Food and Agriculture Organization of the United Nations

Technical guidelines on soils for nutrition

Sustainable soil management for nutrition-sensitive agriculture

With the technical support of

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Sustainable soil management for nutrition-sensitive agriculture

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Abbreviations and acronyms

BARC	Bangladesh Agricultural Research Council
BMEL	Federal Ministry of Food and Agriculture of Germany
BUNASOLS	National Bureau of Soils of Burkina Faso
CBD	United Nations Convention on Biological Diversity
CGIAR	Consultative Group for International Agricultural Research
DARS	Department of Agricultural Research Services of Malawi
Fertilizer Code	the international Code of Conduct for the sustainable use and management of fertilizers
GSDP	Global Soil Doctors Programme
GSP	Global Soil Partnership
IFAD	International Fund for Agricultural Development
ISFM	integrated soil fertility management
NSA	nutrition-sensitive agriculture
SDG	Sustainable Development Goal
SOC	soil organic carbon
SOM	soil organic matter
SRDI	Soil Resource Development Institute
SSM	sustainable soil management
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
VGSSM	Voluntary Guidelines for Sustainable Soil Management
WHO	World Health Organization

Chemical formulae and elements

Al	aluminium
B	boron
Ca	calcium
Cr	chromium
Cu	copper
Fe	iron
i	iodine
K	potassium
Mn	manganese
Mg	magnesium
Mo	molybdenum
N	nitrogen
p	phosphorus
Se	selenium
Zn	zinc

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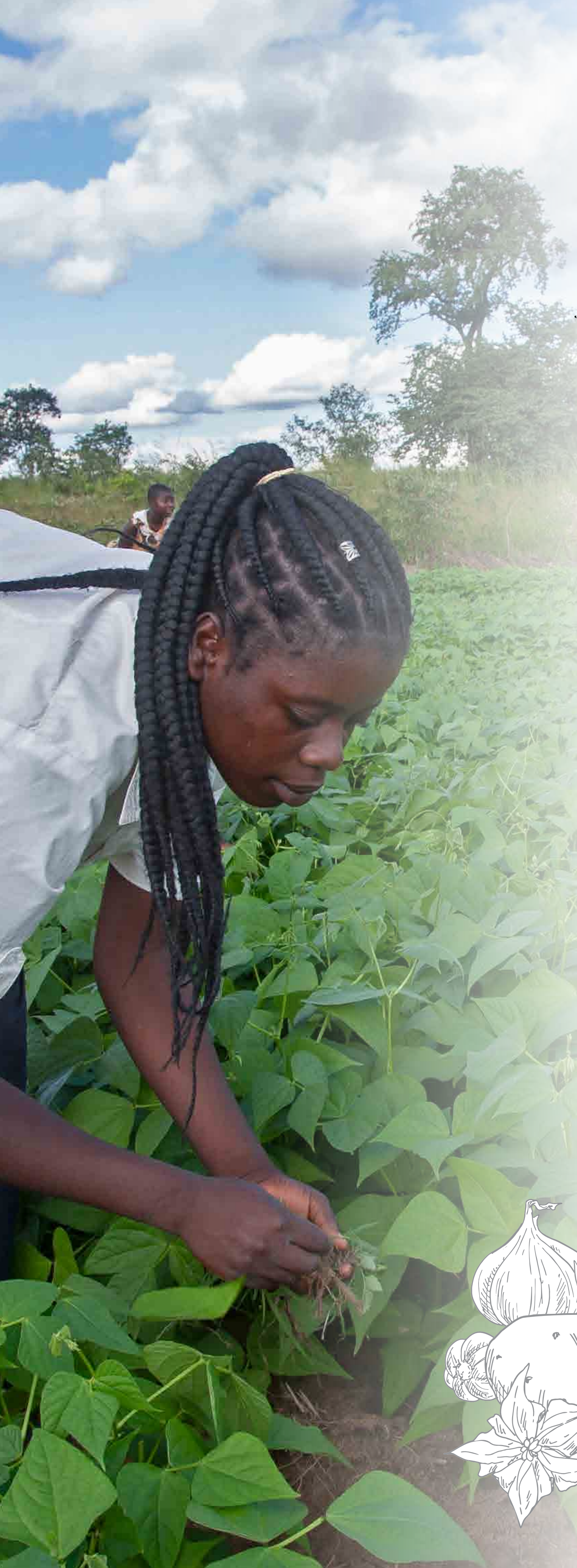

Aim and scope

The guidelines compiled here originate from a scoping review of the existing literature on the subject (Food and Agriculture Organization of the United Nations [FAO], 2022a) and of the empirical evidence gathered under the project *Sustainable soil management for nutrition-sensitive agriculture in sub-Saharan Africa and Southeast Asia* (GCP/GLO/730/GER), (Soils4Nutrition), funded by the Federal Ministry of Food and Agriculture of Germany (BMEL). The Soils4Nutrition project explored the linkages between soil health, crop micronutrient content and human nutrition in cropland areas of Bangladesh, Burkina Faso and Malawi and tested the efficacy of sustainable soil management (SSM) practices in increasing the micronutrient contents of crops, through conservation agriculture, crop diversification, integrated fertilization and agronomic biofortification (see Box 1).

The objectives of these technical guidelines are to present the role of soil health and SSM in the nutritional quality of locally produced food and to generate management recommendations aimed at an increased input of micronutrients to the food chain and an improvement in human nutrition. This document is addressed to all stakeholders involved in food security and nutrition, from farmers to policymakers, to engage them in SSM for nutrition-sensitive agriculture (NSA).

The technical guidelines are structured around seven key messages and include a general explanation for each one based on a synthesis of existing literature and the results from each specific topic of the field trials and demonstration sites of the Soils4Nutrition project.

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Sustainable soil management, the key to combat hidden hunger

Key messages

Over two billion people suffer from hidden hunger worldwide

Crops grown in healthy soils have a higher nutrient content than in degraded soils

Healthy soils are a cornerstone for better plant, animal and human nutrition

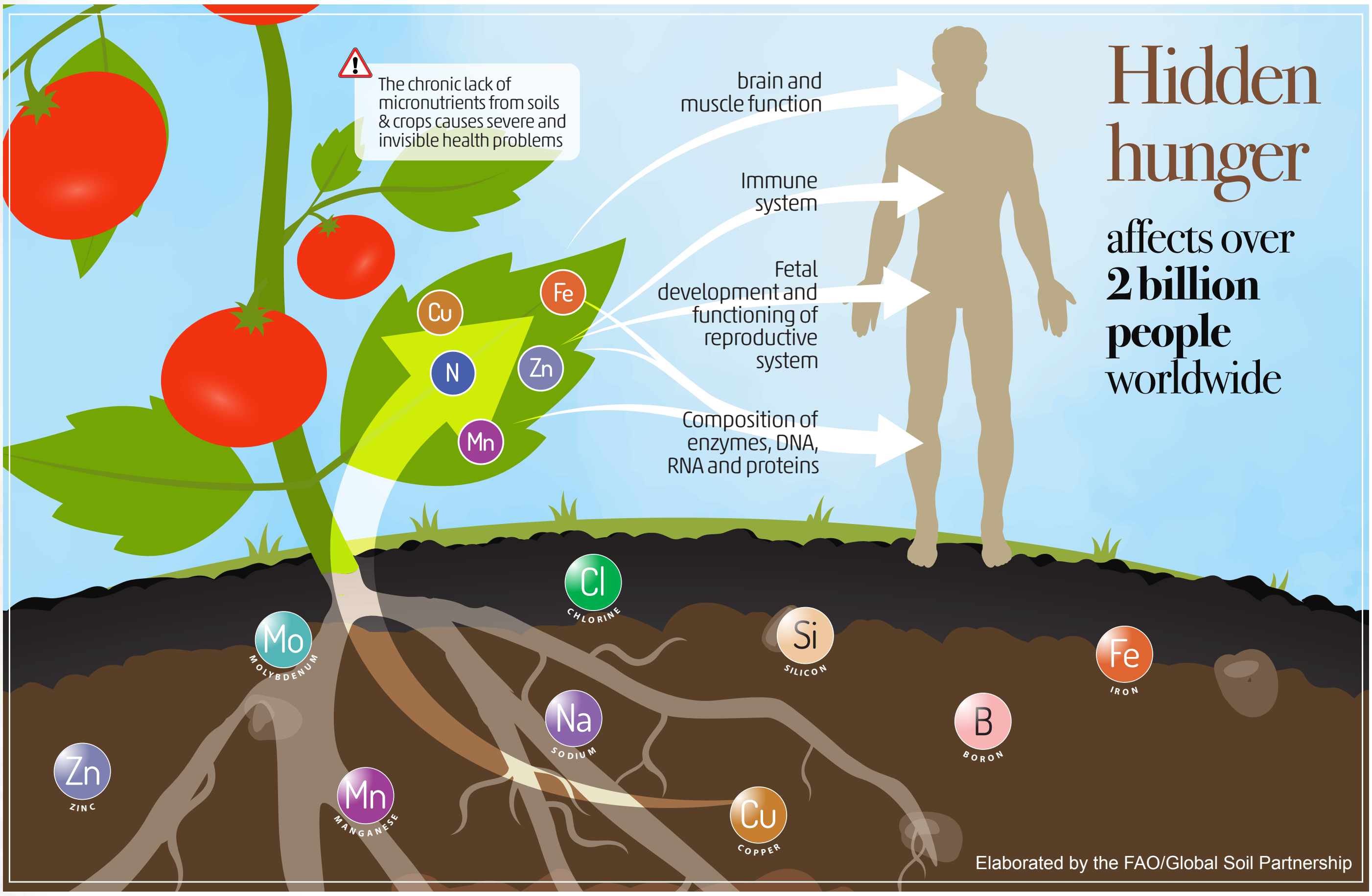
Hidden hunger or micronutrient deficiencies is a form of malnutrition that occurs when the intake of vitamins and minerals (particularly iron, zinc, iodine and vitamin A) are insufficient to maintain good health and development. It is attributed to diets that may have enough food energy but not sufficient nutrients.

Malnutrition includes hidden hunger and correspond to a more general condition which refers to all deficiencies, excesses or imbalances in a person's intake of energy or nutrients and is a key global challenge. Healthy diets are out of reach for three billion people and according to the latest report on The State of Food Security and Nutrition in the World 2022 (FAO *et al.*, 2022), about 828 million people suffer from hunger, 149 million children under the age of five are affected by growth disorders and 676 million adults are affected by obesity.

As per the definition of the Second International Conference on Nutrition (FAO, 2014):

> *Nutrition-sensitive agriculture is a food-based approach to agricultural development that puts nutritionally rich foods, dietary diversity and food fortification at the heart of overcoming malnutrition and micronutrient deficiencies* (FAO, 2014).

This approach recognizes the nutritional value of food for good nutrition and the importance of the agrifood systems for supporting rural livelihoods. The overall objective of nutrition-sensitive agriculture (NSA) is to make the global agrifood system better equipped to produce good nutritional outcomes (FAO, 2014), taking action at all stages of the food chain, from production and processing to retail and consumption, while also including a focus on the promotion of healthy diets, as per the outcome of the UN Food Systems Summit.



