An AgriFoSe2030 Brief
September 2019


AgriFoSe2030

Agriculture for Food Security 2030
- Translating science into policy and practice

# Agronomic bio-fortification of sub-Saharan soils and crops – an opportunity to alleviate hidden hunger

*This brief aims to identify the current status of micronutrient losses in soils in sub-Saharan Africa (SSA) and the effects on human nutrition. We conducted a synthesis of existing datasets and peer-reviewed scientific literature to i) improve the understanding of the relationships between soil quality, management and crop quality, and ii) evaluate the potential profitability of applying secondary nutrients and micronutrients to staple crops in SSA.*

## Key messages

- Agronomic bio-fortification in staple crops provides an opportunity to alleviate hidden hunger by raising the concentrations of trace elements, important for human nutrition, in the produce.
- Profitability increase for smallholders as a result of yield increase often exceeds the extra cost of the secondary nutrient and micronutrient-enriched fertilizers.
- There is a large variation in potential nutritional improvement and the profitability of the agronomic bio-fortification practices.
- Best effect and cost-efficiency would be reached if farmers were supported to apply secondary nutrients and micronutrient-enriched fertilizers for the specific crop demands and soil properties tailored to local conditions.

## Linkages between soil micronutrient content and food insecurity

Soil nutrient status governs not only crop productivity but also the nutrient concentrations in plant parts consumed as food and feed. There is evidence for widespread but varying crop micronutrient deficiencies in SSA. This literature review showed that micronutrient and sulphur (S) application to the soil most often had a positive effect on micronutrient concentrations in edible plant parts including an increased content of selenium (Se), copper (Cu), boron (B), zinc (Zn) as follows:

1. Applying moderate amounts of selenium in soils increase the content and therefore the quality of maize grains during the season of application. Low rates of application (less than 5g S $ha^{-1}$) are seldom sufficient for proper Se concentration in the grain.
2. Application of secondary nutrients and micronutrients increases copper concentration in maize grain by 15% relative to an unfertilized control.

**Micronutrients** are nutrient elements that have specific functions in the metabolism of an organism and are vital for the completion of its life cycle or its optimal growth yet required in very small quantities. Both crops and humans require micronutrients, although their specific needs differ.
*Key micronutrients include: Selenium (Se), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), and Zinc (Zn)*

**Secondary nutrients**, like micronutrients are essential plant nutrients. They are called "secondary" nutrients because plants require them in smaller quantities than nitrogen, phosphorus, and potassium. On the other hand, plants require these nutrients in larger quantities than the "micronutrients".
*Key secondary nutrients include: Sulfur (S), Calcium (Ca), Magnesium (Mg).*

**Hidden hunger** is the same as micronutrient malnutrition. It occurs when the food does not provide the vitamins and minerals required by the human body for growth and development.

**Agronomic bio-fortification** is the application of micronutrient-enriched fertilizers to soils or growing crops, in order to increase the concentrations of the micronutrients required by humans in the edible crop organs, such as grains or tubers.

3. Maize ear leaf concentrations of zinc are increased by 15% and quadrupled for boron when secondary nutrients and micronutrients are applied to the soil.

This implies that micronutrient-enriched fertilizer products can be used to improve the nutritional quality of crops. Agronomic bio-fortification in staple crops, which implies application of micronutrients such as zinc, boron and selenium, provides an opportunity to alleviate hidden hunger by raising the concentrations of trace elements that are important for human nutrition in the produce.

## Profitability of agronomic bio-fortification

In addition to improving crop quality, agronomic bio-fortification also increases yields. However, in order for bio-fortification practices to be adopted in SSA there has to be observable increase in profitability.


Figure 1. Maize and beans are major food crops in SSA.

