Circular fertilizers for healthy soils

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Since the 1950s, European agriculture has increased yields significantly thanks to synthetic fertilizers. The Haber-Bosch process and the industrial scale extraction and transformation of phosphate rock allowed the right amount of requested nutrients into the fields. Nowadays, when the agricultural yield has reached a maximum, the focus has moved to environmental sustainability, and maintaining high yields while decreasing the environmental impact.

In addition, over the last few decades, the EU energy and raw materials dependency has turned out to be also a relevant issue to be tackled. In this respect, in 2014 the European Commission (EC) included phosphate rock on the "EU Critical Raw Material" list, due to its pivotal importance and scarcity in Europe. For now, the large majority of phosphate fertilization comes from extra-EU countries. Nitrogen-based fertilizers are also an issue - while they do not require a finite raw material to be produced, the increasing cost of energy, and especially of methane, that hit the EU in the last year and a half, resulted in an escalation of fertilizer prices.

The paradigm of using recycled organic matter and nutrients

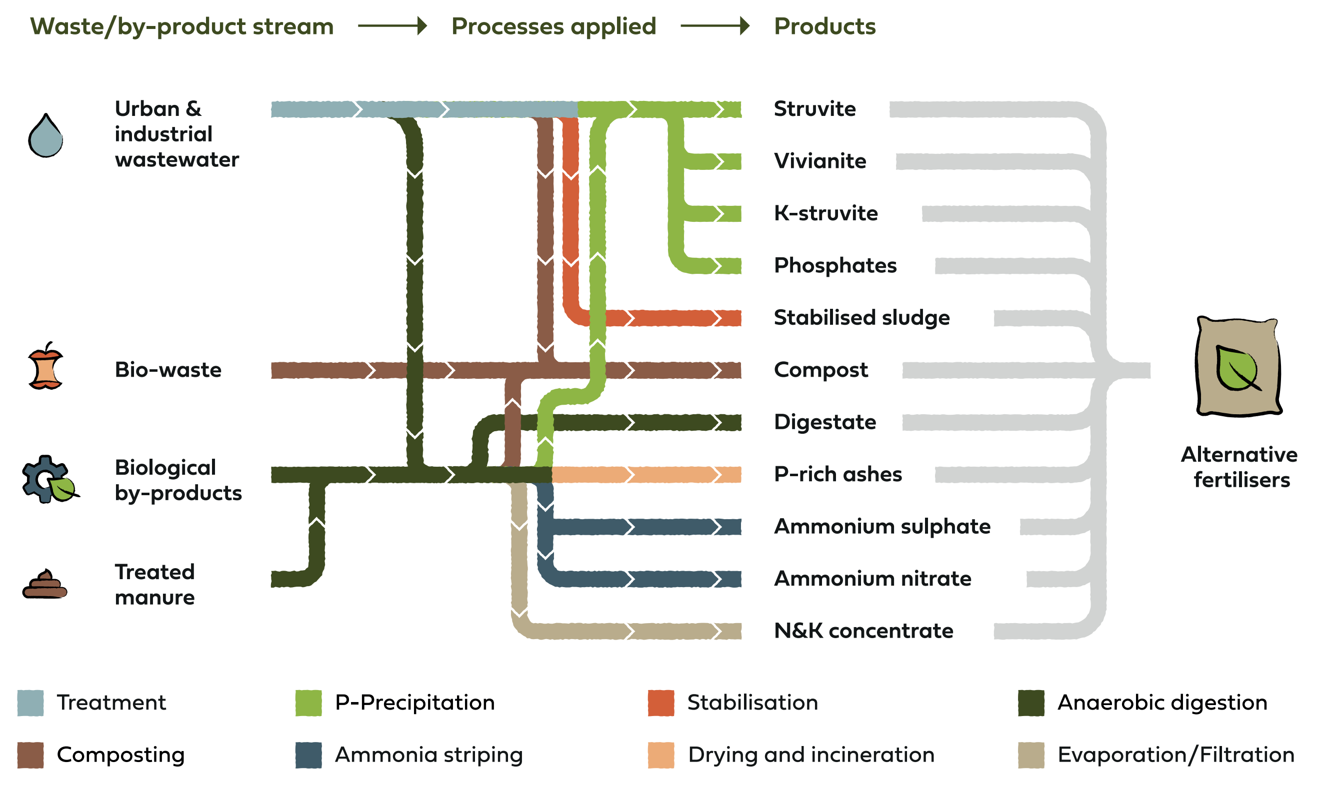
The opportunity of recycling nutrients is not to be missed. These practices reduced both costs and the environmental impact of waste disposal, while assuring the reuse and recirculation of materials that are scarce or absent in the EU and would otherwise be imported. The use of circular fertilizers helps to meet the goals of EU Green Deal of 20% less fertilizer use, 50% less nutrient loss, and 25% more organic farming and help preserve soil ecosystem.