The agricultural sector has the potential to improve food security and contribute to better nutrition and health outcomes. This has to be achieved through comprehensive long-term strategies that enable a stable and sufficient supply of nutritious food without harming the environment, and consider other parts of the agrifood systems, from production to consumption. Sustainable soil management (SSM) is a keystone in that endeavour.

These guidelines provide advice for the production of nutrient-rich edible crops through SSM, within a nutrition-sensitive agriculture strategy.

Recent estimates show that the diets of around two-thirds of the world's population are deficient in at least one micronutrient (Stevens *et al.*, 2022). While iron deficiency is most commonly observed, around 30 percent of the world's population are deficient in zinc and iodine, and up to 15 percent are deficient in selenium (White *et al.*, 2012). In addition, dietary deficiencies of calcium, magnesium and copper occur in many developed and developing countries. This is expected to worsen in the coming decades due to soil degradation and global warming. It is likely that by 2050, minerals such as zinc and iron, present in main crops such as wheat, corn, rice and soybean could be reduced by up to 10 percent and 5 percent respectively (Smith and Myers, 2018), potentially contributing to major nutritional deficits.

In recent years, national and international initiatives have adopted the nutrition-sensitive approach for agriculture to fight against malnutrition. Organizations such as FAO, the World Bank and IFAD, in collaboration with national governments, have led actions towards an enhanced global nutritional status of the population. FAO's Food and Nutrition Division has explicitly included the aim for "nutrition-sensitive agrifood systems and value chains" in its extension and advisory services, with specific mandates and activities in that regard (FAO, 2021).

These efforts have resulted in advances towards a higher awareness of nutrition and to tangible outputs in terms of improved nutritional status in many communities worldwide. To ensure that these initiatives are sustained over time and become more cost-effective and widespread, soils must be considered, as they are the basis of the entire agricultural system and have a role in all four dimensions of food security: availability, access, utilisation and stability (Hwalla *et al.*, 2016). Soil health and SSM are key elements in supporting long term NSA.

Soil health is defined as "the ability of the soil to sustain the productivity, diversity and environmental services of terrestrial ecosystems" (ITPS, 2020). Healthy soils require a mixture of minerals, living organisms, air, water and organic matter to sustain plant growth. But, in spite of the known strategic importance of soil health, only a small percentage of farmers practice SSM.

According to FAO´s Voluntary Guidelines for Sustainable Soil Management (VGSSM), (FAO, 2017a), soil management is sustainable if the supporting, provisioning, regulating and cultural services provided by soil are maintained or enhanced without significantly impairing biodiversity or the soil functions that enable those services. The balance between the supporting and provisioning services for plant production and the regulating services that soil provides for water quality and availability and atmospheric greenhouse gas composition are a particular concern.

Unsustainable practices such as monocropping, intensive tilling, lack of cover crops and the overuse or misuse of agrochemicals have led to the degradation of approximately one-third of the world's productive topsoils, including a severe reduction of their organic matter content and ability to retain nutrients, a too low (<5.5) or too high (>8.0) pH value and poor infiltration and moisture retention qualities.

Different soils naturally have different nutrient supply capacities, due to their specific mineralogical build up, resulting from the action of climate, topography and biota on rocks through time. Weathering processes are responsible for the chemical and mineralogical transformations that gradually release the nutrients stored in rocks and make them available to plants. Since the original amount of minerals in the rocks is finite, this means that the soil nutrient content will be slowly reduced over time due to leaching, erosion and removal by plants. Soil nutrient depletion is thus a natural occurrence, but it is usually accelerated by unsustainable activities. Since the 1950s, agriculture has accommodated a growing food demand through practices that have prioritized high yields over soil health and crop quality, overlooking soil properties and capacities and leading to widespread soil degradation, including nutrient imbalances in agricultural land.

Whether it is naturally occurring or induced by humans, the depletion of minerals in soils can be reflected in human nutrition and health. Crops grown on nutrient-deficient soils also tend to be nutrient-poor and, for that reason, there is an increased likelihood of malnutrition or certain nutrient deficiencies. For instance, in the case of zinc, deficiencies observed in humans show a geographical overlap with zinc-depleted soils (Cakmak *et al.,* 2017). The following technical recommendations aim to provide guidance on how to improve the nutrient content of plant food through improved soil health to better support healthy diets and improved human nutrition.

Box 1. Soils4Nutrition: a project to tackle soil and crop nutrient deficiencies

Through the project *Sustainable soil management for nutrition-sensitive agriculture in sub-Saharan Africa and Southeast Asia* (GCP/GLO/730/GER), the Global Soil Partnership (GSP) supported FAO members in adopting SSM practices, in their efforts to improve the nutritional quality of locally produced food, towards better diets and to address human micronutrient deficiencies. The project was funded in Bangladesh, Burkina Faso and Malawi by the German Federal Ministry of Food and Agriculture (BMEL), where governments had highlighted the need to address hidden hunger, particularly in poor, rural communities. The three main outputs of the project were a review of existing knowledge, the demonstration of best management practices in the field and a set of country-specific and global soil management recommendations to combat crop nutrient deficiencies.

Figure B1.1 Demonstration site in rotation of rice, cauliflower and mung bean in the Chuadanga district (Bangladesh)

A thorough review of the existing literature showed that there is a good level of knowledge about the mechanisms of micronutrient uptake by plants and their interaction with soil conditions. Soil organic matter, pH, texture, structure, water content, and the presence of macronutrients all play an essential role in micronutrient uptake. There is also some information on the relationship between the nutritional value of food and the spatial distribution of nutrients in soils that allows to envisage opportunities for the increase of crop nutrient content through SSM.

The results of the field trials indicate that, by following the basic principles of SSM, farmers can produce higher quality food that can contribute to healthier diets. The project field trials (Figure B1.1) provided important information on the right time, the right source and the right place to apply micronutrient fertilizers, along with the benefits of associating micronutrient supply with SSM practices. Also, given the limited level of knowledge of farmers on the role of soils for an improved nutritional value of crops, the project focused much of its efforts on training farmers and extension services at each of the demonstration sites.

Figure B1.2 Onsite capacity development with farmers within the Soil Doctors Programme

Capacity development activities (Figure B1.2) were facilitated by the Global Soil Doctors Programme (GSDP), focusing on transferring knowledge and practical skills on soil health, plant nutrient uptake mechanisms and SSM. The GSDP is a farmer-to-farmer training initiative that enables the establishment of long-term collaboration among farmers, as well as between farmers and institutions and other stakeholders, providing the conditions for a continued and sustainable knowledge transfer system.

The evidence provided by the project field trials, together with first-hand information on the barriers for the generalized adoption of SSM, was the input for country-specific briefs containing policy recommendations for the mainstreaming of SSM in NSA.

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Technical recommendations for sustainable soil management in nutrition-sensitive agriculture

Key messages

It is necessary to maintain soil health to ensure an adequate soil nutrient balance and plant uptake

Soil organic matter enhances soil health through the improvement of its physical, chemical and biological properties, including a higher capacity for storing and mobilizing nutrients

It is important to maintain and increase soil organic matter through the implementation of specific SSM practices

The chemical, physical and biological characteristics of soils are crucial for boosting soil fertility and avoiding nutrient losses and must be monitored

1. Increase soil organic matter and improve soil health

The amount of **soil organic matter (SOM)** is one of the most important properties influencing soil health and nutrient availability. Soils with higher amounts of organic matter will lead to systems with improved nutrient supplies and storage capacity, as SOM is a reservoir for essential plant nutrients, continuously supplying nutrients to crops upon decomposition. Therefore, SOM mitigates inherent soil fertility issues, ultimately reducing the amount of fertilizers required for agricultural production.

Other soil-related constraints to agronomic productivity can also be mitigated through enhancement of the soil organic pool. A higher amount of SOM leads to improved soil structure and aggregation, which govern soil aeration and water retention. In addition, SOM retains pollutants, thus improving water quality. Soils constitute the largest terrestrial carbon (C) pool and, if sustainably managed, could compensate for up to 31 percent of the greenhouse gas (GHG) emissions from the agricultural sector through carbon sequestration (FAO, 2022b). These essential ecosystem services provided by soils (food production, climate and hydrological regulation and nutrient cycling, among others) contribute to the achievement of the Sustainable Development Goals (SDGs).

The amount of soil organic carbon (SOC) is the indicator more frequently used for reflecting the content of SOM. Soils that have high SOC contents usually have improved nutrient cycles and soil internal architecture and thus have an enhanced nutrient availability and promote better plant growth.

The kind and kinetics of the SOM transformation and decomposition as well as the capacity of SOM to store nutrients in forms available to plants, depend on the overall level of acidity or alkalinity of the soil, denoted by **soil pH**. It influences not only the capacity of organic compounds to bind nutrients, but also the solubility of chemical elements. In acid soils (pH below 5.5), most of the micronutrients are highly available, but soil fertility can be limited due to toxicity derived from increased metal solubility such as aluminium (Al) and manganese (Mn). Acid soils may occur naturally on acidic parent materials and in high rainfall areas (>1000 mm per year) subjected to moderate to high leaching. Acidity can also be exacerbated by continuous cultivation, excess of nitrogen (N) fertilizer and burning of crop residues during land preparation. Alkaline soils (pH above 8.0), on the other hand, occur mostly in low rainfall areas (< 500 mm per year). If soils are too alkaline, many essential nutrients (especially Fe and P) may not be available to plants, even if they are abundant in absolute terms. In turn, the availability of other elements such as molybdenum (Mo), chromium (Cr), Se and boron (B),

Box 2. Voluntary guidelines for sustainable soil management

The high cost of healthy diets, coupled with persistent elevated levels of income inequality, puts healthy diets out of reach for around three billion people, especially the poor, in every region of the world, according to FAO's latest estimates published in the **State of Food and Nutrition** (SOFI) report. **Healthy soils** are an essential element in the production of highly nutritional crops. Through **SSM**, farmers can increase the nutritional value of local produce (particularly micronutrients,) which has a direct impact on the foods accessible to their communities and can contribute to address nutrient deficiencies in diets.

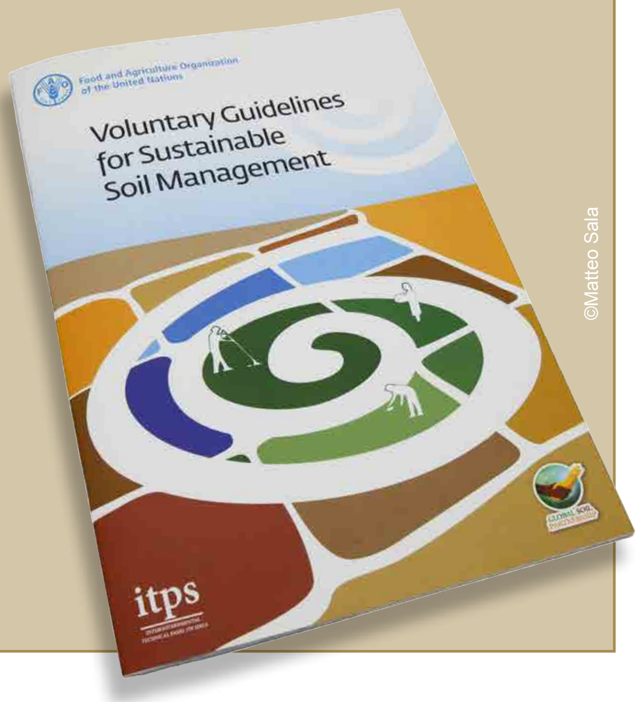
In 2017, FAO´s GSP published the **Voluntary Guidelines for Sustainable Soil Management (VGSSM)**, (FAO, 2017a) as a materialization of the growing concerns about the status of soil health. Soils have been included in the 2030 Agenda for Sustainable Development through a number of soil-related targets, such as those aimed at restoring degraded soils, the goal of achieving a land degradation-neutral world and the implementation of resilient agricultural practices that progressively improve soil quality and minimize soil contamination.

