ALTERNATIVES FOR THE SUSTAINABLE MANAGEMENT OF SOIL FERTILIZATION AND PLANT NUTRITION

Since the end of 2021, the world has faced a shortage of fertilizers driven by a rise in prices, which have increased by approximately 78 percent during this period. Prices of P and K fertilizers have increased from USD 450 to USD 1 200 per tonne, while the price of urea has increased from USD 500 to more than USD 1 000 (Bourne, 2022). Additionally, some fertilizers are no longer available in the market, since numerous production plants, facing negative margins, have halted production due to the increase in energy prices, among other challenges (Agronews Castilla y León, 2022). Consequently, the reduction of fertilizer applications is expected to decrease the yield and quality of food production (Agronews Castilla y León, 2022).

All practices that promote an increase in organic matter and greater soil biodiversity will improve its fertility and ability to supply nutrients to plants. However, it is important to maintain a balance between the physical, chemical and biological properties of the soil (Rey, 2009; Castillo, n.d.), since it is necessary to ensure an adequate medium for the development of plant roots. The particular conditions of each soil must be known in detail in order to adapt its management using the available resources.

This document briefly summarizes the alternatives compiled to date by the Soil Community of Practices (CoP-Soils) for Latin America and the Caribbean (LAC),[1] adding some additional alternatives implemented in the region and identified by TCP/RLA/3805: Support for regional cooperation on climate management of agricultural ecosystems with an emphasis on water and soil (ASLAC, 2020), and for the virtual seminar Biofertilizers and other available technologies to face the fertilizer crisis in Latin America and the Caribbean (FAO, 2022).

SOME ALTERNATIVES:

1. Identification of nutritional deficiencies. Since it is easy to confuse nutritional deficiencies with diseases and other physiological disorders caused by extreme weather, farmers often apply more fertilizer than required, thereby increasing costs without solving the problem. Therefore, capacities must be generated in producers and extension agents to: i) recognize nutritional deficiencies in the field using manuals or guidelines that include photos, diagrams, graphs and the location of the deficiency, while taking into account the mobility of nutrients; ii) differentiate symptoms of nutritional deficiencies and diseases that manifest in a similar way, using guidelines to improve precision in identification; and, iii) perform rapid field diagnoses until the results can be confirmed by plant tissue analysis (Medina, 2022).

[1] The Soil Community of Practices (CoP, https://dgroups.org/fao/soil_lac) is an initiative promoted by the FAO Regional Office for Latin America and the Caribbean and by the Latin America and the Caribbean Soil Partnership, and has been made available to all interested parties to promote sustainable land management. The CoP offers a platform for farmer organizations, cooperatives, civil society organizations, academia, research centres, non-governmental organizations (NGOs), decision makers and the private sector to: i) raise awareness about the importance of assessing soil degradation and sustainable soil management; and ii) promote the use and management of data, tools and good practices for the management and sustainable use of soils, in particular to stop soil degradation and salinization and increase the potential for carbon sequestration. This community exchanges information and ideas on practices, projects, lessons learned, initiatives, programmes, and public policies on sustainable land management. It is an open platform for stakeholders to share information, co-create knowledge and systematize their experiences, with a particular focus on sustainable soil management, best practices, technologies and case studies (in areas such as salinization, soil management, carbon sequestration, climate-adapted agriculture, reduction of greenhouse gas (GHG) emissions, cooperation mechanisms that support management, financing mechanisms, use of maps for decision-making, soil restoration as an adaptation measure and mitigation of carbon sequestration, among others).

2. Sampling, soil analysis and balanced fertilization at the farm level. Analysis can be carried out to determine the physical properties of the soil, such as texture and structure (contact between roots and soil), as well as its chemical (nutrient level and pH) and biological properties (nitrogen fixation, ammonification and nitrification). Then, depending on the results, the balanced and efficient management and application of fertilizers (organic and/or mineral) can be promoted through fertilization programmes. A basic principle, in the event that soil analysis is not available, is to assume that the soil does not have nutrient reserves, which means the fertilization recommendations available in the countries for different crops should be followed. This strategy also helps to maintain a minimum level of nutrients in the soil, avoiding soil degradation in the medium and long-term. The results of the soil analysis, and the recommendations for each crop are key information, among other variables, for the development of soil fertilization programmes (Medina, 2022).

