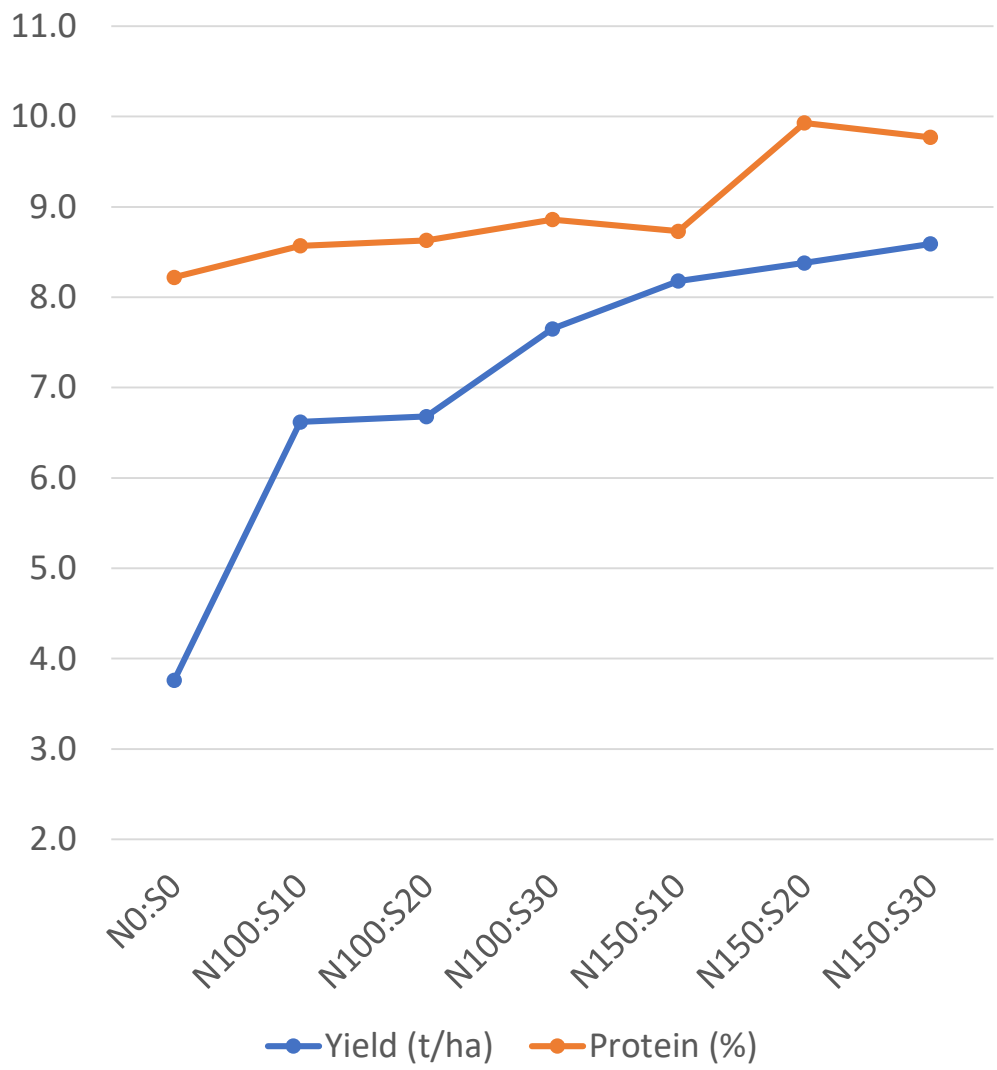




Ottmana et al., 2000

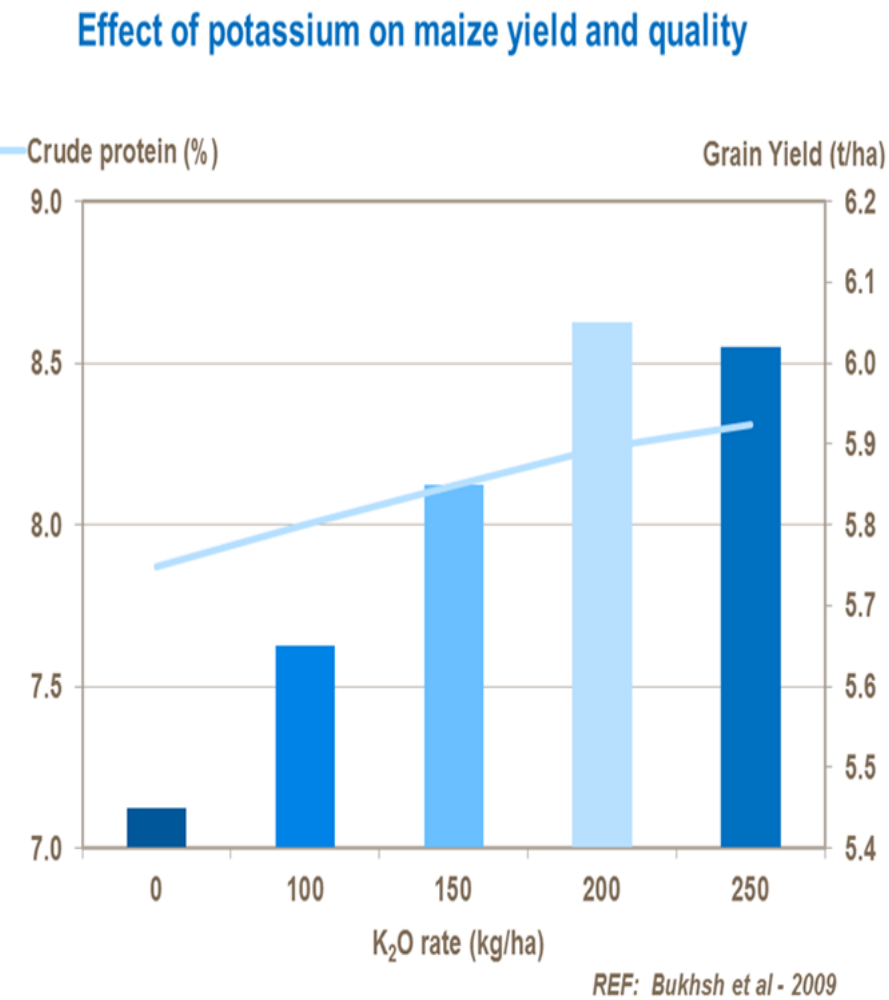
Sulphur is needed for nitrogen