Sustainable soil management is seen as a means for achieving these targets because it contributes to climate change adaptation and mitigation through carbon sequestration in soils, it is key in the fight against land degradation and it helps enhance biodiversity. Therefore, SSM has specific relevance to the United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD) and United Nations Convention on Biological Diversity (CBD).

The VGSSM are based on the revised **World Soil Charter**, adopted by the FAO Conference in 2015, (FAO, 2015) which called for the incorporation of SSM principles and practices into policy guidance.

The VGSSM present generally accepted and practically proven principles, based in the most up-to-date science, to promote SSM and provide guidance to all stakeholders on how to translate these principles into practice. They address the technical aspects of SSM, including core characteristics of sustainably managed soils, key challenges and potential solutions to address them. While mostly focused on agriculture, many of the principles they contain are also appropriate for non-agricultural soils.

Notes:
FAO. 2015. *Revised world soil charter.* Rome.
FAO. 2017a. *Voluntary Guidelines for Sustainable Soil Management.* Rome, FAO. https://www.fao.org/3/bl813e/bl813e.pdf



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can increase in alkaline soils. Fertility issues related to an excess of salinity or sodicity, and poor soil physical properties are common in alkaline soils. Alkalinity issues can be mitigated through practices that increase the SOC content (FAO, 2022c).

Among physical soil properties**, soil texture** has a significant effect on the soil's nutrient availability. Coarse-textured (sandy) soils are often deficient in micronutrients because, as water drains through them, it often carries soluble micronutrients along with it (leaching). Fine-textured (clay) soils are less likely to be nutrient-poor, as clays have a high nutrient and water-holding capacity.

Bulk density, which is mainly a consequence of SOM content and soil texture, is also a very important property, informing about soil structure, porosity and compaction. For a given texture and mineralogical composition, soils with higher bulk density values also have a lower porosity, and less space for water and air circulation. This limits SOM decomposition, nutrient cycling and plant uptake, since water and oxygen are essential for the biological and chemical processes that make nutrients available to plants. Furthermore, a too high bulk density (>1.8 tonnes per m^3) can be an impediment to root growth, thus reducing the volume of soil that can be explored and exploited by plants.

Soil biota, on the other hand, are essential for nutrient availability. Particularly important are soil microorganisms, which are crucial agents in the decomposition of SOM and thus in nutrient cycling. Soil biological properties feature among the most dynamic soil characteristics, showing a rapid response to land use change and soil management.

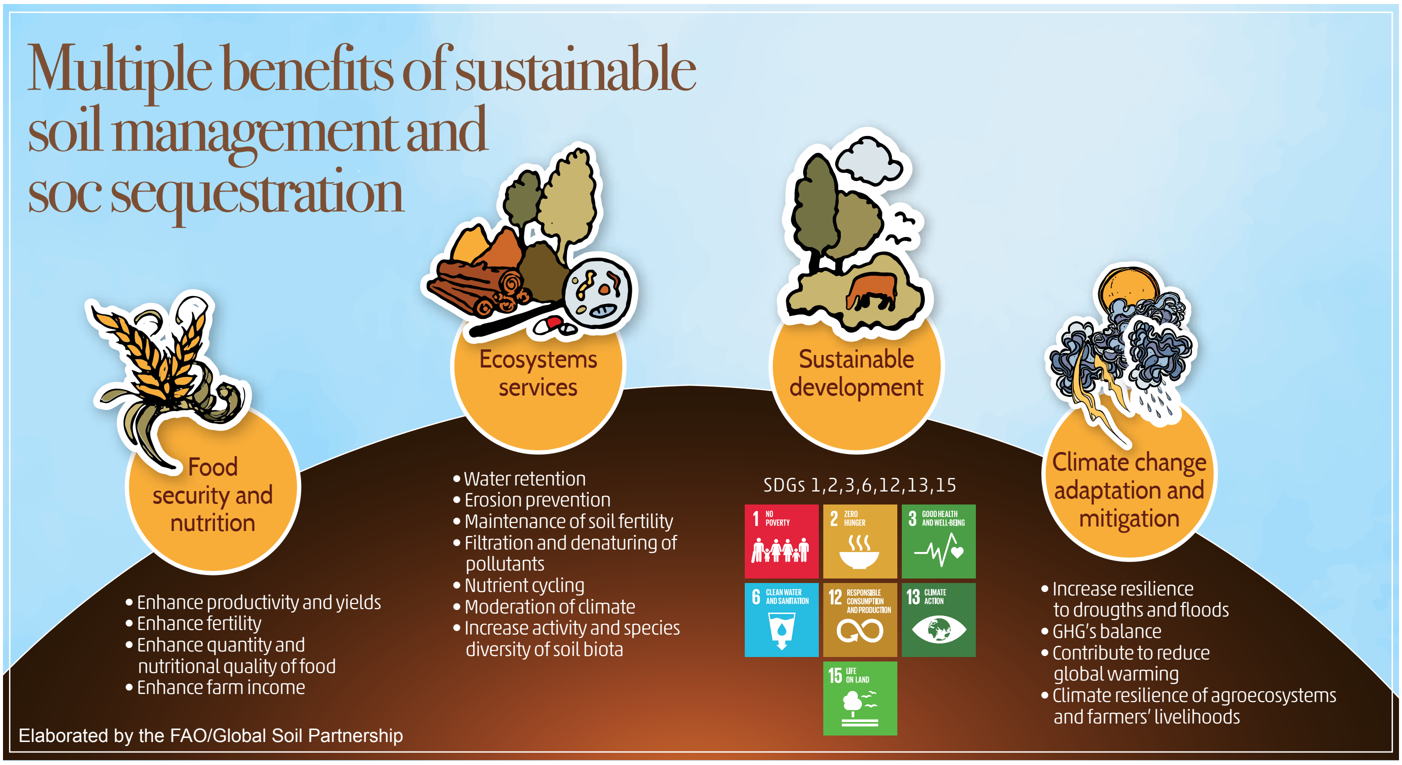
Therefore, by being more informed about the state of the soil and its organic content, we can plan for future use and ensure the most beneficial management practices for soil health and long-term food security. Monitoring soil properties and soil health is a prerequisite for nutrition-sensitive and sustainable agricultural management, so it is important that all the strategies aimed at improving the nutritional content of crops are based on a sound knowledge of the soil status and its nutrient storage capacity.

Resources: monitoring soil health

Methods and instructions for measuring and interpreting soil health indicators are given in the FAO's Protocol for the Assessment of Sustainable Soil Management and its User Manual (FAO and ITPS, forthcoming). In practical terms, the Protocol provides a set of tools to assess soil functions under agricultural use, thus providing a method for evaluating the status of the soil in a given moment and if a specific intervention is carried out in line with the VGSSM.

Methodologies for the analysis of soil properties have been standardized and harmonized by the Global Soil Laboratory Network (GLOSOLAN). Laboratory Standard Operating Procedures are available at its webpage.[1] Soil nutrient maps provide an instrument for identifying areas where nutrient levels are critical for crop growth and thus serve as an important decision-making tool. The Global Soil Nutrient and Nutrient Budget Map (GSNmap) initiative focuses on generating national maps of soil nutrients and other fertility-related soil parameters (organic carbon, pH, soil texture, bulk density and cation exchange capacity) in agricultural lands, at 250 m resolution. It is based on a country-driven approach and the country guidelines and technical specifications for its first phase have been recently released (FAO, 2022e).

A compilation of case studies on the implementation of recommended management practices to increase SOM content can be found in *Recarbonizing global soils – A technical manual of recommended management practices* (FAO and ITPS, 2021). Practices directly addressed to increase the SOC content are examined in different regions of the world and their benefits assessed in term of ecosystem services and socioeconomic impacts, such as organic matter addition, soil organic cover, crop diversification, minimum tillage, integrated nutrient management, mineral amendments and addition of living organisms. The manual also presents other approaches that indirectly contribute to increase SOC, such as soil and water conservation techniques, grazing management, agroforestry, conservation agriculture, agroecological farming and climate-smart agriculture.



[1] See FAO (2022d)

2. Promote crop diversification

Crop diversification is the production of diverse crops on the same land and has significant advantages over monoculture. It not only has a direct effect through supporting dietary diversification, but also can produce many agronomic benefits in terms of increased soil health, crop yield, human nutrition and resilience to climate change.

Diversifying production enhances land use efficiency, allows the farmers to take advantage of the biological cycles to minimize fertilizer inputs, contributes to preventing soil degradation, maximizes yields, increases nutrient content in crops and reduces the uncertainty and risk due to ecological and environmental factors.

Of particular importance is the capacity of legumes to fix nitrogen from the atmosphere. Their inclusion into rotation or intercropping schemes increases soil nitrogen content, thus enhancing soil fertility. The nitrogen fixed by legumes is then made available to be used by the neighbouring crops, reducing nitrogen fertilizer requirements and increasing yields and cost-efficiency.

Plant nutrient uptake is also improved in diversified crop systems, through the restoration of the soil nutrient balance and an increased nutrient availability derived from a higher SOM return. For instance, the results of the Soils4Nutrition project have shown that intercropping of maize with drought-resistant legumes in semi-arid lands increases nutrient content in the edible part of crops compared to monocropping. Furthermore, diversification strategies also prevent other forms of soil degradation, such as soil erosion and crusting, since soil remains covered over a larger part of the year.

While crop diversification may serve as an important opportunity to gain higher income for rural communities through the reduction of production costs, the magnitude of the benefits depends on the specific arrangements. This has to be considered when introducing new practices that replace pre-existent subsistence crop patterns. When planting different species together or consecutively, the plant density, architecture, required period for maturing, irrigation, sunlight and nutrient needs must be considered. Crop diversification systems need field operations to be carefully planned and may require special interventions to keep the competition between the different species included in balance.

Therefore, technological options and training have to be provided to farmers, to promote the adoption of the best suited cropping system and management options and to achieve an overall improvement of farm economics and crop nutritional status.

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Box 3. Crop diversification and rotation for boosting soil health

The use of crop diversification with pulses and other legumes is acknowledged in The international Code of Conduct for the sustainable use and management of fertilizers (FAO, 2019) as a way to improve soil health and fertility when used within integrated soil fertility management strategies. The direct positive effects on soil health and the nutrient balance of crop association and crop rotation are now globally recognized and attributed to the diversity of the shape and depth of roots of the different plants, the wider array of nutrients used and to the increased associated biodiversity.

- In Bangladesh, crop rotation has been adopted nationwide as an agricultural practice and specific rotations (cropping patterns) are recommended in each agroecological zone. The fertilization scheme corresponding to each zone is defined according to the Bangladesh Fertilizer Recommendation Guide (Ahmmed *et al.*, 2018).

