Food and Agriculture
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Sustainable soil management as a keystone of nutrition sensitive agriculture in **Malawi**

Country factsheet

GLOBAL SOIL PARTNERSHIP

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Key messages

- In Malawi in 2018, 52 percent of the population experienced severe food insecurity (IPC, 2022), and the prevalence of undernourishment was 19 percent (FAO, 2021a).
- Malawi is one of the countries in sub-Saharan Africa (SSA) with a higher prevalence of micronutrient deficiencies, with zinc deficiency rates of around 60 percent in all demographic groups (NSO, 2017) and 70 percent of the population consuming insufficient selenium (Phiri *et al.,* 2019).
- Micronutrient deficiencies can be linked to the difficult climate conditions and the degraded status of soils. Indeed, over 40 percent of Malawi soils are nutrient-poor (Chilimba, 2013), while 75 percent of Malawi soils are degraded or threatened by degradation (Omuto and Vargas, 2019).
- In Malawi, the use of mineral fertilizers (macro- and micronutrients) is promoted by the government, representing an investment of USD 150 million, or more than 50 percent of the national agricultural budget.
- The results of the Soils4Nutrition project show that the addition of sufficient organic matter increases yields and the amount of available micronutrients in crops at a higher rate than through the addition of chemical fertilizers alone.
- Moreover, sustainable soil management (SSM) practices, including intercropping and integrated soil fertility management (ISFM), increases the organic matter of the soil. The addition of micronutrients at the right time, the right place and the right source increases yields by 5 to 10 percent and increases the concentration of micronutrients in the edible parts of maize, soybean and amaranth by 10 to 30 percent.
- Soil management and fertilization recommendations must be adopted to maintain soil health and increase the nutrient uptake by plants, thus enhancing the amount of micronutrients in diets.

Background

Malawi is faced with multifaceted nutrition security challenges. The country has 37 percent of children under five being chronically undernourished (stunted) and 52 percent of the population experiencing severe food insecurity in 2018 (IPC, 2022). The prevalence of undernourishment was 19 percent in 2018 (FAO, 2021a) and there are widespread deficiencies of zinc (60 percent) and iron (22 percent) among children under five (NSO *et al.*, 2017).

Malawi is one of the countries in sub-Saharan Africa (SSA) with a higher prevalence of micronutrient deficiencies, with zinc deficiency rates at around 60 percent in all demographic groups (NSO, 2017) and 70 percent of the population consuming insufficient selenium (Phiri *et al.*, 2019).

The soils of Malawi are naturally poor in nutrients and organic matter and have been further depleted due to unsustainable farming practices. As a result, the crops grown in those soils cannot obtain enough nutrients and this has led to a low nutritional value of crops in addition to decreased yields and consequently, contributed to micronutrient deficiencies in the population. This relationship between soil properties and the nutrient content of crops has been dealt with in the international scientific literature. The data obtained show that there is a geospatial variation in the micronutrient composition of nutritionally important Malawian crops at subnational scale, and that soil and landscape are important factors affecting that variation (Botoman *et al.*, 2022; Gashu *et al.*, 2021). Soil properties, namely soil pH and soil organic matter, are therefore factors that affect the population's nutrient status (Hurst *et al.*, 2013; Phiri *et al.*, 2019; Ligowe *et al.*, 2020) (Figure 1). These data were obtained in the framework of the Geonutrition project, through a multipartner effort, including the University of Nottingham, the Lilongwe University of Agriculture and Natural Resources, Rothamsted Research and the International Maize and Wheat Improvement Center (CIMMYT) among others.

The Government of Malawi has traditionally encouraged the replenishment of the depleted nutrients in soils through fertilization. The Farm Input Subsidy Programme (FISP) put in place by the Malawian government in 2005 had, on average, succeeded in supporting 30 percent of households each year, managing to supply 43 percent of the fertilizer applied to maize. The programme has now been replaced by the Affordable Inputs Programme (AIP) that is based in a similar approach and targets 3.6 million smallholder farmers, subsidizing the purchase of cereal but not legume seeds.