to be utilized efficiently in Maize

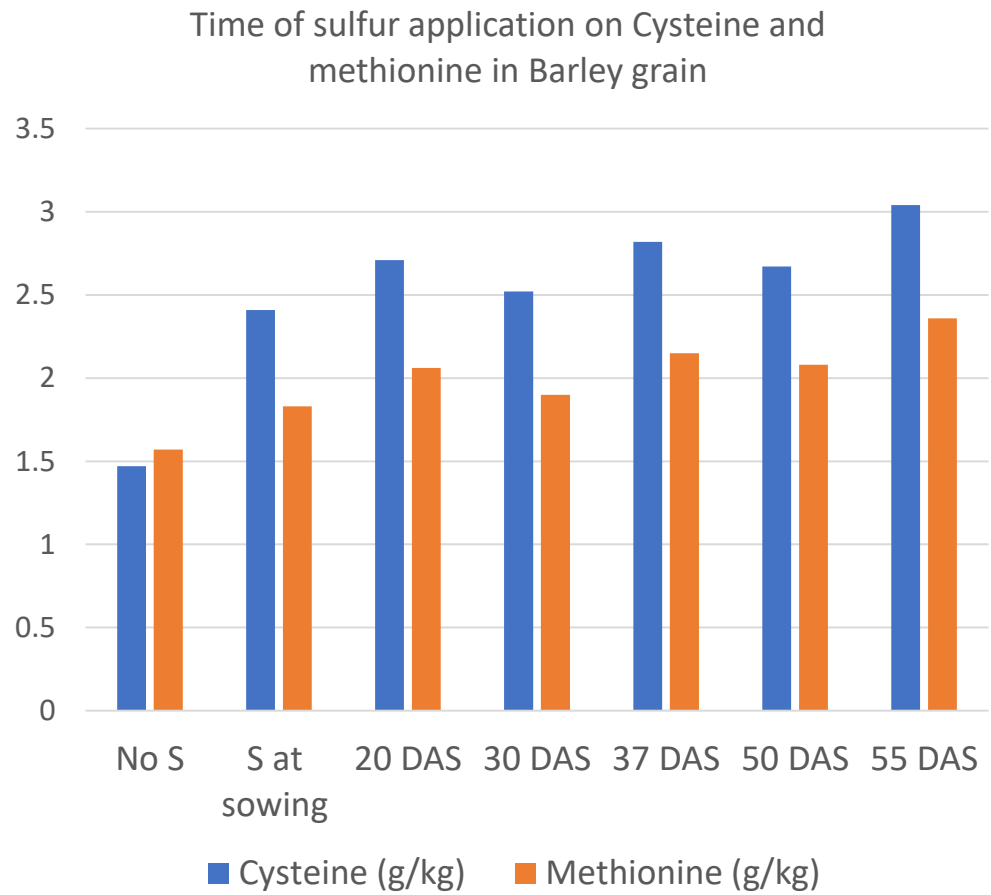
- Sulphur helps in conversion of nitrogen to protein