Figure B3.1 Maize, soybean and amaranth intercropping in Kasungu (Malawi)

- Experiences in the Kasungu, Mzimba and Mulanje districts in Malawi (under the Soils4Nutrition project), showed that the increases in maize and soybean yield obtained through micronutrient application were maximized when combined with legume intercropping. In the three districts, intercropping systems were more productive compared with monocultures (Figure B3.1).

- The effect of intercropping compared to single crops was also evident in an increase in the amount of macro and micronutrients in maize, soybean and amaranths, particularly when applied together with integrated fertilizer management.

- Similar results were obtained in field trials in Burkina Faso, including cowpea and sorghum.

The results of the Soils4Nutrition project back up the suitability of crop diversification and incorporation of leguminous plants as an advantageous element for maintaining soil health while improving the quantity and nutritional quality of crops.

Nortes:
FAO. 2019. *The international Code of Conduct for the sustainable use and management of fertilizers.* Rome. https://doi.org/10.4060/CA5253EN
Ahmmed, S., Jahiruddin, M., Razia, S., Begum, R.A., Biswas, J.C., Rahman, Ali, M.M. *et al.* 2018. *Fertilizer Recommendation Guide-2018.* Dhaka, Bangladesh, Bangladesh Agricultural Research Council (BARC). http://www.bfa-fertilizer.org/wp-content/uploads/2019/09/Fertilizer-Recommendation-Guide-2018-English.pdf

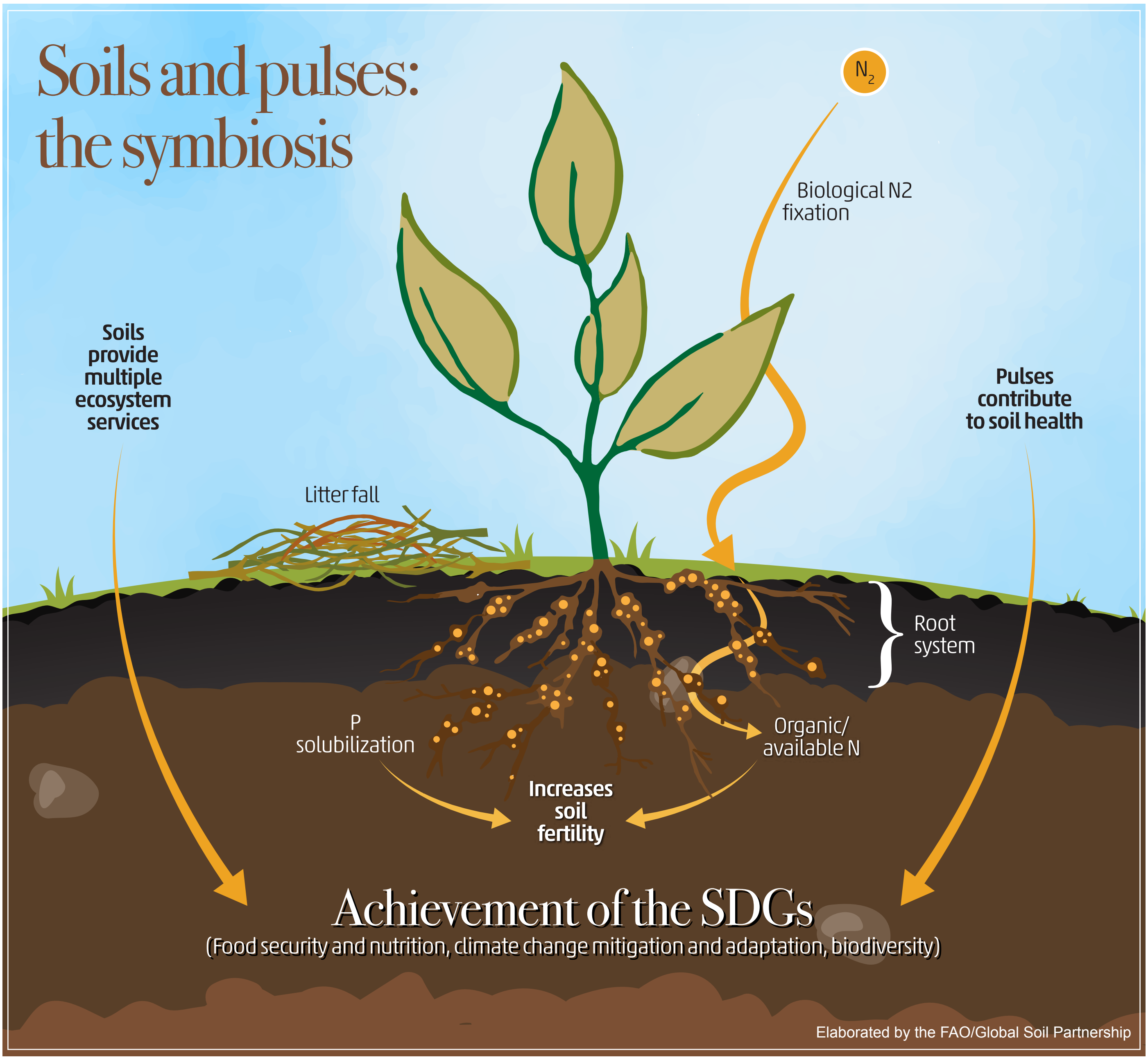
Resources: crop diversification

Crop diversification is acknowledged in the VGSSM as one of the approaches recommended for fostering soil nutrient balances and cycles, minimizing soil erosion, increasing the SOM content and preserving and enhancing soil biodiversity. In particular, diversifying the cropping system through the association of legumes with staple crops has the potential of improving soil health while, at the same time, reducing the amount of N fertilizer required for crop growth, enhancing plant nutrient uptake and contributing to diet diversification.

The inclusion of legumes (pulses) in the cropping system must consider several critical aspects. The time of peak nutrient demands of component crops must not overlap, so that there can be an optimal use of nutrients. The same applies to the competition for light among component crops. In both cases, the species included in the cropping system must be complementary. They must reach maturity at different times (with a gap of at least 30 days), while allowing for the differences in root distribution between the species. The selection of crops to be included must also consider pathogen metabolism and multiplication cycles, as well as crop pests and diseases.

The booklet *Soils and Pulses: Symbiosis for Life* (FAO, 2016) provides an overview for decision makers and practitioners describing the main scientific facts, information and technical recommendations regarding the symbiosis between soils and pulses, including their use within multiple cropping systems such as intercropping, or in simple crop rotations.

The World Pulses Day website (see FAO, 2022f) features a series of publications offering guidance, tools and data on pulses. It highlights the key role that pulses play in addressing the ongoing challenges of poverty, food security, nutrition, soil health and climate change. In addition, crop diversification is a promising strategy for improving dietary diversity and the nutritional status of farming households that consume their own produce. Countries define what constitutes a healthy diet in their specific context through their food-based dietary guidelines. Such guidelines can also inform the crop diversification strategies of smallholder farmers that eat their own food, to improve the household's diets and nutrition. A repository of nearly 100 national dietary guidelines as well as a database on the nutritional value of legumes can be found on the FAO website (see FAO, 2022g, 2022h).



3. Use fertilizers wisely

Key messages

Soil fertility is the ability of a soil to sustain plant growth by providing essential plant nutrients and favourable chemical, physical and biological characteristics as a habitat for plant growth (FAO, 2019)

Nitrogen, phosphorus (P) and potassium (K) are required in high quantities and correspond to macronutrients. Other elements like iron, zinc and boron are needed in smaller amounts, but they are still essential for plants, animals and humans.

Macro and micronutrients are naturally provided by soils through a series of chemical and biological processes or added as fertilizers and are available to plants through the soil solution.

The use of biofertilizers and biostimulants are recommended in any fertilization plan, to promote biological cycles and increase nutrient use efficiency.

The judicious use and management of fertilizers must consider the status of soil health, crop requirements and soil parameters for maximized nutrient use and to avoid pollution and greenhouse gas emissions

The replenishment of the nutrients extracted from soils by crops has conventionally relied almost exclusively on the addition of mineral and synthetic fertilizers (focused on nitrogen, phosphorus and potassium), with little organic and micronutrient inputs. In addition, usual practices have often been based on blanket fertilizer recommendations, regardless of soil and crop characteristics and normally using more nitrogen fertilizer than phosphorus and potassium. While this has allowed for an immediate increase in crop growth and yield, it has also led to soil micronutrient depletion, and the decline of productive capacity. Furthermore, higher yields mean that nutrients from the soil must be distributed across a greater volume of crops, diluting the nutrients in fruits and vegetables (Benbrock and Davis, 2020). This has led to the production of crops with high food energy but gradually lower nutritional value.

An excess of macronutrients such as nitrogen is common in many regions, causing widespread pollution of water bodies and eutrophication. In other regions, however, a negative budget of nutrients commonly occurs, meaning that nutrients are being extracted from soil faster than they are replaced. Regarding micronutrients, it has been estimated that 49 percent of the world's agricultural soils are deficient in zinc, 31 percent are deficient in boron, 15 percent are deficient in molybdenum, 14 percent are deficient in copper, 10 percent are deficient in manganese and 3 percent are deficient in iron (Sillanpää and FAO, 1990).

To achieve a sustainable agricultural production that ensures sufficient yields and nutritious crops without degrading soils, the application of fertilizers must be just enough to ensure the replenishment of the extracted macro and micronutrients. Integrated soil fertility management (ISFM) consists in combining the balanced application of organic matter, mineral fertilizers and biofertilizers through different and complementary methods of application (basal and foliar).

Following the guidelines for an adequate use of fertilizers set in the International Code of Conduct for the Sustainable Use and Management of Fertilizers (Fertilizer Code) (FAO, 2019), ISFM requires careful consideration of the crop nutrient needs and the soil type and condition. The natural nutrient dynamics of biological fixation and biomass decomposition must be also considered, to achieve an efficient and environmentally friendly use of fertilizers. Determining soil properties and crop nutrient requirements and their biological cycles is thus the key starting point for an optimal use of fertilizer application that incorporates the 4R nutrient stewardship: fertilizers must be used at the **right rate** and at the **right time**, applied in the **right place** and come from the **right source**. This is crucial for avoiding overuse, underuse and misuse of fertilizers.

Box 4. Integrated soil fertility management for improved nutrition

The 4R nutrient stewardship is based on applying fertilizers considering synergies with key parameters of the soil and the plant, to contribute to the conservation of soil health while increasing yields and reducing nutrient losses to the environment. From this holistic approach, decisions are made considering where, when, how much and which fertilizer will be used, and also the most convenient combination of inputs.

Experiences in sub-Saharan Africa and Southeast Asia depict the beneficial effects of the SOM additions in terms of soil health and nutrient cycling.

Figure B4.1 Soil organic matter application in Baliadanghi district (Bangladesh)

The experience in Oubritenga and Sissili provinces in Burkina Faso showed that organic matter-depleted soils have less capacity to preserve and maintain soil productivity and cannot retain the nutrients added through fertilization. Soil organic matter can be depicted as a bank holding plant nutrients and protecting them from loses by means of its colloidal properties, while still available for plant uptake. This was demonstrated in the field trials, in which the use of SOM together with basal fertilizer applications improved yields and produced a higher content of micronutrients in crops.