However, the success of the FISP has been limited: food production has not increased at the same rate as the expansion of harvested land and yields for key crops such as maize and legumes (below 5 t/ha) are still far from the potential figure of more than 10 t/ha (Benson, 2021; FAO, 2021b), while the risk of environmental degradation increases because more land is needed to maintain production. In addition, malnutrition figures remain too high, with 19 percent of the population being undernourished in 2018 (FAO, 2021) and large percentages of the population suffering from micronutrient deficiencies, with women and children being the most affected segments.

Several reasons for this have been identified. In addition to the fact that fertilizers are generally applied below the recommended rates, the national formulation of FISP fertilizers is skewed towards macronutrients. While the Ministry of Agriculture and Food Security (MoAFS) recently mandated the incorporation of 1 percent elemental zinc into granular basal fertilizers (MoAFS, 2016), other nutrients are absent from the recommended formula. Furthermore, the current official fertilizer recommendation (23:10:5 + 6S + 1.0 Zn (MoAFS, 2018) is targeted at maize production and is the same across the country, thus disregarding soil and crop characteristics, with farmers attempting to self-modify, depending on the specific context (Mutegi *et al.*, 2015).

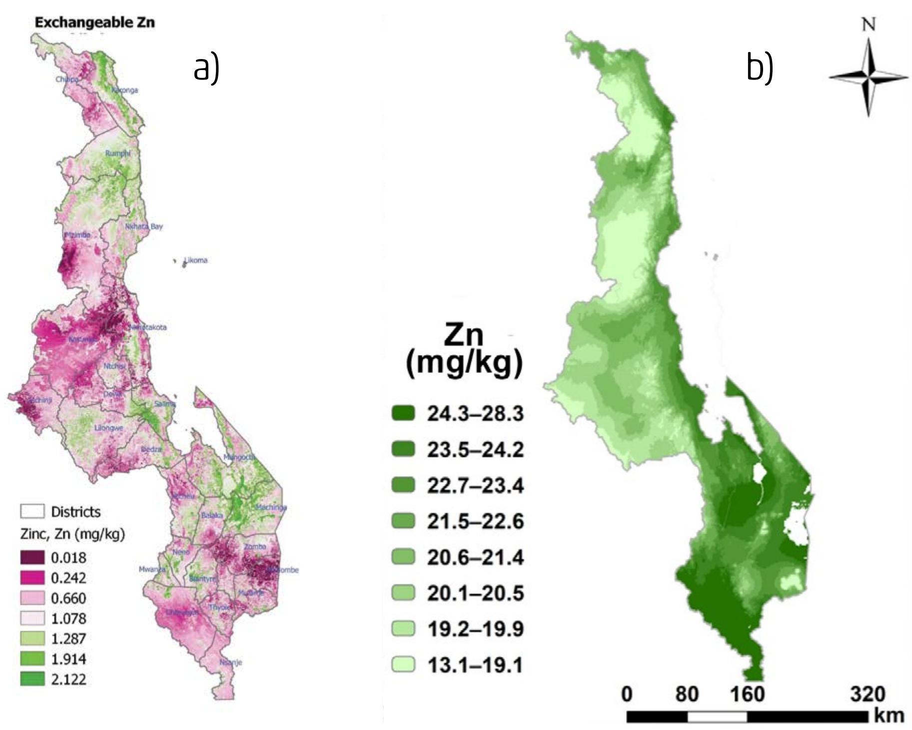

Figure 1. (a) the geographic distribution of soil exchangeable zinc, against (b) areas with a high probability (darker tones) of zinc deficiency (Zn <18.6 mg/kg) for maize grain across Malawi

Sources: adapted from Omuto, C.T. & Vargas, R.R. 2019. Soil Loss Atlas of Malawi. Rome, FAO. *https://www.fao.org/3/ca3624en/CA3624EN.pdf* Botoman, L., Chagumaira, C., Mossa, A.W., Amede, T., Ander, E.L., Bailey, E.H., Chimungu, J.G. et al. 2022. Soil and landscape factors influence geospatial variation in maize grain zinc concentration in Malawi. Scientific Reports, 12(1): 1–13. *https://www.nature.com/articles/s41598-022-12014-w* Data from the GeoNutrition project.