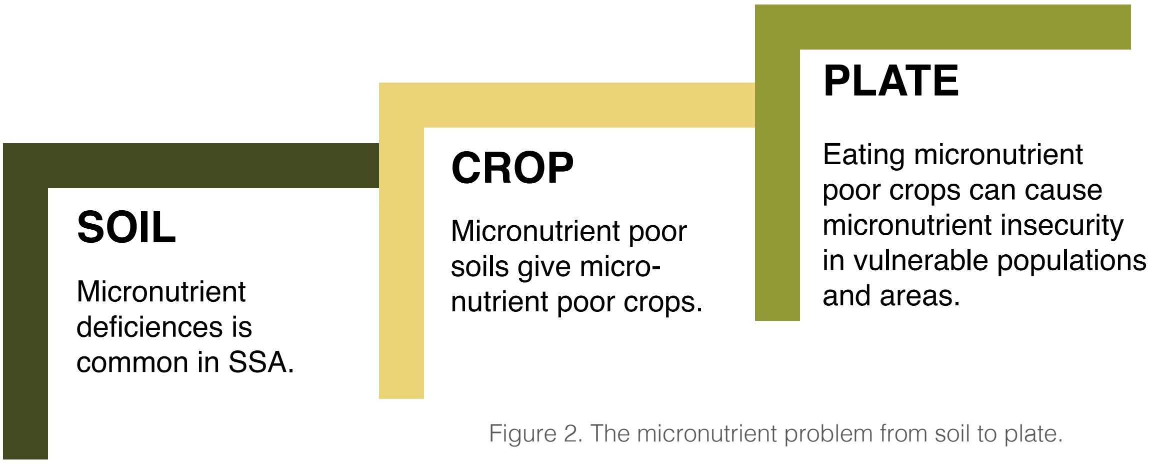


Figure 2. The micronutrient problem from soil to plate.

This review found that agronomic bio-fortification often was profitable for smallholder farmers. Application of secondary and micronutrients to maize has positive net economic benefits in at least 70% of the cases, for example for combined application of both secondary nutrients and micronutrients reaching up to 85% of the cases for copper. Similarly, for wheat, positive net benefits for sulphur were observed in 84% of the cases.

The extra cost of the fertilizer products was compensated for by yield increases (see figure 3). However, if there is no increase in crop productivity, although the quality of crops is improved, the increase in profitability for farmers applying bio-fortified fertilizers to their soils will not be realized, also meaning that the benefits of micronutrient fertilization will be unrealised. In addition, residual effects, meaning the crop response in subsequent seasons after the season of application, are often unknown in SSA. This also contributes to an underestimation of the added value of micronutrient fertilization.

We observed large variation in the effect of micronutrient-enriched fertilizers on both micronutrient elemental concentrations in harvested plant parts and on profitability of the agronomic bio-fortification (figure 3). The variation can be explained by many factors, for example genetic differences