In the Chandina, Chuadanga and Baliadangi districts in Bangladesh, SOM is decreasing and hence soil health is deteriorated. The addition of organic manure (cow dung) to the soil allowed a 50 percent reduction of chemical fertilizers in both acidic and calcareous soil conditions (Treatments T5 and T6) (see Figure B4.1). The increment was maximum after the third crop (mungbean) cultivation (Figure B4.2).

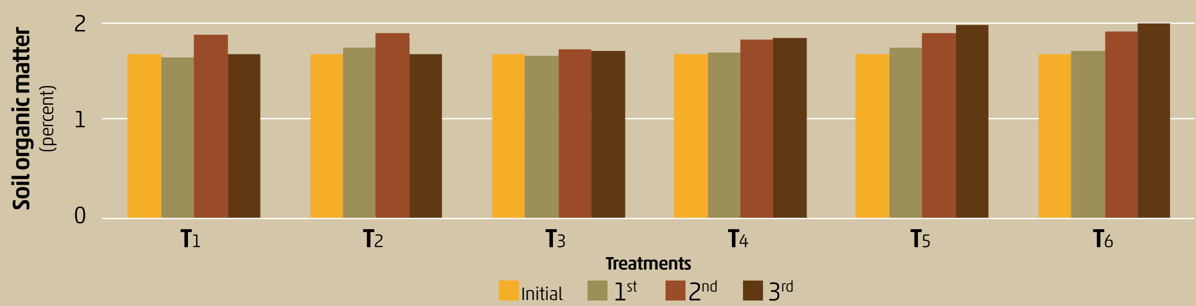


Figure B4.2 Soil organic matter changes

T1 (farmers' practice), T2 (recommended fertilizer dose of NPKS (RFD) with Zn as basal), T3 (RFD with Zn as foliar spray), T4 (RFD with Zn and B as foliar spray), T5 (50 percent RFD + 50 percent organic manure), T6 50 percent RFD + 50 percent organic manure + Zn and B as foliar spray).

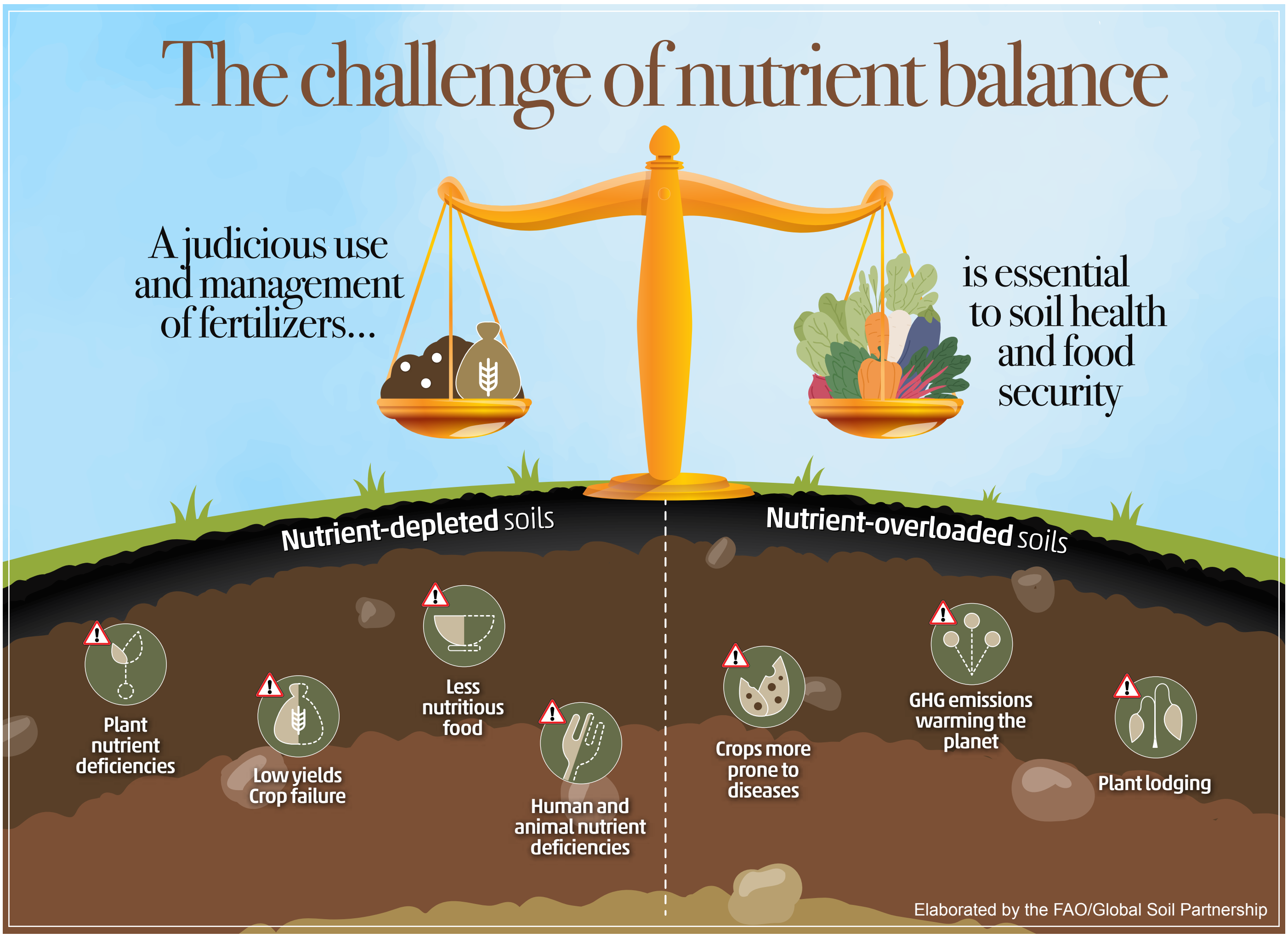
The ISFM approach incorporates the 4R nutrient stewardship by making the best complementary use of inherent soil nutrient stocks, locally available soil amendments (crop residues, compost, animal manure, green manure) and inorganic fertilizers, and applying them at the adequate phase of plant growth. This combination provides the necessary nutrients for plant growth, while soil nutrient storage and supply is enhanced by the increase in SOM content, so that improved crop yield and nutritional value are possible without impairing soil fertility.

The use of nutrients from reused and recycled locally available sources such as crop residues and composted organic wastes should be encouraged within ISFM strategies, in line with circular economy and lower carbon footprint approaches.

The joint use of biostimulants and biofertilizers with organic and mineral inputs can contribute to enhanced plant nutrition. They can also have a significant impact on pest and diseases by building up disease-suppressive soils. Biostimulants are substances of natural or synthetic origin that, when applied to soil or plants, have the effect of boosting nutrient uptake efficiency, abiotic stress tolerance or crop quality traits. They can have a variety of chemical formulations, often including humic substances, hormones and amino acids, as well as microbiological mixtures (typically fungi and plant growth-promoting rhizobacteria). These latter products are known as biofertilizers, which are products containing living microorganisms that promote plant development through an improved nutrient supply and can contribute to the increase in micronutrients concentrated in the edible parts of crops.

However, to guarantee the agronomic efficiency of all types of fertilizers, it is necessary to ensure their chemical and biological composition, as well as their quality. In this way, the associated risks to safety, environment and biosafety can be prevented, as laid out by the International Network on Fertilizer Analysis (INFA) (INFA, 2021).

It is essential that the composition of fertilizers and sources of recycled nutrients are assessed and that they are compliant with quality and safety standards, and that the amounts of nutrients they contain are known so that the needed amount of nutrients can be provided while avoiding potential toxicity and pollution issues. Regulations and policies regarding fertilizer use must include provisions in that regard, so good quality fertilizers as well as reusing and recycling technologies are available to farmers. Research must be focused on the development of better and cleaner fertilizers.



Resources: judicious use of fertilizers

The practices presented in Recommendation 1 of these technical guidelines are intended to improve and protect SOC as a central component of soil health. In turn, the ISFM recommendations on sustainable fertilizer management are compatible and complementary because they also consider SOC as a key factor in soil health.

The international Code of Conduct for the sustainable use and management of fertilizers (the Fertilizer Code) (FAO, 2019) is a reference document to support the implementation of the VGSSM and provides a locally adaptable framework and a voluntary set of practices to serve the different stakeholders directly or indirectly involved with fertilizers. By following the Fertilizer Code, stakeholders will contribute to sustainable agriculture and food security from a nutrient management perspective, by adhering and supporting the implementation of the recommendations provided. The Fertilizer Code advocates for a soil-based and circular approach to fertilization and recommends the use of nutrients from reused and recycled sources such as crop residues, wastes and other sources, especially those that are locally available. It provides definitions, basic concepts of soil fertility and recommendations to the different stakeholders to implement the 4R nutrient stewardship and ISFM strategies. It also highlights the need of controlling the quality of fertilizers, to ensure that the right amount of nutrients is added and to avoid potential pollution issues.

In that regard, FAO is promoting a global effort including institutions and experts from around the world for developing and strengthening the capacity of laboratories in fertilizer analysis and harmonizing fertilizer standards globally, through INFA, established in 2020. The objective is to facilitate the assessment of fertilizer quality, with the goal of enabling their fine-tuned application under soil and site-specific conditions and guarantee environmental and human health and safety. Important aspects of INFA's activity are the harmonization of protocols and methodologies for the evaluation of the quality of fertilizers, capacity development and advice for fertilizer-related policy development and regulation.

To achieve the wise use of fertilizers, most countries in the world have accurate information on the requirements of the main crops. However, as stated in the conclusions of the global symposium on Soils for Nutrition (FAO, 2023), the optimization of all factors involved in nutrient use efficiency should be enhanced, through the use of innovative fertilizers, nutrient reuse and recycling and monitoring of soil nutrients data, among others.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4. Make use of biofortification strategies for more nutritious food

Key messages

Agronomic biofortification with micronutrients increases yield and nutrient content in the edible part of crops

The use of multi-micronutrient fertilizer has a higher effect on the nutritional value of crops compared to single-element dressings

Foliar application of micronutrients provides an increase of crop yield and nutrient content in the same harvest season

Basal application of micronutrients enhances soil nutrient balance so improves nutrition in the long term

Biofortified varieties must be employed together with measures for maintaining soil health and within a diversified food system (diversified crops and diets)

The objective of biofortification is to ensure that the food consumed is nutrient-rich, rather than to increase the amount of food available for consumption. Two non-exclusive approaches can be adopted: agronomic and genetic biofortification.

Agronomic biofortification is the deliberate use of micronutrients from mineral fertilizers to increase the concentration of a target nutrient in the edible parts of crops, with the goal of increasing the dietary intake. This can be achieved through different methods of application including basally (to the soil) or foliarly (to the leaves) and can be complemented with biostimulants and biofertilizers, to increase the capacity of plants for accessing and taking up nutrients from the soil.

The findings on agronomic biofortification reported in the literature back up the results of the Soils4Nutrition project, that biofortification increases both yields and nutrient contents in crops. Foliar application of micronutrients is recommended for a rapid effect on the nutritional value of crops, with its application providing an increased crop nutrient content within the same agronomic season. In fact, the correction of visible plant nutrient deficiency symptoms occurs within the first several days after foliar sprays are applied.