The FISP's initial focus on mineral fertilizers has also probably neglected the relationship between soil organic carbon (SOC) and soil health with food productivity. In 2006, the government started promoting the use of compost manure, farmyard manure and crop residues (Chilimba *et al.*, 2005), with the campaign resulting in about a 30 percent increase of organic manure use per hectare between 2006 and 2015. At the same time, the share of farmed areas allocated to maize–legume intercropping also increased from 25 percent in 2006 to 43 percent in 2015 (Katengeza *et al.,* 2019). However, considering that SOC levels are lower than the 2 percent critical levels required for structural stability (Omuto and Vargas, 2019; Tamene *et al.*, 2019), the extent of organic inputs commonly applied today in Malawi is insufficient to ensure the buildup of SOC and provide an adequate nutrient supply to vegetation.

Soils4Nutrition project

In 2019, in collaboration with FAO, the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) of Malawi launched the project Sustainable Soil Management for Nutrition-Sensitive Agriculture in sub-Saharan Africa and South East Asia (Soils4Nutrition). The project explored the soil–crop–human micronutrient linkages in Malawian cropland areas, and the efficacy of SSM practices in increasing the micronutrient contents in crops (maize, soybean and amaranth). The aim was to produce management recommendations leading to an increased input of micronutrients into the food chain and therefore to a better human nutrition.

Healthy soils, essential for better nutrition

A change in paradigm is needed towards a broader and long-term strategy for agricultural production and food security and nutrition, beyond the mere addition of nutrients through mineral fertilizers. This new strategy must aim for abundant and highly nutritional crops through enhanced soil health and the generalized adoption of SSM.

According to the Voluntary Guidelines for Soil Sustainable Management:

> *Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity. The balance between the supporting and provisioning services for plant production and the regulating services the soil provides for water quality and availability and for atmospheric greenhouse gas composition is a particular concern (FAO, 2017, p.3).*

In practical terms, managing soils sustainably consists of adopting practices that improve a soil's physical, chemical and biological properties, and thus the overall soil health, without impairing production. SSM practices include adding sufficient organic inputs, making judicious use of fertilizers, diversifying crops and minimizing soil nutrient depletion. These practices can be adapted to any agroecosystem, provided that local soil conditions are known. SSM can thus deliver the foundations of a food system able to alleviate micronutrient deficiencies and malnutrition in the long run.

Many of these SSM practices are not novel technologies in Malawi, as they are already part of farmers' traditional practices. For instance, organic matter-based technologies and maize–legume intercropping can be traced back to indigenous knowledge. However, these practices have been generally replaced over recent decades by the use of mineral fertilizers.

Among SSM practices, those aimed at increasing soil organic matter are of particular relevance. 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, due to soil organic matter being a reservoir for essential plant nutrients, continuously supplying nutrients to crops upon decomposition. A higher amount of SOM improves soil aeration and water retention, thus leading to improved soil structure and aggregation, and enhancing the capacity of plants to access nutrients. Therefore, organic matter mitigates inherent soil fertility issues, ultimately reducing the amount of fertilizers required for agricultural production and contributing to alleviate dietary micronutrient deficiencies in the long run.

This has been demonstrated by the results of the Soils4Nutrition field trials in Malawi (Figure 2), which have shown that the addition of sufficient OM had the largest effect on increasing yields (Figure 3) and on the amount of micronutrients in crops, (Figure 4), with the increases being much larger than the sole addition of chemical fertilizer and from insufficient amounts of OM.