Rasheed et al., 2004

Pottasium and sulfur application increases protein in Maize and Barley



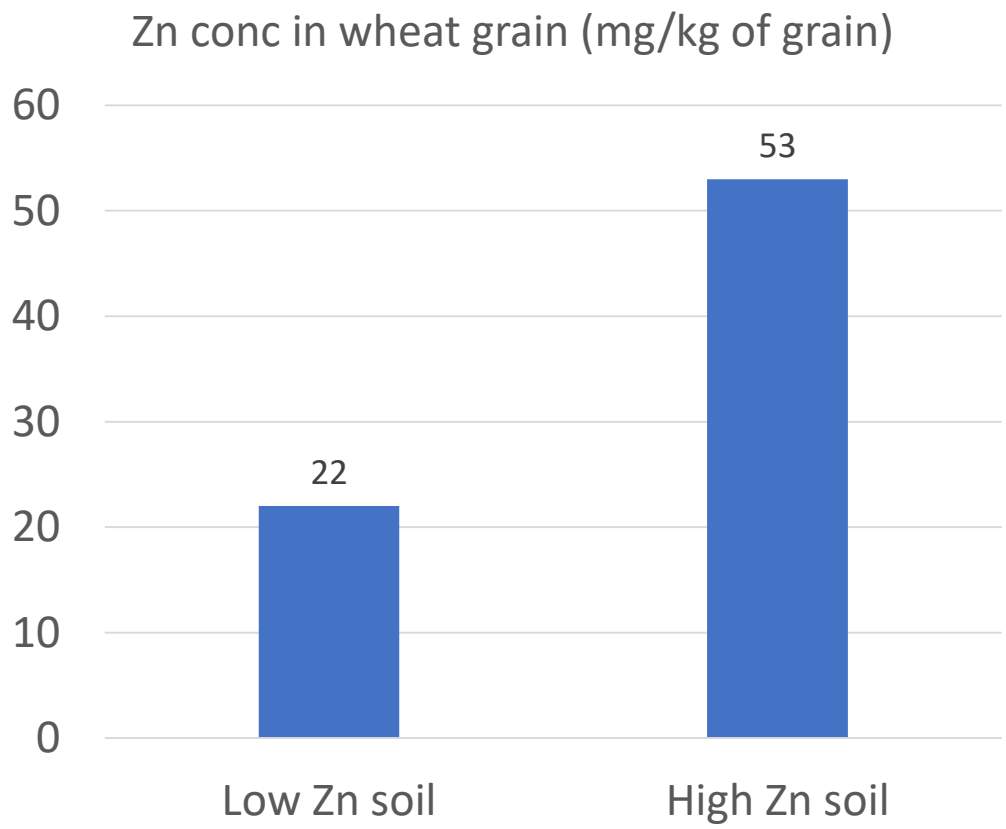


Eriksen et al., 2002

Soil Zn content influences Zn conc in grain

- ZINC DEFICIENCY
  - Contributes to stunting
  - Lowers immunity
  - Increases risk of respiratory infections