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Box 5. Agronomic biofortification on a locally adaptable framework

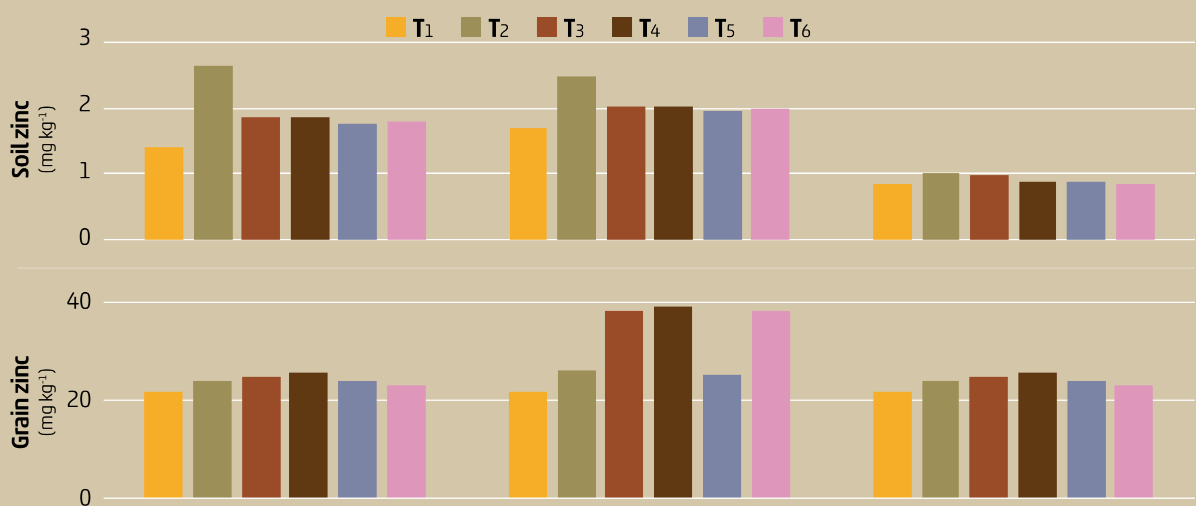
Although the 4R nutrient stewardship for adequate fertilizer use has been widely used within macronutrient fertilization, its use is uncommon in the case of micronutrients. The Soils4Nutrition project has tested the 4R approach for biofortifying crops in demonstration areas of Malawi, Bangladesh and Burkina Faso.

Field trials in Malawi tested the take-up of micronutrients through application at different stages of development as well as effects on yield (Figure B5.1).

Figure B5.1 Different application stages in maize crops in Malawi

Figure B5.2 Soil zinc and grain zinc content of after third crop harvest for different treatments in Bangladesh

Key: T1 (farmers' practice), T2 (recommended fertilizer dose of NPKS (RFD) with Zn as basal,) T3 (RFD with Zn as foliar spray), T4 (RFD with Zn and B as foliar spray), T5 (50 percent RFD + 50 percent organic manure), T6 (50 percent RFD + 50 percent organic manure + Zn and B as foliar spray).



A 30 to 50 percent increase in maize and soybean yield was obtained through micronutrient application, with highest values obtained when micronutrients were applied in combination with soil organic amendments.

The zinc levels in the edible parts of the plants increased by 15 to 30 percent upon the foliar application of micronutrients. The effects of multi-micronutrient dressings were higher than single element fertilizers.

Best effects were obtained when micronutrients were applied just before flowering (the application before the third-leaf stage being too early and the application during fruiting being too late). Multiple applications of micronutrients provided no added benefits.

In Bangladesh trials, foliar fertilization showed an immediate effect in increasing micronutrients in the edible parts of plants (Figure B5.2). Basal fertilization had a longer-term effect, as it acts through an improvement of soil nutrient budget, which remains available for future production. In that regard, the effect of basal applications showed also to be dependent on soil pH and trials demonstrated that regulating pH and achieving adequate levels of SOM allow for a higher and more stable increase in nutrients.

Using the 4R nutrient stewardship for agronomic biofortification in the Oubritenga and Sissili provinces in Burkina Faso led to a 20 percent increase in profit for farmers. The analysis of cost-effectiveness of micronutrient application showed that one to two applications were enough to obtain benefits and that more than two were not cost-effective. This finding not only significantly contributes to improving the cost-effectiveness of the fertilization process, but also environmental quality conservation through the reduction of fertilizer-associated GHG emissions, as well as further reducing water, air and soil pollution.

The effect of multi-micronutrient foliar fertilizers has proved to be more positive than of single element dressings and optimal effects have been observed when the micronutrients are applied at the mid-maturity stage of the crop. If applied too early, leaf surface may be insufficient for foliar absorption. If, in contrast, foliar sprays are applied too late, yields can be impaired because nutrient demand is often higher in the initial phases of plant growth. Since plants differ in the amount and timing of the micronutrients they need, this means that the growth cycle of the target crops must be specifically considered for a cost-efficient micronutrient foliar application.

On the other hand, basal micronutrient applications act through an enhancement of soil fertility, thus contributing to longer term fertility improvements, compared to foliar application, when used in conjunction with other soil health-enhancing practices. The use of combined basal and foliar strategies is thus recommended.

In addition to agronomic biofortification, the use of biofortified varieties of staple crops can be beneficial. These are varieties selected based on the higher nutrient content in their tissues, using conventional plant breeding or even transgenic techniques, with the explicit intent of enhancing the nutrient ingestion of the population. When used in association or in rotation with leguminous species and within ISFM strategies on healthy soils, biofortified varieties can be very effective in providing increased amounts of nutrients to nutrient-poor diets.

Disadvantages of biofortified crop varieties relate to socioeconomic aspects such as low adoption due to safety concerns and not always being accessible to farmers. There are some technical disadvantages, including that the micronutrient range of variation of many crops may not be sufficient for breeders to increase their levels and that some micronutrients (such as minerals), are not produced in the plant and therefore need to be present and available in sufficient quantities in the soil. Thus, it must be ensured that biofortified varieties are used in conjunction with strategies for preserving soil health, so that soils are not further depleted in nutrients and within comprehensive plans that also include the promotion of diversified agrifood systems (FAO, 2021b). When consumed to complement healthy diets,

Box 6. Use of biofortified varieties in nutrient available soils

In spite of previous efforts to improve human nutrition, micronutrient deficiencies still affect a large proportion of the population in the countries where the project was implemented, especially among young children and pregnant women. The Soils4Nutrition project highlighted barriers to the implementation of best fertilization management recommendations, which are:

Figure B6.1 Field trials with biofortified varieties of rice (Binadhan-20), in Baliadanghi district, Bangladesh

- Micronutrient fertilizers are not accessible to farmers in sufficient quantities.
- Soils are degraded which means that even if nutrients are present in the soil, plants are only able to take up small amounts.
- Lack of ownership of SSM practices by farmers, which means that the guidelines and support provided by the government are not applied on the ground.

Biofortified crop varieties can provide some advantages when facing these barriers, since they are plants with the genetic capacity to extract more nutrients from the soil and with a higher nutrient content in their edible parts compared to non-biofortified varieties, regardless of whether or not fertilizers are added. However, the use of biofortified varieties in nutrient-depleted soils can lead to low cost-efficiency of the investment and, importantly, to further soil degradation (Figure B6.1). Therefore, biofortified crops shall not be used in isolation, but must always be accompanied by measures to maintain adequate soil health and nutrient balances.

nutrient-enriched crops can contribute to addressing hidden hunger. However, implementing biofortification strategies without considering key factors such as soil health, micronutrient needs, and the underlying causes of any deficiencies involves a high risk of losing cost-effectiveness.

Resources: crop biofortification

A review of the state of the art of the role of soils in delivering sufficient, high quality, safe and more nutritious food for better nourished plants, animals and people is provided in FAO's *Soils for nutrition: state of the art* booklet (FAO, 2022a). It provides the concepts and literature resources for understanding the processes related to soil fertility, particularly micronutrients, from the perspectives of food production and food security. It also outlines the main areas of opportunity and the way forward to solve the micronutrient deficiencies prevailing in today's agrifood systems, including agronomic biofortification approaches.

The potential for breeding crops to obtain staple crop varieties with increased micronutrient contents in their edible parts started to be looked at in the late 1990s by CGIAR (Consultative Group for International Agricultural Research). Most of CGIAR's work on this subject has taken place under the HarvestPlus programme, which began with a "proof of concept" phase in 2003 and is today a part of the CGIAR Research Programme on Agriculture for Nutrition and Health (A4NH).

The HarvestPlus programme and FAO released a joint brief on biofortification, presenting the latest research evidence and implementation lessons learned on how agriculture-based nutrition solutions can best contribute to improved agrifood systems and public health for all:

> *The objective of the brief: Biofortification: a food-systems solution to help end hidden hunger, is to "encourage the adoption and scaling up of biofortification through national policies and programs, with collaborative support from FAO and HarvestPlus* (HarvestPlus and FAO, 2019).

It summarizes essential information on biofortified varieties, including data on their availability worldwide, their agronomic properties, the rates of adoption and consumer acceptance of each variety and on the health-related benefits and their cost-effectiveness. In addition, pilot sites and study cases can be found in the HarvestPlus website (HarvestPlus, 2022).

The *Nutrition-sensitive agriculture and food systems in practice. Options for intervention* manual (FAO, 2017b) includes genetic biofortification as one of the recommended food-production based interventions for NSA. The manual recommends its implementation together with production diversification and biodiversity conservation policies that prevent biodiversity loss due to selective breeding of a few varieties.

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Sustainable soil management for nutrition-sensitive agriculture