3. Fertilization programmes at the farm level. These should be based on the results of the soil analysis, the expected yield (according to the variety, management and level of technology), available fertilizers (N, P, K, Ca and Mg), frequency of application, area, type of crop and fertilizer prices. In addition, it is important to know the texture and structure of the soil and the interrelationships with field practices, such as the application of irrigation water and organic matter (Medina, 2022), since both are related to the availability and absorption of nutrients. Water carries nutrients found in the soil, which once dissolved in the water are then absorbed by plant roots. The quality of irrigation water is key to increasing precision and efficiency, since, for example, the content of minerals and other elements in the water can affect the recommendation of fertilizers, soil pH, and the availability and assimilation of nutrients by plants. Between 30 and 50 percent of the applied nitrogen is lost through leaching, while for phosphorus it is only 15 percent. As for the applied potassium, between 50 and 60 percent is absorbed (Hungria da Cunha, 2022). This is enhanced through increased frequency in applications and by using methods such as fertigation. At the country level or in different agroecological zones, it is important to obtain maps of soil and water quality as an input to identify best practices and recommendations for fertilization and/or nutrition programmes.

4. Use of efficient microorganisms (EM) growth promoters. Beneficial or efficient soil microorganisms are an essential element of nutrient cycles, since they improve soil conditions, suppress rot (including diseases) and microbes and improve the efficiency of the use of organic matter by plants (EMPROTEC, n.d.). In addition, they reduce the emission of greenhouse gases (1 kg of N = 10,7 kg CO2-e) (Hungria da Cunha, 2022). Arbuscular mycorrhizae

and rhizobacteria – symbiotic and non-symbiotic – (Cáceres, n.d.) are capable of increasing phosphorus solubility and nitrogen fixation in the soil. They also help in the solubilization of minerals, mineralization of organic matter, biological nitrogen fixation, root growth and morphology, production of enzymes, vitamins and cofactors, soil aggregation and stability, production of growth-promoting compounds, absorption and translocation of nutrients and chelation reactions (Reyes, 2022). Under favourable conditions, the amount of nitrogen fixed through the Rhizobium bacteria is equivalent to an average 15 kg/ha, with a maximum of up to 200 kg/ha. In addition, phytohormones favour root growth (12 percent), which contributes to the absorption of water and nutrients. Considering that plants have multiple needs, the use of microorganisms should take place under the approach of integrated systems and multifunctional use of microorganisms and microbial molecules (Hungria da Cunha, 2022). In this regard, integrated programmes are required that include the six Ms: microorganisms, molasses, minerals, organic matter, mulch and technical management (Reyes, 2022).

5. Use of fertilizers – organic amendments (Hirzel, 2021). Organic matter (OM) in the soil helps store nutrients, improve soil structure, improve exchange capacity (electrical conductivity), increase water infiltration and prevent compaction. In addition, it buffers rapid changes in alkalinity, acidity and salinity of the soil (Ramírez, 2017). The organic amendments used in agriculture correspond to sources of organic matter of animal and vegetable origin, among which are manures in a fresh and semi-composted state, fossilized manures, compost, humus vermiculture (Agrosavia, n.d.), green fertilizers, crop residues, wood residues from the forestry industry (sawdust, shavings and bark), sludge from agro-industries or cities, wastewater or combinations of some of these sources. It is calculated that the contribution of nitrogen from amendments amounts to: green manures 5-20 percent (slower in grasses, faster in legumes); compost 25-40 percent; beef litter 40-50 percent; broiler or turkey litter 60 percent and slurry 90 percent. The organic amendment must be applied between 7 and 15 days before planting, thus avoiding phytotoxicity. In periods of rain, 10 to 20 percent of the nutrients can be lost due to leaching (Hirzel, 2022).