- High soil Zn- increased yield, income and Zn conc in grain



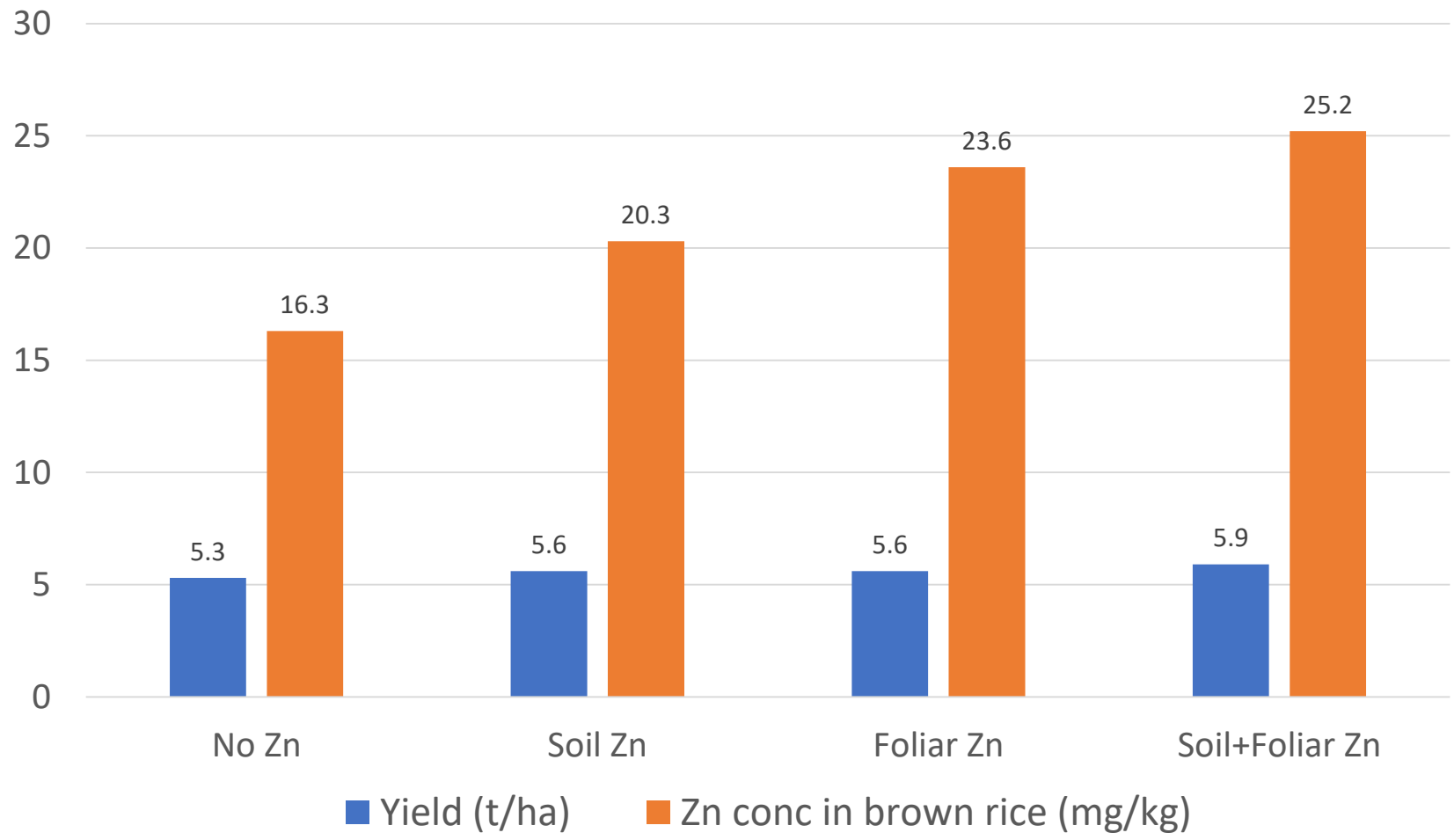
Bevis et al., 2019; Joshi et al., 2010

Zn fertilizer application improves child health

- Soil Zn deficiency drives child stunting across the Nepal
- One ppm increase in available Zn conc in soil effectively moves “low Zn” to “high Zn” soils
  - 20 kg/ha Zn sulfate is adequate to increase soil Zn conc by above one ppm
  - Child height increased by 6 to 8%
  - Child stunting reduced by 9 to 14%
  - This effect is equal to two months of direct Zn supplementation