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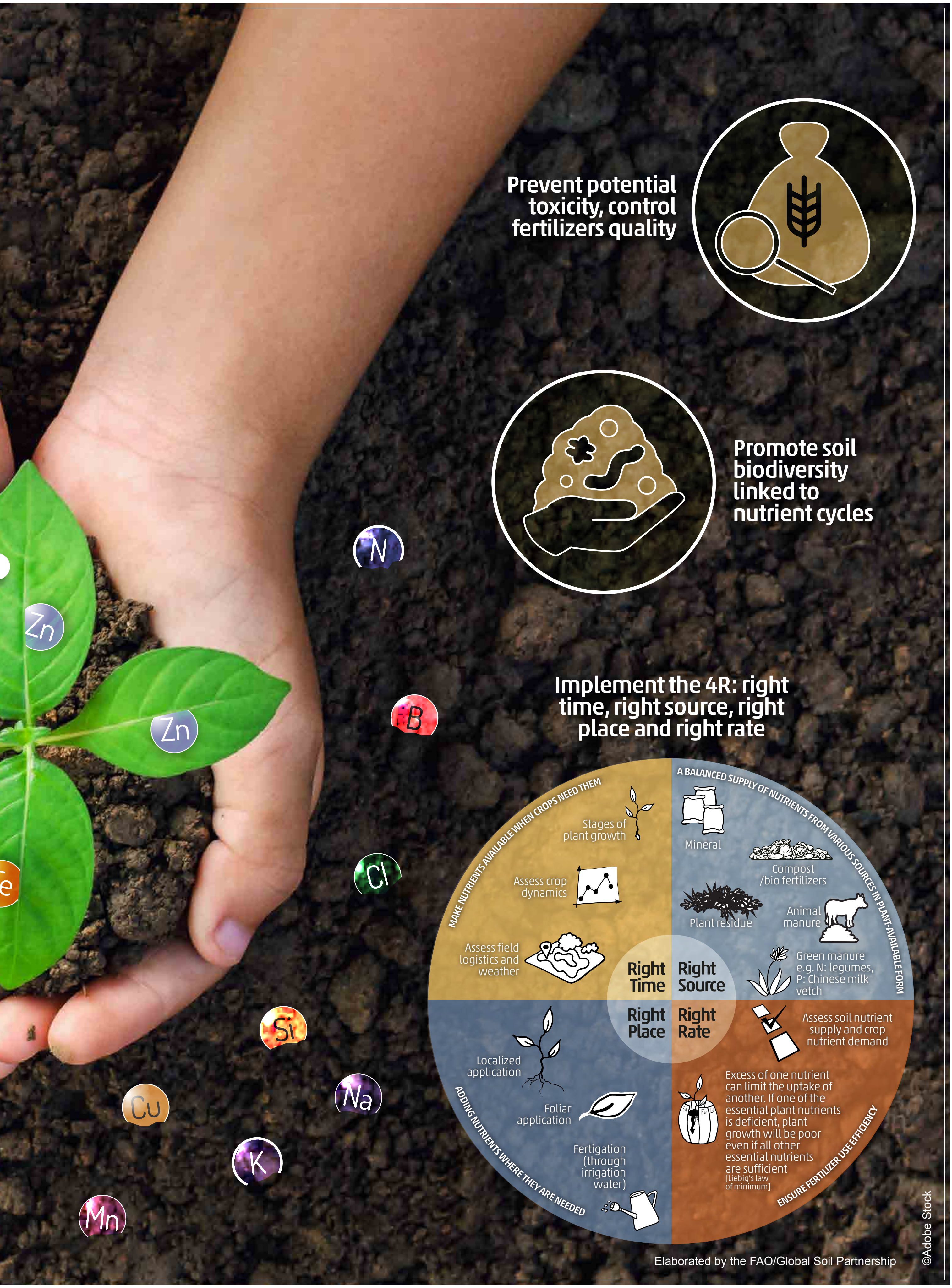
Prevent potential toxicity, control fertilizers quality
Promote soil biodiversity linked to nutrient cycles
N
Zn
Zn
B
Cl
Si
Cu
Na
K
Mn
Implement the 4R: right time, right source, right place and right rate
MAKE NUTRIENTS AVAILABLE WHEN CROPS NEED THEM
Stages of plant growth
Assess crop dynamics
Assess field logistics and weather
A BALANCED SUPPLY OF NUTRIENTS FROM VARIOUS SOURCES IN PLANT-AVAILABLE FORM
Mineral
Compost /bio fertilizers
Plant residue
Animal manure
Green manure e.g. N: legumes, P: Chinese milk vetch
Right Time
Right Source
Right Place
Right Rate
ADDING NUTRIENTS WHERE THEY ARE NEEDED
Localized application
Foliar application
Fertigation (through irrigation water)
ENSURE FERTILIZER USE EFFICIENCY
Assess soil nutrient supply and crop nutrient demand
Excess of one nutrient can limit the uptake of another. If one of the essential plant nutrients is deficient, plant growth will be poor even if all other essential nutrients are sufficient [Liebig's law of minimum]
Elaborated by the FAO/Global Soil Partnership
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5. Choose SSM practices according to a cost-benefit analysis and national context

Key messages

Sustainable soil management leads to increased nutrient content in crops through improved soil health

Suggested management strategies include additions of manure that improve soil organic carbon and biological activity, as well as prevention and control of soil degradation by erosion or soil biodiversity loss

Sustainable soil management can be a triple win for agricultural production, contributing to better soil health, greater yields and increased nutrient content of foods. A further added value is a better environment

The costs and benefits of specific practices must be assessed for achieving an SSM implementation that is best suited to local conditions

Production of food for a rapidly growing population has partially been fulfilled by agricultural intensification, enabled by the increased application of synthetic fertilizers and pesticides and the selection of higher-yielding crop varieties often grown as a monoculture. In many areas, this has led to soil degradation, including the loss of soil structure, erosion, nutrient depletion and reduced soil biodiversity. This decline in soil health has in turn led to a lower soil production capacity.

The application of SSM, including strategies related to conservation agriculture, integrated and diverse cropping and farming systems and integrated fertility management, in combination with a nutrition-sensitive approach, has the potential of covering the threefold objective of meeting the nutrient requirements of crops and population while avoiding soil degradation. SSM practices such as minimum tillage, permanent organic soil coverage, legume intercropping and crop diversification have been demonstrated to increase SOM and nutrient storage capacity, while the complementary application of organic manures and mineral fertilizers increases the amount of soil nutrients.

However, the application of any of these techniques in a cropping system requires that the site-specific needs are evaluated along with the environmental and economic impacts that their implementation may have. Interventions need to be tailored to the soil type, farming system, agroecological zone and diet typology, as well as to the market conditions and sociocultural aspects.

For example, access to fertilizers is an issue when planning soil management for NSA. It is essential to consider the cost of inorganic and organic inputs as well as how to obtain sufficient quantities of both. The amount of labour needed to collect, transport and manage organic materials and aspects related to input quality and nutrient balance must be taken into account and technological options must be optimized for the site-specific context. It is also very important to include the fertilizer industry and distribution companies in discussions and planning processes, as this largely determines farmers' access to fertilizers.

When choosing the cropping system and practices to be implemented, it is essential to involve all stakeholders in consultations and participative planning. Practices that may be considered adequate from an environmental or agronomic perspective could be inadequate due to the unavailability of fertilizers. Adoption could also be limited due to social and cultural factors, as found by Chiutsi-Phiri *et al.* (2021) in Malawi, for example, or may just be considered not advantageous because of tenure issues.

The economic impact of adopting new practices on income must be closely evaluated, since this is determinant in terms of increasing adoption and fostering long-term engagement with SSM.

Although the integration of the principles of SSM into NSA minimizes the risks of pollution and land degradation, the possibility of offsite ecological and biodiversity impacts have to also be considered.

Box 7. Stakeholder consultation in Burkina Faso

In Burkina Faso, malnutrition continues to increase, despite the government's efforts to diversify diets and fortify foods. In fact, 92 percent of children between six and 59 months have nutritional anaemia, 13 percent of which is severe. This situation is also of concern among pregnant women and nursing mothers, with prevalence rates of 68.3 percent and 52.5 percent respectively (INSD and ORC Macro, 2004). Data on other micronutrients such as zinc or copper are scarce, but estimates suggest that those deficiencies are also very high. These deficiencies relate, to a large extent, to the rate of soil degradation in Burkina Faso, which reaches 65 percent of the national territory, according to Bureau National des Sols du Burkina Faso (BUNASOLS), the national soil survey office.

During a national workshop held in Burkina Faso in April 2022 in the framework of the Soils4Nutrition project, the suitability of the best known and commonly used SSM practices was evaluated regarding the country social and economic context (Figure B7.1). The workshop gathered forty-one national experts from national and local institutions, NGOs and the private sector. The active participation and fruitful discussions allowed actions to be identified that could be prioritized in the country to improve the micronutrient content of locally produced food:

Figure B7.1 Traore Mamoudou, Director General of BUNASOLS in the national workshop in Burkina Faso

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The rational use of organic and mineral fertilizers in combination with micronutrients must be developed in the country. The main barrier identified for its application is the lack of availability of specific fertilizers. The solution envisaged is to share the results obtained by the project with the agrodealers and request products with the adequate characteristics.

The elaboration of on-farm compost from organic residues needs to be promoted. This seems to be the most suitable solution to increase the SOM in small farms, who can easily access wastes from fallow lands or harvested residues. Appropriate technical support is needed for achieving wide adoption.

Agroecology, which already is widely adopted in the country, must be further developed and promoted. Agroecology implements the combination of agrobiodiversity and the use of natural products, which is very favourable to soil health and to an integral management of fertility.

Practices of soil conservation and erosion control must continue to be promoted and disclosed.

Among the management options considered in the workshop, some practices widely known to be beneficial for soils, such as green manures and cover crops, were discarded as priorities because of socioeconomic and cultural aspects that prevent farmers from appropriating them.

It became clear that soil health is not understood as a priority by itself and allocating resources to its improvement, instead of to obtaining products to be sold or consumed, is not considered to be advantageous. **The key role of soil for improving the nutritional value of food needs to be further communicated**.

In conclusion, efforts in SSM for NSA in Burkina Faso must be multiplied. These efforts should be directed primarily to the most promising sectors and practices in order to achieve an effective scaling up of results.

Note:
INSD (National Institute of Statistics and Demography & ORC Macro. 2004. BURKINA FASO. *Enquête Démographique et de Santé 2003.* Calverton, USA, ORC Macro & Ouagadougou, Burkina Faso, INSD.

Resources: cost–benefit analysis

To choose the SSM practices that are cost-effective, in addition to improving soil health and minimizing wider environmental risks, an analysis of the economic costs and benefits of their adoption must be carried out. Within the Soils4Nutrition project, the selection of SSM practices applied the criteria for a sound cost–benefit analysis provided in FAO's briefing note on *Cost–benefit analysis for climate change adaptation policies and investments in the agriculture sectors* (FAO, 2018). For instance, the following items were considered for each of the practices under consideration in Burkina Faso's field trial, in Table 1. Also see FAO (2022e) and UNFCCC (2011).

Table 1. Items considered for the cost–benefit analysis

Costs	Direct benefits (short term)	Indirect benefits (medium/long term)
Yearly assessment of soil needs (soil health status, nutrients, degradation). Training on soil knowledge and new practices and technologies and follow-up. Yearly purchase of inputs (such as better-adapted organic and mineral fertilizer, and seeds of associated crops). One-off purchases of materials and equipment (such as accessories for direct seeding, erosion barriers, and water management structures).	Yield increase within the same harvest season. Improvement of nutrient content of food and diets. Reduction of the risk of food contamination. Reduction of the quantity of mineral fertilizers required.	Improvement of soil health and reversing land degradation. Increase in the magnitude and length of the residual effect of fertilizers due to soil recarbonization. Decrease of GHG emissions. Decrease of soil and water contamination.

Source: FAO. 2018. *Cost-benefit analysis for climate change adaptation policies and investments in the agriculture sectors*. Rome, FAO. https://www.fao.org/3/I8905EN/i8905en.pdf

To quantify the environmental benefits of SSM implementation, several tools are available to assess the derived ecosystem services and their economic value (FAO, 2022i). Such tools can provide simulations of the impacts of land use, soil characteristics and management practices on soils and water bodies, allowing the calculation of the resultant ecosystem services. These can then be valued through different methods, including models and participatory strategies for appraising their value under current socioeconomic conditions and under foreseen scenarios of change.

In that regard, the potential of soils to sequester carbon from the atmosphere must be considered as an asset in the valuation scenarios, since there are various funds and mechanisms promoting the reduction of GHG emissions from agriculture. One of these mechanisms is the RECSOIL programme, which incentivizes farmers who agree to implement good practices that lead to the recarbonization of soils. The RECSOIL programme is focused on agricultural and degraded soils and its priorities are: a) to prevent future SOC losses and increase SOC stocks; b) to improve farmers' incomes; and c) to contribute to food security.