In line with this, the EC is facilitating the transition towards a more sustainable use of fertilizers through various regulatory mechanisms. For instance, the Common Agricultural Policy (CAP) implements eco-schemes that provide financial support to farmers who take extra steps in environmental conservation and climate action by adopting organic fertilizers for their land. The Soil Monitoring Law, which has not yet been released, will establish indicators and their respective thresholds to determine healthy soil conditions, alongside a plan for mapping and monitoring European soils. Concerning agricultural soils, their state is significantly impacted by fertilizer usage, and with the final version of the law, it is anticipated that many of these indicators will be positively affected by the use of the circular fertilizers discussed in this article.

Circular fertilizers and soil health

Reducing industrial emissions from fertilizer production is not the sole reason for the widespread adoption of nutrient recycling. Organic matter must be supplied to agricultural soil to maintain current levels of agricultural productivity. Before the introduction of synthetic fertilizers, agricultural soils were naturally rich in organic matter. In fact, the primary method of fertilization was through the use of animal manure, crop rotations,

Figure 1. Main alternative fertilizer value chains evaluated by the project. Waste and by products (dark blue), output products (light green) and processes (grey)



and green manure – all practices that provided significant quantities of organic matter to the soil.

With the introduction of synthetic fertilizers on organic matter-rich soils, crop performance increased initially. However, over the years, this organic supply diminished, and nowadays, most arable land in Western countries exhibits very low organic carbon content. This situation not only results in reduced yields but also makes crops more susceptible to drought and diseases. Furthermore, it leads to soil compaction, requiring more energy for cultivation, and increased erosion. These issues are of great concern to farmers and growers. Additionally, loss of biodiversity, nutrient leaching and CO_2 emissions are subject of ongoing attention.

All of these reasons underscore the importance of recycling organic matter from organic-based waste and by-products into circular fertilizers.

Anaerobic digestion and composting are common methods to produce carbon-rich, stabilized, and sanitized organic fertilizers from waste and by-product streams, enabling safe application to agricultural soils.

Regarding nutrients, especially nitrogen and phosphorus, circular fertilizers differ from conventional fertilizers in providing these components in a different chemical form. Conventional fertilizers release nutrients rapidly, resulting in immediate availability to crops but also substantial adsorption on soil particle surfaces. This limits nutrient availability to crops during later stages of growth when demand is high. In contrast, the advantage of the slow nutrient release characteristic of circular fertilizers is that it ensures a long-term supply of nutrients that aligns closely with the plant's demand throughout the growing season, increasing efficiency of use.

From bio-waste to high quality compost

The production of compost from bio-waste begins with the separate collection of food waste from household kitchens and the Ho.Re.Ca. sector sources. The importance of a high-quality separate collection is paramount in achieving good compost quality, particularly concerning the presence of contaminants.

Traditionally, this waste stream is mixed with shredded green waste before proceeding to the composting phase. However, in recent years, an increasing portion of this waste undergoes anaerobic digestion before composting. This is because it generates an important energy by-product known as biogas. In the industrial practice, prior to anaerobic digestion, the waste typically undergoes pre-treatment to remove residual impurities like plastic, glass, and metal present in the food waste.

High quality compost and struvite for agriculture

After about 20-25 days of anaerobic digestion, the resulting by-product, rich in organic matter (known as digestate), is mixed with shredded green waste. This green waste is necessary as a bulking agent and to balance the C/N ratio, and then proceeds to the aerobic composting phase. The composting process consists of two stages: an oxygen-consuming phase called Active Composting Time (ACT), which is often static with forced air flow, followed by a curing phase that usually involves periodic mechanical turnings.