6. Associated crops, intercropping and crop rotation. Integrated crop systems, including legumes that are capable of fixing atmospheric nitrogen, reduce nitrogen fertilizer requirements, promote cover, increase soil biodiversity and diversify production units. Legumes such as soybeans and beans can fix between 45 and 450 kg/ha of N per year (Wani and Lee, 1992), leaving a large amount in the soil for use by other crops. They also reduce losses due to leaching and the contamination of water sources by this nutrient. Depending on the species, the type of plant inoculant and agroclimatic conditions, an annual fixation of between 72-350kg N/ha can be achieved. In addition, crop rotation helps to break the pest cycle, which reduces the use of pesticides (Calles, 2022).

7. Cover crop. The use of living or dead cover crops promotes the improvement of the physical, chemical and biological properties of the soil. They help to improve the infiltration rate, bulk density, and structural stability, which promotes greater root growth and nutrient utilization. More organic matter in the soil and greater biodiversity increases the population of beneficial organisms and microorganisms that promote the mineralization of organic matter and make the absorption of nutrients more efficient.

8. Agroforestry (Stadler-Kaulich, n.d.) **and use of biochar (or biocarbon).** Agroforestry is used as a restoration mechanism for degraded soils, due to its ability to provide organic matter to the soil, promote soil cover and improve its biodiversity. The remains of tree pruning can be used to produce biochar, since it has fertilizing properties, helps regulate the pH of highly acidic soils and improves their physical and chemical properties. Biochar is organic matter that is carbonized by heating in an oxygen-limited environment and used as a soil amendment. Biochar can be produced from a wide range of organic sources, such as agricultural and forestry residues, food processing residues, urban green waste, biosolids, algae, and animal manure (Cowie *et al.*, 2017). Biochar can improve plant yields, improve the soil's water-holding capacity, and reduce fertilizer needs, although results vary greatly between different types of soils, climates, and crops.

9. Use of phosphate rock[2]. Phosphoric rock is the main source for the production of phosphate fertilizers; however, in powdered form, it can be used directly as a source of phosphorus and calcium in acidic soils where these nutrients are slowly released, which improves soil pH and is much cheaper than mineral fertilizer.

10. Fertigation in greenhouses (Martínez-García, n.d.). The production of vegetables in greenhouses using a universal nutrient solution minimizes the use of resources and reduces the ecological impact (there is no loss of mineral fertilizer). This technology allows cost reduction, increased productivity, increased net profits and reduced water use. In the production of these crops at the field level, very large amounts of fertilizer and irrigation water are applied, causing the appearance of fungi and pests, as well as problems due to contamination.


©FAO/José Hernández

[2] https://docs.google.com/document/d/10TJjz9gSTFSvsGMlJrP3Rm-Y56dLxsc-Mx_xGQjsi564/edit?usp=sharing (Use of phosphate rock in acid sulfate soils)

EXAMPLES OF PUBLIC POLICY

The transition from the use of traditional mineral fertilizers to other technologies for the sustainable management of soil fertilization and plant nutrition requires governance mechanisms and instruments that promote and regulate their production, use and marketing. In this regard, some countries have been developing laws, regulations and programmes related to this topic. Some examples from the region are presented below.

Colombia (Botero, 2022). This approach is based on training, strengthening of transfer mechanisms and coordination between research and extension, as well as the development of public policies.

1. Legal actions. Presentation to Congress of a bill that creates the national system of agricultural inputs and promotes the use of bio-fertilizers and bio-inputs in the country, thereby seeking a transition to more sustainable and friendly production systems. In this regard, and based on studies carried out in cooperation with the country's National Research Centre (AGROSAVIA), it has been identified that by using available chicken and pig manure the country could reduce the use of artificial fertilizers by 62 percent.

