Food and Agriculture Organization of the United Nations

ITPS | SOIL LETTERS

INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS

6

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SOILS, WHERE FOOD BEGINS:

HOW CAN SOILS CONTINUE TO SUSTAIN THE GROWING NEED FOR FOOD PRODUCTION IN THE CURRENT FERTILIZER CRISIS?

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Hunger is a painful crisis that persists despite global efforts to eradicate it, affecting 828 million people worldwide in 2021 (FAO *et al.*, 2022). In addition, the COVID-19 pandemic has led to an additional 150 million people suffering from hunger, making healthy diets even less accessible for some segments of the world´s population (Poch *et al.*, 2020; FAO *et al.*, 2022). The State of Food Security and Nutrition in the World 2022 report concludes by urgently calling on governments to rethink how to redistribute resources in ways that make healthy and sustainably produced foods available to all. In a world where resources are increasingly threatened, healthy, fertile soils underpin the continuing supply of wholesome, responsibly-produced foods with minimal environmental impacts and a neutral carbon footprint.

Soils are directly and indirectly involved in the provision of most ecosystem services vital for humans, including food production, which is fundamental for food security and sovereignty. Soils are the basis for producing more than 95 percent of our food, according to the analysis of data available in FAOSTAT (FAO, 2022). Basic grains, oilseeds, sugar, vegetables, nuts and fruits directly rely on soils, and livestock meat and products, such as eggs and dairy products, are supported by animal feeds that also grow in soils. When produced by healthy and fertile soils, these foods are wholesome and nutritious. However, one-third of the world's soils are degraded to some extent due to erosion, loss of organic carbon and biodiversity, salinization, acidification, compaction, and nutrient imbalance, among other causes (FAO and ITPS, 2015). There is a close link between soil degrading processes and fertility loss, and the loss of topsoil and the exposure of subsoil can greatly reduce nutrient availability.

Healthy food production is hampered or limited if soils are degraded. Together with poor diets, nutrient-deficient soils contribute to micronutrient deficiencies in crops which in turn endanger human health: a condition called "hidden hunger", which affects more than two billion people worldwide (WHO, 2016).

Soil health and fertility depend on a vital triad of physical, chemical and biological soil properties. Physical properties such as texture and structure help to regulate pore spaces, aeration and consequently, drainage conditions and the water available for plants (Tan, 2009), while clay particles and some organic constituents in the soil help to regulate nutrient availability, thanks to their electrochemical activities, as well as assisting other important functions associated with soil health.

Soils are nature´s recycling system (Weil and Brady, 2017). Through the mineralization processes of the soil organic matter (SOM), nutrients are released and become readily available for plant uptake. SOM has multiple direct and indirect effects enabling the availability of nutrients, gas exchange, water infiltration and retention capacity in soils, and the flourishing of soil organisms. Soil organisms are among the most diverse terrestrial communities on Earth and maintain soil fertility through numerous complex reactions and processes involving

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Farmer in Baliadanghi, Thakurgaon, Bangladesh. 'Sustainable soil management for nutrition-sensitive agriculture' project funded by the Government of Germany

micro-, meso-, mega-, and macro-fauna. The interaction of soil properties, either physical, chemical or biological makes it possible for soils to produce, store, supply, and transfer the essential macro- and micro-nutrients to plants (Weil and Brady, 2017). Management and the interaction with environmentally non-controlled conditions can strongly influence soil properties.

Crop harvest and unsustainable agriculture practices decrease soil macro- and micronutrients, and SOM. Therefore, soils need to be replenished with nutrients by the addition of mineral and organic fertilizers, nitrogen-fixing leguminous crops, and the use of techniques to increase carbon input to prevent crop yields from deteriorating over time.

Mineral fertilizers are more commonly used but not always directly accessible to all farmers. This historical problem has been exacerbated in recent years due to the high prices of mineral fertilizers and logistic constraints in some regions, particularly when they are imported from other countries. Moreover, some mineral fertilizers have reduced efficiency, and nutrients are sometimes not directly accessible to plants. On the other hand, using organic fertilizers, which can increase SOM and improve soil's physical and biological properties, is generally insufficient to sustain large crop productions such as grains and other commodities. In addition, there are barriers to application, including a lack of availability of appropriate organic materials and a lack of knowledge about their adequate and safe processing, use, and production. Moreover, the phosphorous (P) content in organic fertilizers is often low, which is especially needed in old, strongly-weathered tropical soils. Recommendations for better access to organic and inorganic inputs, sustainable nutrient stewardship, better knowledge about biofertilizers, biostimulants, and other alternative solutions for crop nutrition are presented in The International Code of Conduct for the Sustainable Use and Management of Fertilizers (Fertilizer Code) (FAO, 2019).