Figure 2. Effects on maize development with the addition of zinc

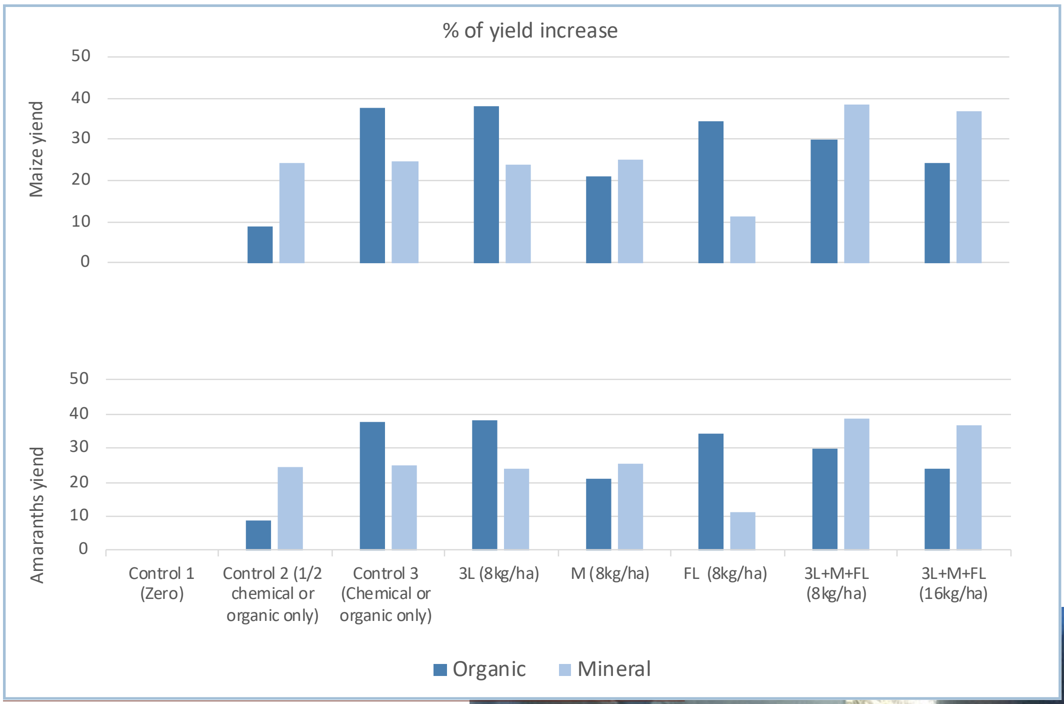

Figure 3. The addition of organic matter improves yields compared to the use of mineral fertilizers only

Source: Soils4Nutrition project

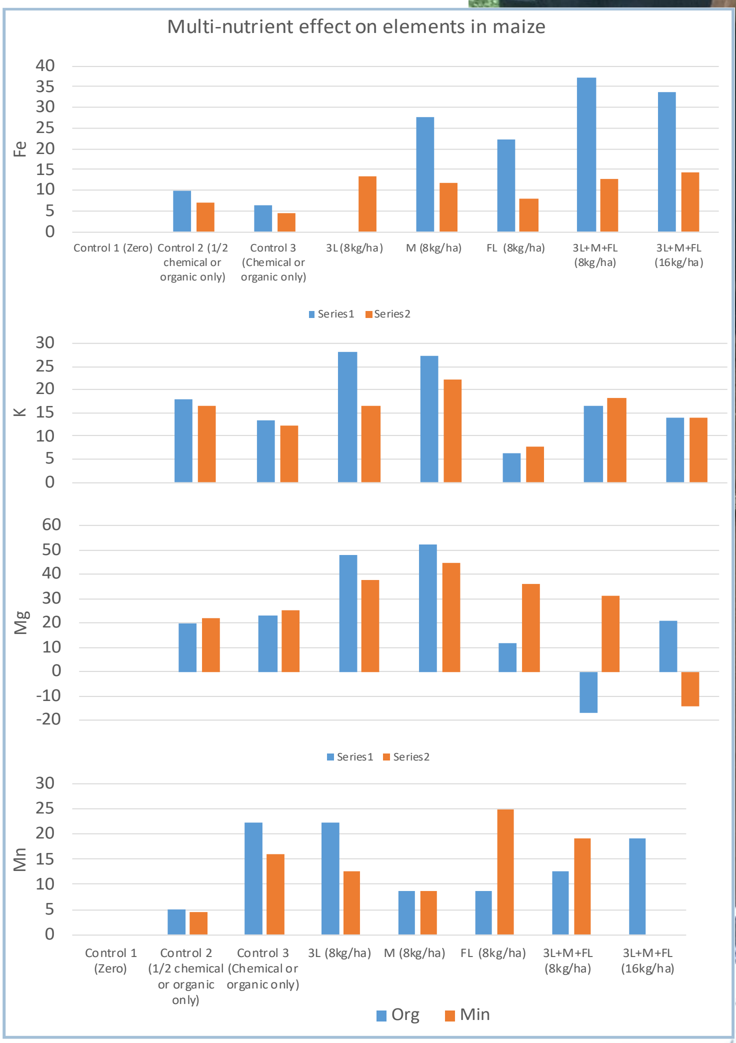

Figure 4. The joint use of organic matter and multi-micronutrient foliar sprays increases the amount of nutrients in the edible part of crops compared with basal mineral fertilizers