Legal actions are based on four strategies:

> **i. Definition of policy guidelines for agricultural inputs aimed at increasing the competitiveness of agricultural activities**, which are comprised of three axes: price policy (continuous monitoring), access and marketing (negotiation capacity, rural financial services, and national fund for access to inputs with the aim of providing producers with the tools and support to access agricultural inputs in the national market) and use and application of inputs (optimal levels of productivity). In addition, the policy seeks to reduce transportation costs from the place of purchase to the municipal capitals, while covering part of the cost of soil analysis and related soil fertilization plans, and supporting research, development, and production of bio-inputs.
>
> **ii. Support the implementation of technology dissemination and transfer strategies** to promote the use of bio-inputs.
>
> **iii. Strengthening of the supervision of input prices** (price monitoring and control). All market agents can set prices freely, but must report them during the first 10 days of the month. This strategy is linked to the bio-inputs sector, inventories, quantities sold and suppliers.
>
> **iv. Regulation of Law 2183 (2022)** on the national system of agricultural inputs and the national policy of agricultural inputs, as well as the formation of the national council for agricultural inputs (made up of all the entities in the input system, including producers and marketers), the national commission (made up of government representatives, which establishes the general policies of the sector), and the monitoring of agricultural inputs (provides information for decision making).

2. National agricultural input policy linked to CONPES TRI. Agricultural input policies, promotion of national production and registration of input producers.

3. International diplomacy to guarantee the supply of fertilizers at the international level. Relations are currently maintained with Morocco and the United Arab Emirates for nitrogenous fertilizers, and with Canada for potash fertilizers.

4. Cut to zero import tariffs on agricultural inputs and mixtures to reduce costs and facilitate access to inputs. In addition, centralized purchases have been promoted through associations and e-commerce.

5. Permanent communication with the six large input distribution companies to permanently monitor the status and quantity of inputs, in order to guarantee the supply of inputs throughout the year.

Brazil (Peixoto, 2022): In the 1980s, a law was passed to regulate the inspection and supervision of the production and trade of fertilizers, correctors, inoculants, stimulants or bio-fertilizers, remineralizers and plant substrates for agriculture (Brazil, LEI No. 6 894, 1980). Since 2020, the Ministry of Agriculture, Livestock and Supply has implemented the bio-inputs programme to take advantage of the potential of Brazilian biodiversity and reduce the dependence of rural producers on imported inputs and expand the supply of raw materials for the sector. Through this programme, an application was developed for mobile phones, with more than 580 bio-products already registered that can be consulted by producers. These efforts have translated into at least 40 million hectares cultivated using growth-promoting bacteria.

In addition, international legal frameworks, such as the Convention on Biological Diversity, National Biodiversity Policy, the National Programme for Biological Diversity (PRONABIO) launched in 2003, and the International Treaty on Plant Genetic Resources for Food and Agriculture, have been linked with the national public policy framework (Agrochemicals law, Biosafety law, inspection and supervision of the production and marketing of fertilizers, correctives, inoculants, stimulants or bio-fertilizers, the National Fertilizer Plan (PNF) and the National Bio-inputs Programme) and with the definition of concepts and guidelines.

Peru: Supreme Decree No. 003-2022-MIDAGRI declared an Emergency in the Agricultural and Irrigation Sector, and proposes the following lines of action: i) mechanical equipment and training for agricultural producers, ii) forms of associativity, prioritizing cooperativism, iii) optimization and diversification of financial and non-financial instruments for agricultural producers, and iv) agricultural inputs and certified seeds, prioritizing organic or ecological production (*El Peruano*, 2022).

Argentina: The Ministry of Agriculture, Livestock and Fisheries has an Advisory Committee on Bio-inputs for Agricultural Use,[3] which advises the authorities on issues related to bio-inputs for agricultural use, proposes new regulations and gives its opinion on the implementation of regulations in relation to bio-inputs for agricultural use. It also proposes technical criteria, priorities and actions in relation to policies, plans, programmes and projects related to bio-inputs, and offers advice on the granting of Argentina's bio-product certification in terms of the evaluation of bio-input development for agricultural use.