(Bevis et al., 2019)

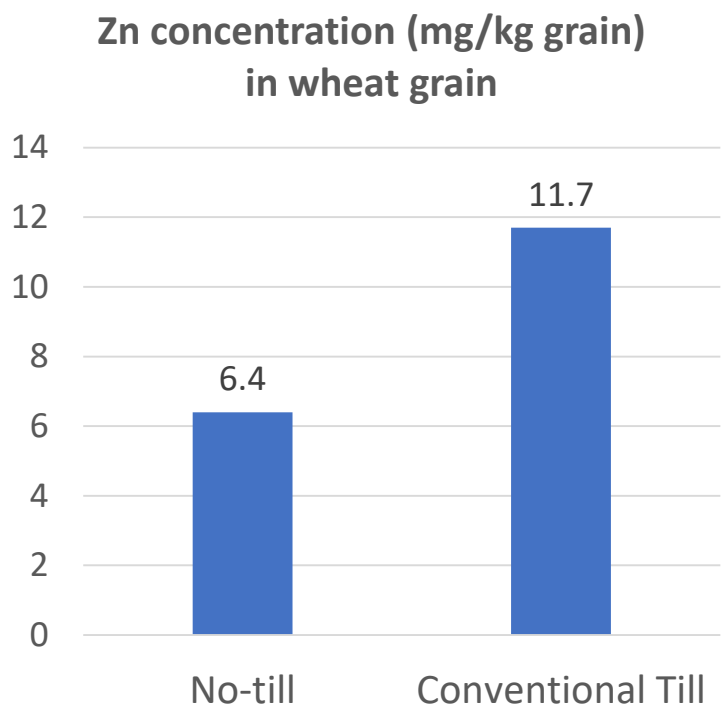
Application methods on yield and Zn conc of rice grain



Phattarakul et al., 2012

Tillage influences Zn conc in wheat grain

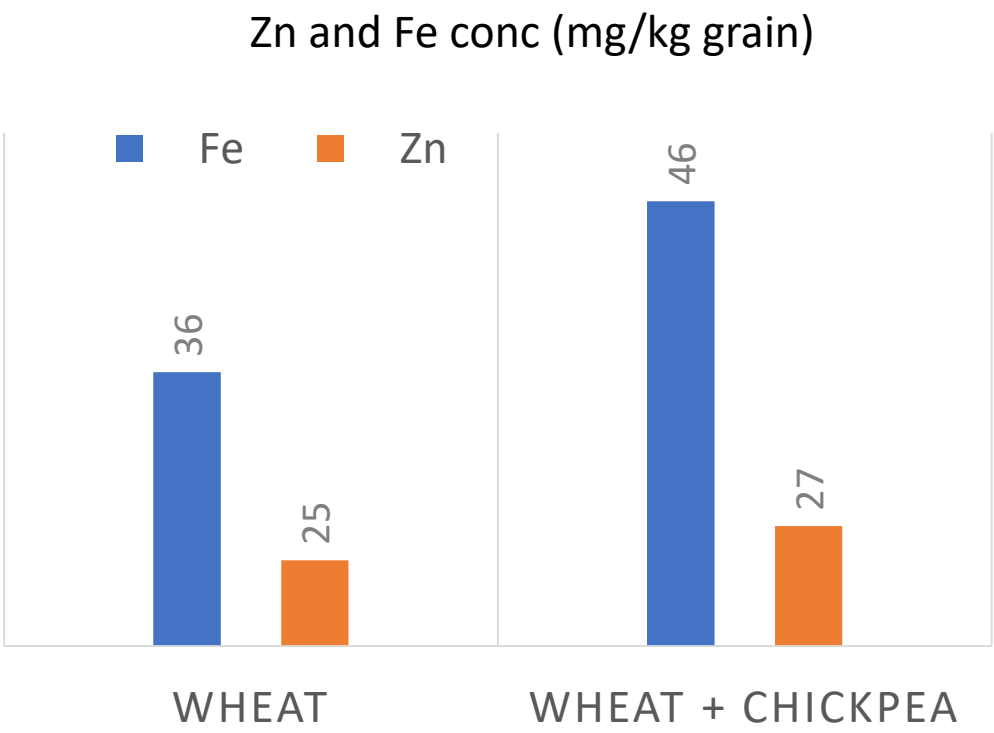
- In no-tillage, accumulation of P in surface soil reduce Zn uptake
- Crop residues are a source of micronutrients. Rice and wheat remove (in g/ha):
  - 96 Zn
  - 777 Fe
  - 745 Mn
  - 42 Cu
  - 55. B
- Rice and wheat residue production in India is 105 MT: 35,400 tons of micronutrients