Source: Soils4Nutrition project

This is in line with previous evidence that shows that Malawian practices that promote resilient crop productivity and healthy soils over the long term are needed for achieving a greater response to fertilizers and, consequently, higher yields and an improved cost-efficiency of fertilizer subsidies (Burke *et al.*, 2022).

However, the amount of organic matter that is "sufficient" for an optimal response is not the same in all soils. This means that knowing the properties of the soil is essential not only to place the agricultural activities in the most adequate soil environment, but to ensure that management practices are best fitted to the site conditions and that fertilizers are used efficiently. Soil mapping and modelling efforts, such as the FAO Global Soil Organic Carbon Map (GSOCmap), can be integrated in national decision-making systems for obtaining a more accurate diagnose of soil suitability and capability and for providing the best fertilizer recommendations.

The results of the Soils4Nutrition trials further show that the effects of OM application on yields and on the micronutrient content in crops were higher when used in combination with legume intercropping, compared to monocropping (Figure 5). This is because legumes are able to capture nitrogen from the atmosphere, making it available to be used by the neighbouring crops, thus adding to the effects of OM on soil nutrient balance. Crop diversification thus contributes to an enhanced soil health at the same time partially replacing external inputs and improving cost-efficiency.

Figure 5. Maize, soybean and amaranth intercropping in Kasungu

These data demonstrate that agricultural practices aimed at improving soil health provide an effective means of enhancing quantity and quality of crops in terms of their nutritional value. However, the one-year duration of the trials is too short to detect trends in slow-changing variables, such as SOM content. In fact, organic manure and maize–legume intercropping may take more than two or three seasons to build up SOM. These delayed benefits of the technologies applied must therefore be communicated and considered in policy design, as otherwise the risk of disadoption of the technologies after one or two seasons of use may increase (Jew *et al.*, 2020).

Importantly, in order to communicate the gains provided by SSM, they must be appraised, meaning that the status of the soil before and after its implementation has to be measured. Guidelines on standardized tools for monitoring the effects of SSM on soil properties are provided in the *Protocol for the assessment of sustainable soil management* (FAO, 2020). Important initiatives, such as the FAO RECSOIL: Recarbonizing Global Soils programme, focus on the promotion of sustainable management practices and provides incentives for farmers who agree to implement SSM practices, including those specifically aimed at improving nutrient use efficiency and the nutritional value of crops through the enhancement of soil health.

The right rate, time, place, and source for micronutrient fertilizers

An adequate use of fertilizers must consider synergies with key parameters of the soil and the plant, in order to contribute to the conservation of soil health while increasing yields and reducing nutrient losses to the environment. This holistic approach is the basis of integrated soil fertility management (ISFM) which consists in the balanced application of organic matter and inorganic fertilizers through different methods of application (basal or foliar) and with attention to the local characteristics and to the plant growth cycle.

Integrated soil fertility management provides the necessary nutrients for plant growth, while soil nutrient storage and supply is enhanced, so that improved crop yield and nutritional value are possible without impairing soil fertility. The benefits of this approach are acknowledged in the International Code of Conduct for the Sustainable Use and Management of Fertilizers (Fertilizer Code) (FAO, 2019), which provides a locally-adaptable framework and a voluntary set of practices to support the different stakeholders (directly or indirectly involved with fertilizers), in achieving sustainable agriculture from a nutrient management perspective.