Meanwhile, at the provincial level, resolutions have been generated that promote the strengthening of bio-factories. Bio-factories are centres for the production, development and fine-tuning of different bio-preparations, both liquid and solid, to be used in production systems. These bio-factories are managed by the State and/or by organizations, with special manufacturing protocols defined for their operation.

Ecuador: In 2019, the first regulation was developed for the registration of biological control agents, mineral preparations, plant extracts, semi-chemicals and other inputs for agricultural use.[4] This has the strategic objective of formalizing the operators dedicated to the manufacture, formulation, distribution and packaging of these inputs, as well as ensuring that they comply with the necessary procedures and criteria that guarantee quality and stability in the market.

Uruguay: Resolution No. 97/018 DGSA includes requirements for the registration and control of the commercialization of inputs formulated from raw material of organic origin for agricultural use.

3 https://www.argentina.gob.ar/agricultura/alimentos-y-bioeconomia/comite-asesor-en-bioinsumos-de-uso-agropecuario

4 ECUADOR ES CALIDAD: Revista Científica Ecuatoriana, 2020, Vol. 7 Num. 1 https://revistaecuadorescalidad.agrocalidad.gob.ec/revistaecuadorescalidad/index.php/revista/article/download/100/258/

BIBLIOGRAPHY

Agrosavia. N.d. *Equipo modular de lombricompostaje para el aprovechamiento de residuos vegetales de pequeños y medianos productores.* (available at: https://www.agrosavia.co/productos-y-servicios/oferta-tecnol%C3%B3gica/0613-equipo-modular-de-lombricompostaje-con-residuos-agricolas). Accessed: 30 June 2022.

Latin America and Caribbean Soil Partnership (LACS). 2020. *Apoyo a la cooperación regional para la gestión climática de los ecosistemas agrícolas con énfasis en agua y suelo*. (available at: https://es.slideshare.net/Soils2012/aslac-pilar-1).

Agronews Castilla y León. 2022. *El mercado mundial de fertilizantes: la FAO hace balance de la situación de un mercado en dificultades*. Online edition of Agronews Castilla y León, 16 March 2022 (available at: https://www.agronewscastillayleon.com/el-mercado-mundial-de-fertilizantes-la-fao-hace-balance-de-la-situacion-de-un-mercado en#:~:text=La%20Asociaci%C3%B3n%20Internacional%20de%20la,precios%20m%C3%A1s%20elevados%20del%20pasado).

Botero, J. 2022. *Presentation in virtual seminar "Biofertilizers and other technologies available to address the fertilizer crisis in Latin America and the Caribbean"*. (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/).

Bourne, J.K. 2022. *La crisis alimentaria mundial se agrava con el tambaleo del suministro de fertilizantes*. Online edition of National Geographic, 24 May 2022 (available at: https://www.nationalgeographic.es/medio-ambiente/2022/05/la-crisis-alimentaria-mundial-se-agrava-con-el-tambaleo-del-suministro-de-fertilizantes).

Brazil, Presidency of the Republic, Civil House, Deputy for Legal Affairs. Regulation LEI N° 6 894. Adopted 1980. (available at: https://www.planalto.gov.br/ccivil_03/leis/1980-1988/l6894.htm).

Cáceres, A. N.d. *Uso de micorrizas arbusculares y rizobacterias en los procesos de recuperación de áreas degradadas por el manejo forestal en la Reserva Forestal Imataca*. Venezuela. (available at: https://drive.google.com/file/d/1u5vxSOeOYeAU5izveg1mTpumGcTMGxwT/view). Accessed: 30 June 2022.

Calles, T. 2022. *Presentation in virtual seminar "Biofertilizers and other technologies available to address the fertilizer crisis in Latin America and the Caribbean"*. (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/).

Castillo, X. N.d. *PROYECTO AGRICULTURA, SUELOS Y AGUA (Evaluación del efecto de los sistemas de agricultura de conservación y sistema convencional en las propiedades físicas del suelo).* (available at: https://drive.google.com/file/d/1lVT3OY3To_dlf3vxPJ3wDCDQ62JZzQeu/view). Accessed: 30 June 2022.