Farmers have been severely affected by the current mineral fertilizer supply crisis. Prices have risen by 30 percent and in some cases even increased by more than 100 percent. As a result, farmers' incomes have decreased considerably, jeopardizing access to food for the most vulnerable populations. One of the main factors affecting the availability of mineral fertilizers is their stock concentration and manufacturing in a few countries, compromising their affordability and availability and directly affecting food production. About 90 percent of P stocks are concentrated in five countries (China, India, Morocco, the Russian Federation, and the United States of America), while more than half of potassium (K) is found in three countries (Belarus, Canada, and the Russian Federation) (Jones and Nti, 2022).

Such a high concentration of minerals, coupled with geopolitical tensions, such as the war in Ukraine, has resulted in an acute mineral fertilizer crisis. Sanctions and the curtailing of supplies in the Russian Federation and Belarus are preventing about 40 percent of the global K supply from reaching the market, causing scarcity and price increases (World Bank Group, 2022a). In addition, the reduction in oil and gas availability restricts the fertilizer industry, resulting in a supply shortage, especially for nitrogen (N). According to The World Bank Commodity Market Outlook 2022 report (World Bank Group, 2022b), the price of mineral fertilizers was 70 percent higher in 2022 than in 2021. The World Bank predicts that high fertilizer prices could remain for up to two more years, putting farmers at risk. The fertilizer crisis, along with other global challenges such as poverty, war, pandemics, migration, and global climate change, are negatively impacting the agrifood systems, causing low crop yields and crop failures, a particularly acute situation for smallholders. Increasing mineral and organic fertilizer use efficiency and finding new nutrient sources and technologies are the keys to recovering from this crisis.

Hence, faced with this complex multifactorial scenario, what can be done to respond to the urgent need of farmers to access nutrient sources and conserve soil health?

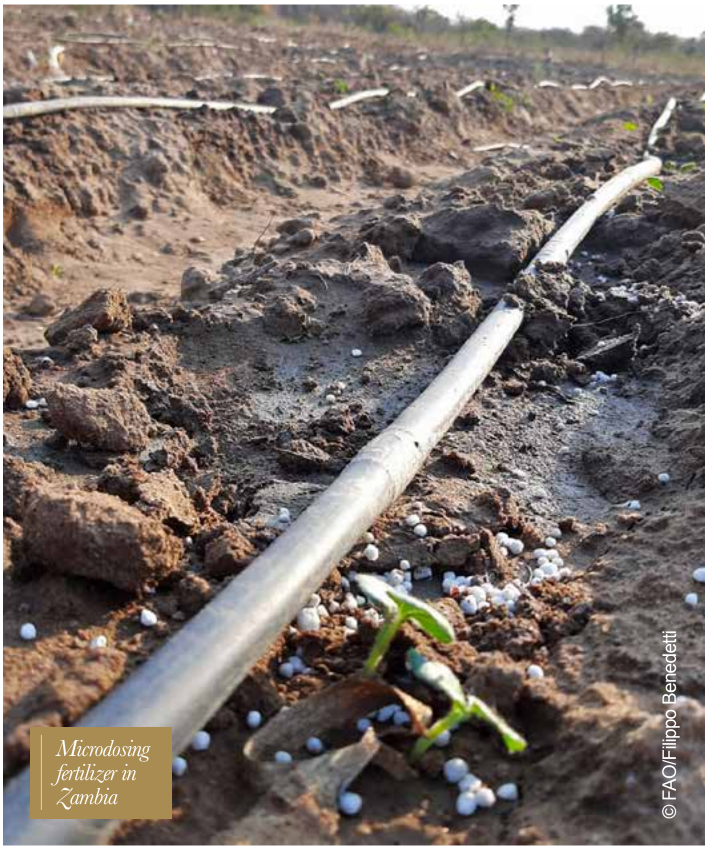
There is no single solution to all soil fertility problems, but a portfolio of alternatives can be employed. Paradigm shifts oriented towards providing the best physical, chemical, and biological conditions to enhance soil nutrient availability and plant uptake are required. In addition, the use of nutrient-efficient crop varieties while maintaining or improving soil health is urgently needed. The current focus on agriculture with low crop diversity and high-yield objectives with high rates of mineral fertilizer application in some crops, while overlooking nutritional quality and the contribution to the emission of greenhouse gases, needs to be rethought.