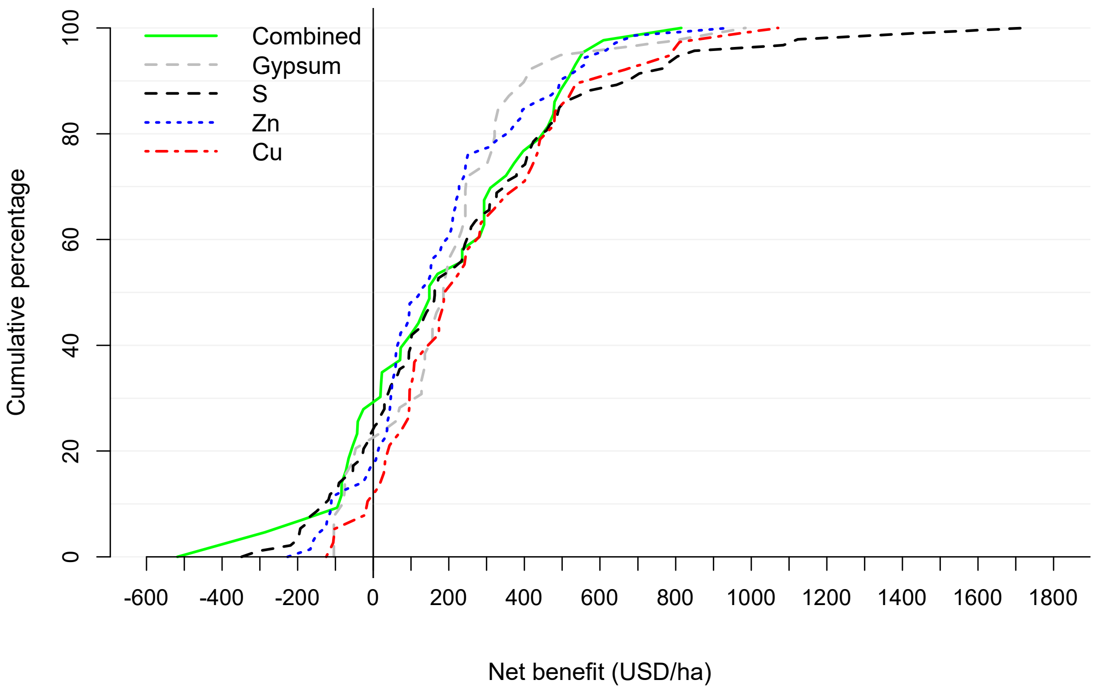


Figure 3. Distributions of net benefits of combined secondary and micronutrients (combined), sulfur (S), zinc (Zn) and copper (Cu) as observed in SSA. The graph is based on 502 data points (ranging from 39 for Cu to 222 for combined) for maize collected from 9 countries, namely Ghana, Kenya, Malawi, Mozambique, Nigeria, Sudan, Tanzania, Togo and Zambia.

between crop species and cultivars, soil chemical properties and soil elemental concentration. In order to make best use of available resources, large-scale digital soil maps, local soil measurements, agronomic knowledge from field trials and well-informed extension agents and services can be used as decision support for whether or not to apply micronutrient-enriched fertilizer products, and what element and rate to use if applied.

## Recommendations and ways forward

- The available data on linking crop quality and profitability to agronomic bio-fortification are scanty. New studies are needed to ensure additional countries are covered and preferably other staple crops besides maize. Such studies would support improved fertiliser practices, policies, extension services and development of appropriate fertilizer blends targeted to various crops and climatic zones.

- There is a need to develop tools for site-specific micronutrient application and decision making supported by local extension services. This will increase chances of increasing the profitability.

- Agronomic biofortification can be achieved through policy interventions such as requirements for inclusion of specific micronutrients in local fertilizer blends.

- In low-income regions, the renewed interest in food systems should increase the appreciation of a high micronutrient content and crop quality in crop value chains and consumer markets, despite micronutrients being invisible in most cases.

This brief is based on a synthesis of peer-reviewed scientific literature and datasets from SSA. The data in the study is primarily for maize (the most researched crop) and only seven countries in SSA had at least 100 data entries and are therefore included in the synthesis.


SIMON D. ALLEN, PIXABAY, CC0

This brief was written by Job Kihara at the International Center for Tropical Agriculture (CIAT)/ The CGIAR Research Program on Water, Land and Ecosystems (WLE), Nairobi, Kenya. Co-authors were Peter Bolo (CIAT), Michael Kinyua (CIAT) and Kristin Piikki (CIAT and Swedish University of Agricultural Sciences, SLU).

The brief is based on a new synthesis of data and literature, aimed for publication in a peer-reviewed scientific journal. It is a follow-up of a previous study (Kihara et al. 2017. Doi: 10.1007/s13593-017-0431-0).

We thank the AgriFoSe2030 programme and the Swedish International Development Agency for the financial support provided.

Review acknowledgement to AgriFoSe2030 Communication and Engagement Team.

For more information contact:
J.Kihara@CGIAR.ORG

**www.slu.se/agrifose**