Prasad et al., 2014

Crop diversification influence Fe and Zn content

- Intercropping of graminaceous and dicot sps:
  - Efficient use of soil nutrients
  - High conc of Zn and Fe in the grains



Zuo and Zhang (2009)

Toxic effect of Arsenic

- Toxic elements that are likely to be taken up by crops and accumulated up to levels that may pose a risk to humans include cadmium (Cd) and arsenic (As).
- Rice contains about ten times more As than other crops and is a serious concern as rice is a staple food
- High level of As in soils also decreases Se and Zn levels in rice
- Applying Silicon (Si), nitrate fertilizer and aerobic conditions (i.e. letting the soil dry) all reduce As

Rahman et al.,2006

Soil intelligence systems: leverage advanced technologies for enhancing efficiency and reliability while reducing costs

Specify use cases, required products, and necessary precision with end users

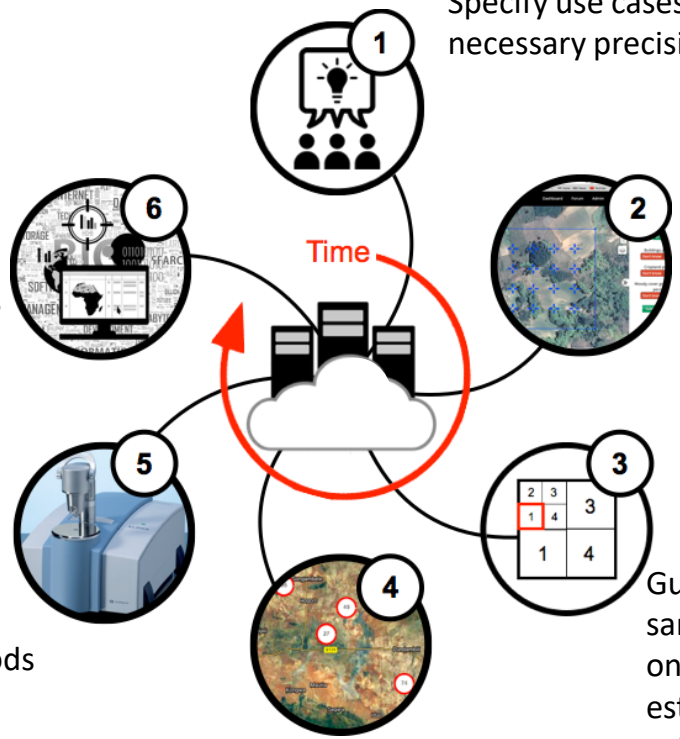
Couple legacy soils data with environmental co-variates to predict soil properties at scale with machine learning and geo-statistics; establish a robust data system incorporating FAIR principles

Guide new soil sampling efforts based on map uncertainty estimates for critical soil parameters

Log field and laboratory measurements using end-to-end digital solutions

Determine which properties can be reliably estimated with sensors and mainstream methods accordingly

Improve spatial predictions through incorporation of new point data from targeted sample locations