A wealth of scientific evidence has shown the utility of soil microbes in increasing soil fertility. Biofertilizers contain living or dormant microorganisms which help to fix atmospheric N and increase the availability of P, K and other nutrients (FAO, 2019). Biological N fixation provides about 100 million tonnes of N with potential annual savings of USD 10 billion in N fertilizer for global agricultural lands (FAO, 2016). In many regions, P supply is not at risk, while in others, it is a scarce and urgently needed element to increase crop yields. In both scenarios, strategies are required to solubilize P and increase its availability. Phosphate-solubilizing microorganisms can transform non-soluble forms of organic and inorganic P by hydrolysis (Chen, Lin and Huang, 2006; Khan *et al.*, 2009), contributing to increasing P availability, although the effect is site-dependent. The efforts mentioned previously and investments focused on increasing soil fertility and plant nutrient uptake could be lost if SOM content, pH, soil structure, and soil moisture are not optimal as the added nutrients cannot be assimilated. Those nutrients can also be lost in the soil, causing pollution of water sources or contributing to greenhouse gas emissions.

Soil microbes and SOM additions in concert with crop diversification and nutrient use efficiency, consequently reduce the need for external inputs, particularly of P and N.

Recycled nutrient sources are alternatives to increase soil fertility. Animal manure, urban wastes, wastewater, algal biomass, compost, and digestates, among other sources, can be recycled to the plant nutrient cycle after consumption by humans or animals, as by-products of food processing or as plant residues returned to the soil (FAO, 2019). Crop yields can be similar or improved by using recycled sources compared to mineral fertilizer. In addition, nutrient recycling contributes to the circular economy since the 3.5 million tonnes of waste produced daily worldwide (Hoornweg, Bhada-Tata and Kennedy, 2013) could be used to return nutrients to soils. By implementing some of these practices, soils can also evolve from a carbon source to a carbon sink and contribute to mitigating climate change in a win-win strategy.

Regardless of the source of nutrients used to improve soil fertility, evaluating their quality and safety is essential to avoid health problems and environmental pollution. Heavy metals associated with certain sources of mineral and organic fertilizers (such as sewage sludge) (FAO and UNEP, 2021), pathogens, antibiotic-resistant microbial strains in organic fertilizers and recycled sources, organic chemicals derived from industry, and pesticides pose a risk of transferring contaminants to crops, humans, and animals or the food chain itself (Mayer and Wang, 2018). In addition to the mentioned contaminants, there is a recent



Microdosing fertilizer in Zambia

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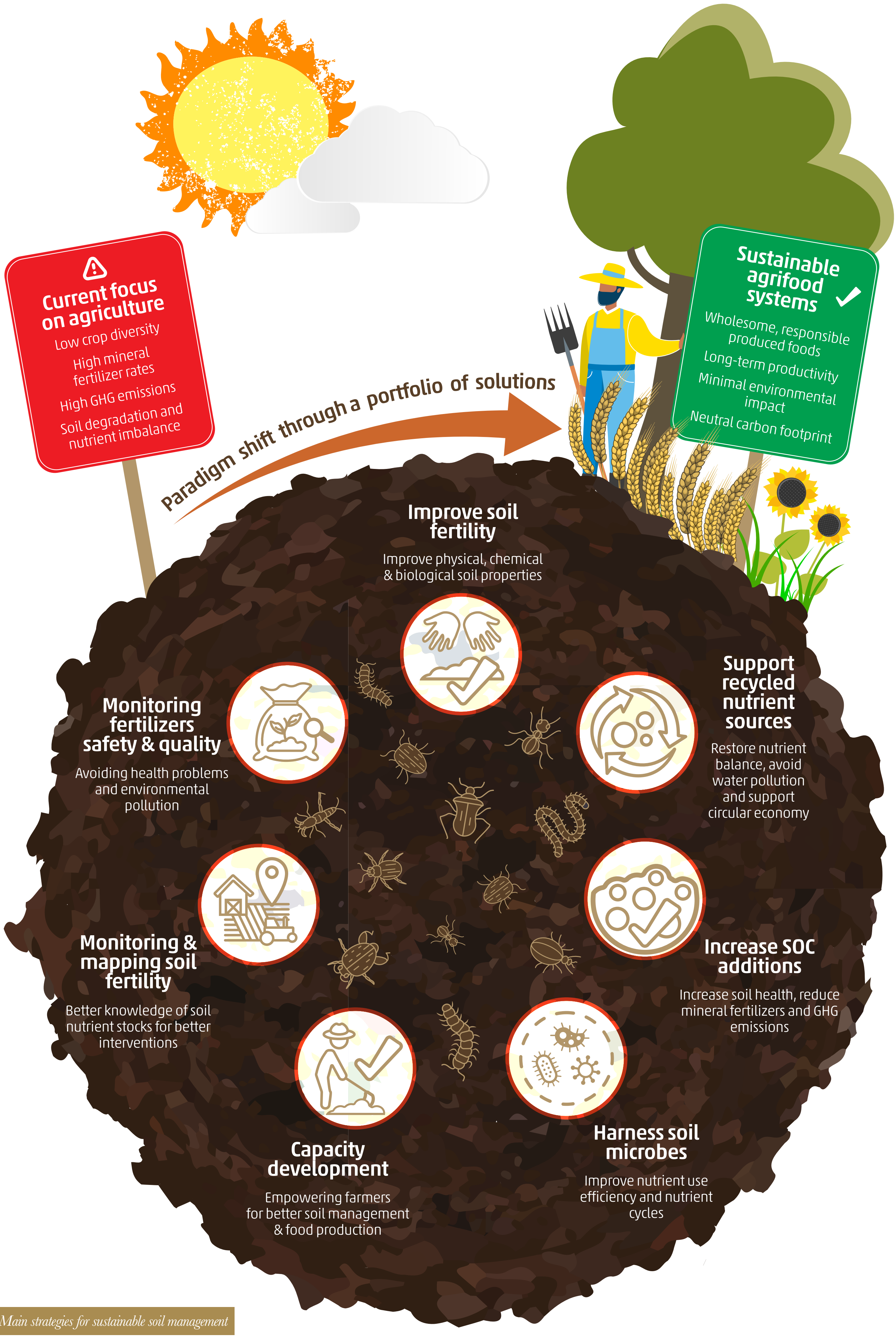
recognition of the presence of emergent contaminants, such as polyfluoroalkyl substances known as PFAS and microplastics in urban wastes and wastewater treatment plants, making the use of these potential nutrient sources challenging (FAO and UNEP, 2021). Other products found in soils, such as organic residues, and wastewater used in agricultural production are secondary metabolites of the human intake of antibiotics, contraceptives, stimulants and antidepressants, among others (Gottschall *et al.*, 2012). Fertilizer quality assessment is also necessary to guarantee farmers that the nutrient source complies with the nutrient content standards.