Within ISFM strategies, agronomic biofortification consists of the addition of micronutrients to basal fertilizer and foliar sprays formulated with the specific aim of increasing the nutritional value of crops. The results of the Soils4Nutrition project show that biofortification had immediate beneficial effects regarding yields and nutritional value of crops, since improvements in crops nutrient content were observed in a single harvest season. The data from Soils4Nutrition field trials showed large increases in yield with the application of foliar dressings containing copper (20 percent) and zinc (25 percent), as well as a 30 percent increase in zinc levels in the edible parts of the plants upon the foliar application of a zinc dressing. The effect was even higher when multi-micronutrient sprays were used (with a 30 to 50 percent increase in maize and soybean yield and a 40 percent increase in zinc concentration in maize grains), compared to a single element fertilizer.

When used in combination with SSM, these beneficial effects are increased compared to ISFM only. The added benefits were also demonstrated in the Soils4Nutrition field trials, since the joint use of intercropping and organic matter additions resulted in further increases in maize, soybean and amaranth yield and in higher micronutrient contents in edible parts of crops.

Regarding the amounts of fertilizer and the timing of application, the results showed that they must be adapted to the plant growing cycle. ISFM was most effective when micronutrients were applied just before flowering, with the application before the three-leaf stage being too early and the application during fruiting too late. Multiple applications of micronutrients seemed to not have any added effects over a single application at the right time (Figure 6).

Figure 6. Multiple micronutrient applications at the three-leaf, mid maturity and flowering stage in maize crops in Malawi

In summary, the spatial and temporal variations of soil fertility levels and plant requirements have to be considered as part of these integrated fertilization strategies and agronomic biofortification approaches. Technologies must be identified and made available to farmers, in order to apply fertilizers from the right source, at the right rate and time, and using the right method.

Summary of recommendations and way forward

This country fact sheet lays out the technical evidence and arguments arising from the evaluation trials of the Soils4Nutrition project and highlights the importance of the relationship between soil properties and management with nutrition aspects in Malawi. The adoption of SSM, namely intercropping and SOM additions, in combination with ISFM, including mineral basal and foliar micronutrient application, qcontributing to a better nutritional status of the population. Specific recommendations are as follows:

- The inception of intercropping maize, soybean and amaranth with three foliar applications of multi-micronutrient fertilizer together with organic or chemical fertilizer have proved to ameliorate crop quantity and nutritional value. These and other similar SSM technologies, fine-tuned for specific soil and plant characteristics (and in regard to socioeconomic priorities), must be promoted and upscaled.
- Soil information at an adequate scale must be integrated in the Malawian decision-making system to obtain a diagnosis of soil suitability and capability. Country-driven soil mapping and modelling efforts, such as the FAO *Global Soil Organic Carbon Map* (GSOCmap), can help in that regard.
- The effects of agricultural management on soils have to be monitored at farm scale, so that changes in soil properties upon management are detected, benefits can be quantified and corrective actions can be implemented if needed. The *Protocol for the assessment of Sustainable Soil Management* and its User Manual provide methodological guidance for soil monitoring.
- The delayed benefits of soil health must be communicated and considered in policy design. Sharing the risk entailed by delayed production benefits with the farmers could be another option for enhancing SSM use. This could be in the form of incentives in the first two or three seasons of use. Important initiatives, such as the FAO RECSOIL programme, focus on the promotion of sustainable management practices to achieve the recarbonization of agricultural soils, and provide incentives for farmers who adopt sustainable soil management.
- SSM and ISFM technologies must be encouraged through policy and extension. We underscore the need for agricultural extension services to go beyond promotion, to also ensure that farmers are aware of potential long-term benefits and how to implement SSM and use ISFM. Farmer-to-farmer extension may play an important role in overcoming information access problems and the lack of knowledge that may preclude the widespread adoption of SSM or induce its disadoption. Initiatives such as FAO's *Global Soil Doctors Programme* can complement Malawi's extension system regarding grassroots knowledge on soil and SSM.
- In summary, we advocate for a long-term nutrition-sensitive agricultural strategy, through enhancing soil health, leading towards higher crop yields and improved crop nutritional value. The principles gathered in the *Voluntary Guidelines for Sustainable Soil Management* (FAO, 2017) and the *International Code of Conduct for the Use and Management of Fertilizers* (FAO, 2019) must be incorporated into agronomic recommendations and policy development.

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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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