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6. Build grassroots capacities

Key messages

Community-based approaches to agricultural extension can reach larger populations, conductive to gender parity and youth engagement.

It is necessary to disseminate nutrition-sensitive SSM strategies, through both formal and community-based extension services that include all related stakeholders.

Farmers and non-farmer rural populations lack knowledge on the links between soil and nutrition.

Farmer-to-farmer extension can be a good complement to formal extension services for developing capacities on soils, SSM and combating micronutrients deficiencies.

Adoption of SSM can be scaled up, and disadoption reduced, if the benefits of the Soil4Nutrition approach are communicated appropriately.

Farmers are then empowered to safeguard healthy soils for good quality nutrition.

One of the consistently observed barriers to widespread adoption of the NSA approach is the lack or paucity of grassroots knowledge on the links between soil health and nutrition. Although farmers are often aware of the importance of soils for abundant harvests and use fertilizers for improving yields, the effects of soil management on the nutritional value of foods, food safety and water resource conservation are not that obvious and soil health generally is not understood as a desirable outcome of agricultural management.

Facilitating training and capacity development of rural populations in these subjects are of paramount importance. Governments must strengthen the knowledge and capabilities of their extension services to that end, and also ensure that all stakeholders (such as the private sector, farmers' associations and trade unions), are integrated in a coherent manner.

Community-based extension approaches have become increasingly implemented in the last decades, especially in rural areas, where the formal agricultural extension services can have limited access due to geographic or cultural factors. One such community-based approach is farmer-to-farmer extension, which is defined as the provision of training by farmers to other farmers, often through the creation of a structure of farmer-trainers.

Farmer-to-farmer extension has thus a complementary role to formal extension services. It facilitates the dissemination of agricultural technologies, enhances farmers' capacities and allows to reach a larger number of farmers with an inclusive approach of gender equity and youth involvement. Farmer-to-farmer extension lowers the cost per farmer trained and enhances the sustainability of the capacity development systems, because increases independence from project or country allocation of funds, as well as encourages the adoption of SSM practices and reduces disadoption.

There are also important gender benefits, especially when extension programmes make special efforts to recruit female farmer-trainers. When dealing with nutrition issues, women should be specifically targeted because, in addition to being a vulnerable group, they commonly have a key role in childcare and household nutritional decisions.

Investing in developing grassroots capacities in SSM for NSA also has the added benefit of creating awareness of soil degradation processes, which can provide long-term environmental and agronomic benefits. Farmers and fertilizer dealers can be simultaneously involved in training on the importance of soils and this learning process can bring additional experiences and profit in terms of agricultural sustainability.

Box 8. Empowering farmers to safeguard healthy soils for good quality nutrition

The Soils4Nutrition project has successfully implemented farmer-to-farmer training initiatives in Bangladesh, Burkina Faso and Malawi through the Global Soil Doctors Programme (GSDP) (Figure B8.1 and Figure B8.2). The overall objective of the programme is to strengthen the capacity of farmers on SSM principles by providing them with targeted training on how to preserve and restore good soil condition and functions. For that, the project developed a specific training module that allowed real contributions to the adoption and scaling up of SSM practices.

The topics included in the Soils4Nutrition training module are:

- general concepts on soil and its importance for food security and food quality;
- the importance of protecting SOM and soil health;
- the importance of soil pH for nutrient uptake by plants; and
- the general components of soil nutrient management and fertilizer quality.

In all three countries, national extension services and soil institutes were registered as promoters of the GSDP. Promoters are an essential component of the programme. They share knowledge, experiences, good practices, policies, technologies, and resources with the local communities. The promoters have a direct link with the GSDP and the certified trainers from each promoter can continue the collaboration for improving soil knowledge after the project ends.

Under the Soils4Nutrition project, 33 trainers were certified, 30 Soil Doctors were selected and more than 1 000 farmers were trained.

Figure B8.1 First lesson of the Global Soil Doctors Programme in Bangladesh

Figure B8.2 Field practice within the Global Soil Doctors Programme in Malawi

A specific request arose in all three countries for fertilizer dealers to be equally involved in the training process on the importance of soil protection, as they have an important presence in the field.

Resources: capacity development

Grassroots capacity development is critical because farmers are the most important actors to promote real changes in the field: Farmers are the ones making the ultimate management decisions.

The **Global Soil Doctors Programme** is a farmer-to-farmer capacity development initiative that has been designed by the Global Soil Partnership with the aim of reaching the grassroots management level. Within this programme, a local promoter provides training to a group of farmers to be Soil Doctors, who then go on to train other farmers in their communities.

A specific training module on SSM and nutrition has been developed under the Soils4Nutrition project, to provide the tools for mainstreaming and upscaling these views. Through an improved knowledge on chemical, biological and physical soil properties, farmers gain capacities on how to assess soil nutrient availability. The training module includes both theoretical and field exercises that can empower farmers to creating a long-term and sustainable capacity developing system.[2]

[2] For more details, see FAO (2022j).

7. Mainstream sustainable soil management for nutrition-sensitive agriculture

Key messages

Soil data and information must be included in land use and management planning actions.

Recommendations on SSM for NSA must be included in national policies to create the necessary legal, financial, institutional and educational tools for their implementation.

Wider adoption of SSM and reduced disadoption depend on social and cultural factors that must be considered within policies.

A better articulation between the actors involved in the use and management of fertilizers and those involved in SSM will allow the coordinated and efficient implementation of actions, thus improving the governance of SSM for NSA.

Originally intended as a measure of the availability of food and individuals' ability to access it, the term "food security" has been expanded to include nutrition, because both *quantity* and *quality* are important. As defined by the UN's Committee on World Food Security (CFS), for a nation, community, or individual to possess food security, at all times, they must:

> *...have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life* (CFS, 2014, p. 6).

Soil health is recognized as a crucial aspect in achieving this goal.

This approach has been acknowledged in global policy instruments, such as the CFS Voluntary Guidelines on Food Systems and Nutrition (CFS, 2021) that state, in its recommendation 3.2.2 on promoting sustainable use and management of natural resources in food production, that:

> *Governments, farmers and their organizations, private sector and other relevant stakeholders should address soil health as central to agricultural production systems, with due attention to FAO's VGSSM. Governments*

should encourage the use of integrated fertility and nutrients management practices as well as ecosystem services productivity for sustainable production and promote the use of sustainable land management services and agricultural practices to maintain soil biodiversity and nutrient balance, reduce soil erosion, improve water management and promote carbon storage and sequestration (CFS, 2021, p. 18).

The pursuit of soil health must also include an adequate use of fertilizers. This was established in the Fertilizer Code, as a recommendation by the FAO's Committee on Agriculture (COAG) to increase food safety and the safe use of fertilizers, and at the third session of the United Nations Environment Assembly (UNEA, 2017).

In following this international developmental and environmental agenda, countries are encouraged to move beyond focusing on direct measures to maximize crop yields, such as just increasing fertilizer input or localized agronomic actions. Instead, holistic and synergistic approaches involving the different national public and private institutions, as well as other stakeholders such as farmer's associations and agrodealers, must be adopted. Such an integrative environment can catalyse cooperation within the country and in the region for undertaking larger scope actions leading to better soils and better nutrition.

The Soils4Nutrition project has allowed the identification of four recommendations that must guide any actions addressed to the upscaling and mainstreaming of SSM for NSA to action:

1. Emphasis should be placed on increasing SOC, given its many benefits in facilitating the assimilation of soil nutrients. All existing technical, financial and policy mechanisms should be mobilized to recognize the value of soil recarbonization.
2. SSM must be articulated with ISFM for the production of more nutritious food according to dietary needs identified in the community and should be promoted with a positive economic, social and environmental balance.
3. It is essential to strengthen the capacities of farmers and train them on the important role of soil health in the production of healthy and nutritious food and in the application of SSM.
4. Sustainable and judicious fertilizer use and management must involve all stakeholders, especially the fertilizer industry and distribution, to facilitate the use of micronutrients in fertilizer plans.

The following paragraphs compile a set of policy recommendations for the materialization of these principles:

On an enabling institutional environment:

- Reinforce the national institutional environment, to enhance collaboration and communication between national institutions, private initiatives, academia and NGOs. It is recommended the establishment of a **National Soil Partnership (NSP)** that unites all interested and active partners in the country that are committed to SSM in the framework of the Global Soil Partnership. The functions of NSPs include advisory, advocacy, communication, facilitation and implementation tasks, as well as mobilization of financial resources and monitoring the effectiveness of the activities implemented. In the specific topic of fertilizers use and management, the role of the fertilizer industry and distribution companies needs to be accounted and included in the orientations on SSM for NSA.[3]

On soil data and information as a basis for SSM for NSA:

- Include soil monitoring and national soil information systems among national priorities to enable the assessment of soil health status and trends at adequate scales. The collection of standardized soil information must start with reliable soil analyses, for which facilities must be put in place. The adoption of standardized procedures for soil analysis and monitoring such as the ones proposed by the FAO's Global Soil Laboratory Network and the Protocol for the Assessment of Sustainable Soil Management (FAO and ITPS, forthcoming) is highly recommended to that end. Soil information must be made available to all stakeholders through national soil information systems, which must be cross-referenced with databases on nutrition aspects and on causes of malnutrition and accompanied with crop information for an improved decision-making in agricultural management.

On enabling legal and normative environment:

- Adopt the VGSSM in the environmental and agricultural policies and develop a legal and normative framework that encourages its effective implementation.
- Sustainable use and management of fertilizers must be adopted, as per the recommendations included in the Fertilizer Code, which countries are urged to adopt and integrate in their agricultural policies. Micronutrient deficiencies

[3] See FAO (2022k) for information on the structure, governance and functions of NSP, as well as instructions on how to establish a NSP.

in population and in soils must be considered and included in country scale interventions.

- Capacity development and extension programmes must be reinforced for the mainstreaming of the links between soils, nutrients in crops, human nutrition and health. Training on SSM needs to be facilitated to rural communities, through national policies on agriculture, nutrition and rural education. Research focused on the development of better and cleaner fertilizers, as well as on innovation and alternative sources of fertilizers, must be encouraged, from both from public institutions and industry.
- National institutions must ensure that all the interventions addressed to improve the nutritional status of the population observe the "do no harm" principle from the economic, social and cultural perspectives, in addition to environmental, paying particular attention to gender aspects and children.

Resources: institutional environment, policy and legislation

Regarding legal and regulatory aspects, the GSP has made SoiLEX available, which is a global database that aims to facilitate access to information on existing legal instruments on soil protection and prevention of soil degradation. The platform was created in coordination with FAOLEX, which is to date one of the largest databases of legal frameworks and instruments related to natural resource management, food and agriculture. Within SoiLEX, the legal and policy instruments can be searched by country profiles or by soil-related keywords. The information provided by the database allows users to access the complete document as well as a detailed summary of its content, focusing mainly on the purpose and specific objectives of the instrument.

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GLOBAL SOIL PARTNERSHIP

The Global Soil Partnership (GSP) is a globally recognized mechanism established in 2012. Our mission is to position soils in the Global Agenda through collective action. Our key objectives are to promote Sustainable Soil Management (SSM) and improve soil governance to guarantee healthy and productive soils, and support the provision of essential ecosystem services towards food security and improved nutrition, climate change adaptation and mitigation, and sustainable development.

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