The transformation of the agrifood system should include a medium- to long-term view when it comes to soil management. Soil fertility should be built in the medium-term and the solution should be integral and not only about adding fertilizers (inorganic or organic). The Voluntary Guidelines for Sustainable Soil Management and the International Code of Conduct for the Sustainable Use and Management of Fertilizers should guide such a process.

Finally, farmers should be at the centre of plans for the maintenance and enhancement of soil health and sustainable nutrient management. The empowerment of farmers through capacity building, technical support, and financial incentives is part of the core solution to soil fertility loss. It is also essential to raise awareness that soil degradation hinders nutrient availability and causes soil nutrient losses with a negative impact on the environment and human health.

Evidence shows that sustainable soil management could produce up to 58 percent more food while preserving soil health (FAO, 2015). Strategies aimed at achieving food security should be based on soil health, which is both a prerequisite and the ultimate goal.



Main strategies for sustainable soil management

24 October 2017, Jatrapur, Bangladesh - Beds for earth worms cultivation are prepared at Mahilata Organic Fertilizer Production Farm. Between 2011 and 2016, FAO worked with farmer organizations and government departments in Bangladesh to improve the design and management of agricultural investments. These technical and capacity building activities formed part of the Integrated Agricultural Productivity Project (IAPP), funded by the Global Agriculture and Food Security Program (GAFSP).

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25 October 2017, Jatrapur, Bangladesh - A local worker spreads cow dung at the Mahilata Organic Fertilizer Production Farm in Jatrapur, where the vermicompost, an organic fertilizer, is produced. Between 2011 and 2016, FAO worked with farmer organizations and government departments in Bangladesh to improve the design and management of agricultural investments. These technical and capacity building activities formed part of the Integrated Agricultural Productivity Project (IAPP), funded by the Global Agriculture and Food Security Program (GAFSP).

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Crop association in perennial crops (broccoli with citrus) in Montalban, Carabobo State, Venezuela

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Cover crops (cassava and paprika) in Valles altos Carabobo State, Venezuela

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Placing farmers at the centre of SSM implementation. Capacity development, field exercises in the Soil Doctors Programme

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Soil sampling for monitoring soil health. Chandina, Bangladesh

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Increasing crop production caring for sustainability and nutritional quality is essential. Chandina, Bangladesh

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The Intergovernmental Technical Panel on Soils (ITPS) is composed of 27 top soil experts representing all the regions of the world. ITPS members have a 3-year mandate and provide scientific and technical advice and guidance on global soil issues to the Global Soil Partnership primarily and to specific requests submitted by global or regional institutions. Created in 2013 at the first Plenary Assembly of the Global Soil Partnership held at FAO Headquarters, the ITPS advocates for addressing sustainable soil management in the different sustainable development agendas.

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