Cowie, A., Van Zwieten, L., Pal, B. and Anaya de la Rosa, R. 2017. *Biochar as a strategy for sustainable land management and climate change mitigation*. Rome. Global Symposium on Soil Organic Carbon. (available at: https://www.fao.org/3/br997e/br997e.pdf).

El Peruano. 2022. Normas legales. Online edition of *El Peruano*, 19 March 2022 (available at: https://busquedas.elperuano.pe/download/url/decreto-supremo-que-declara-en-emergencia-el-sector-agrario-decreto-supremo-no-003-2022-midagri-2049959-6). Accessed: 30 June de 2022.

EM Producción y Tecnología S.A. (EMPROTEC). N.d. *Guía de la Tecnología de EM*. San Juan de Tibás, Costa Rica.

FAO. 2022. *Biofertilizers and other technologies available to address the fertilizer crisis In Latin America and the Caribbean* (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/). Accessed: 30 June 2022.

Hirzel, J. 2022. *Presentation in virtual seminar "Biofertilizers and other technologies available to address the fertilizer crisis in Latin America and the Caribbean"*. (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/).

Hirzel, J. 2021. *Respuesta productiva de cultivos y frutales a la aplicación de enmiendas orgánicas como fuente nutricional alternativa al uso de fertilizantes convencionales – Caso Chile*. Chile. (available at: https://drive.google.com/file/d/1kTLWv-gRcxW9p_Qtiuzpq_vU_RX0wnL1/view). Accessed: 30 June de 2022.

Hungria da Cunha, M. 2022. *Presentation in virtual seminar "Biofertilizers and other technologies available to address the fertilizer crisis in Latin America and the Caribbean"*. (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/).

Martínez-García, A. N.d. *Fertirrigación eficiente para la producción sustentable de jitomate (Solanum lycopersicum) en Quiroga Michoacán: Estudio de Caso*. Mexico. (available at: https://drive.google.com/file/d/15LJ92ddw4p_T5HuUczbf-r4IDyJv7o1D/view). Accessed: 30 June de 2022.

Medina Navarro, M. FAO plant nutrition specialist of the Plant Production and Protection Division (NSP), in personal communication with the author. June 21, 2022.

Peixoto, M. 2022. *Presentation in virtual seminar "Biofertilizers and other technologies available to address the fertilizer crisis in Latin America and the Caribbean"*. (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/).

Ramírez, L. 2017. *Agricultura orgánica de bajo costo y cambio climático*. San José, Costa Rica. INTA. (available at: http://www.platicar.go.cr/images/buscador/documents/pdf/04/Agricultura_organica_de_bajo_costo_y_cambio_climatico-min.pdf).

Rey, J.C. 2009. *Innovaciones tecnológicas para el manejo y mejoramiento de la calidad y salud de suelos bananeros de América Latina y el Caribe – Caso Venezuela*. (available at: https://drive.google.com/file/d/1u48vAlYxtFHhKt-BLg4LSe7LsCXjOg9e/view). Accessed: 30 June de 2022.

Reyes, F. 2022. *Presentation in virtual seminar "Biofertilizers and other technologies available to address the fertilizer crisis in Latin America and the Caribbean"*. (available at: https://www.fao.org/americas/eventos/ver/en/c/1513177/).

Standler-Kaulich, N. 2006. *Agroforestería Dinámica o también llamada Sucesional*. Bolivia. (available at: https://drive.google.com/file/d/13nmTMAj_cT0smYq5xLeoLuiL_OvJMLyL/view). Accessed: 30 June de 2022.

Wani, S. and Lee, K. 1992. Role of Biofertilizers in Upland Crop Production. In H.L.S. Tandon, ed. *Fertilizers Organic Manures Recycle Wastes and Biofertilizers*. Bhanot Corner, New Delhi, Fertilizer Development and Consultation Organization. Pp. 912.

Some rights reserved. This work is available under a CC BY-NC-SA 3.0 IGO licence

© FAO, 2022
CC0964EN/1/07.22