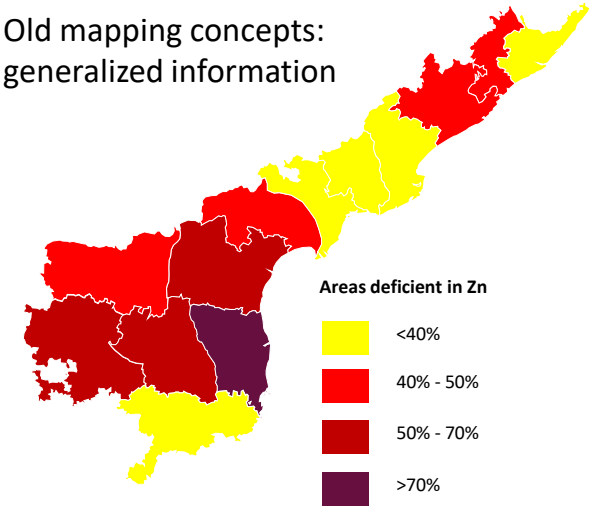
Big data to power soil analytics at scale: *What if a small fraction of current soil sampling could be conducted while improving reliability, reducing costs, and making soil information available for a range of use cases?*

(intelligence = information for action)

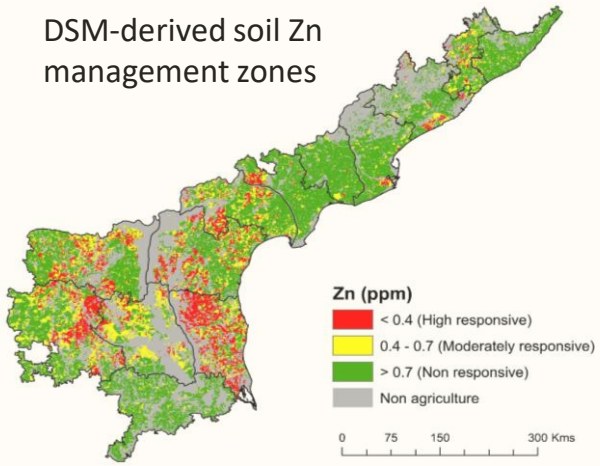
- Source(s): BMGF, AfSIS internal document, CIMMYT

SIS captures spatial variability in soil properties and crop responses for targeted intervention design

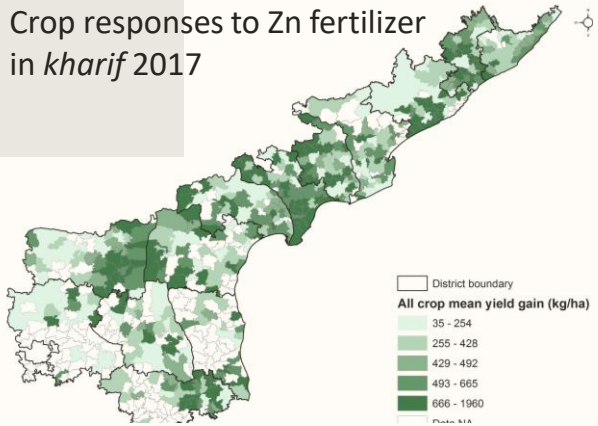
Old mapping concepts: generalized information



DSM-derived soil Zn management zones

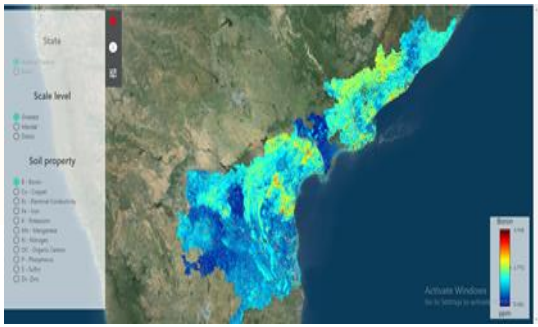


Crop responses to Zn fertilizer in *kharif* 2017



Precise recommendations, efficiently developed through advance analytics and geospatial technologies to increase yield and Zn cons

https://dev-sisindia.isric.org/



Source: State SHC data; CIMMYT analysis

Conclusion and perspective

- Low soil Zn may be one piece of the "South Asian Puzzle" of low nutrition despite growing income levels
- Agronomic fortification offers bright prospects for improved human nutrition
- More research and collaboration are needed to address the spatial variability of soil micronutrients and human health
- Need experimental evidence on soil-crop-human health for addressing public health and nutrition policies, which is especially aggravated during the COVID-19 pandemic.

Thank you for your interest!