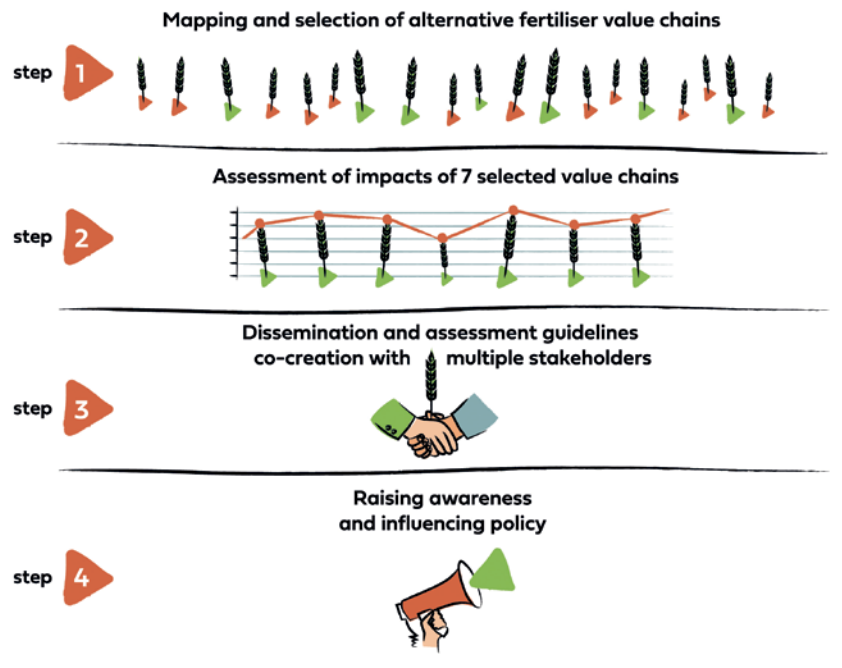
The final step involves screening to remove larger wood particles, which are recirculated to the mixing phase, and physical contaminants that are disposed of. At this point, the compost is ready for use in agriculture. Thanks to its amending properties, derived from a high content of stable organic matter, it can help growers cultivate healthier and more resilient crops. In most cases, when applied alongside synthetic fertilizers, it can lead to increased yields compared to using mineral fertilizers alone.

Compost has already been recognized as an organic soil improver by several EU countries for decades. It has been included (as CMC3) among the component material categories of Regulation (EU) 2019/1009, making it suitable for producing EU-compliant fertilizers. Specifically, compost can easily meet the requirements for organic soil improvers (PFC 3(A)).

Urban and industrial wastewater to struvite

Industrial and urban wastewater contains valuable by-products that, under the right conditions, can be transformed into energy and nutrients.

Figure 2. Scheme of FER-PLAY working plan



The entire concept of nutrient recovery within a wastewater treatment system revolves around capturing, concentrating, and converting these nutrients (such as N, P, and K) into a usable, marketable product, such as fertilizer. Phosphorus, a critical macronutrient for agriculture, is typically added to soil through the use of mined mineral fertilizers, which have significant environmental impacts due to their extraction.

Struvite, a mineral fertilizer rich in phosphorus, can be recovered from either industrial or urban wastewater. The conversion of soluble P found in wastewater streams into struvite can be achieved in a crystallization reactor with proper mixing and alkaline conditions. Magnesium is additionally added to the process to reach the required concentrations for effective phosphorus recovery. The resulting struvite is grown into granules ranging in size from 0.5-2.0 mm and is then harvested from the system. In accordance with the new Regulation (EU) 2019/1009, struvite falls under the category of 'compound solid inorganic macronutrient fertilizer' - PFC 1(C)(I)(a)(ii) - and complies with the requirements outlined in CMC12 for the application of recovered fertilizer products from waste streams.

Struvite, expressed as $NH_4MgPO_4 \cdot 6H_2O$, contains 5% ammonium nitrogen (NH_4-N), 28% phosphoric anhydride (P_2O_5), and 15% magnesium oxide (MgO). It is a slow-release fertilizer suitable for precision and organic farming. Struvite's solubility in weak acids, such as organic acids secreted by plants, gives it the unique property of a slow release and phased delivery of phosphate in proximity to the plant. This results in the development of a stronger root system over an extended period, preventing nutrient runoff into water bodies and thereby mitigating environmental pollution, such as eutrophication. Additionally, the application of struvite leads to fewer to negligible N_2O emissions compared to synthetic fertilizers.

The installation of a struvite precipitation process within a wastewater treatment line is not solely driven by struvite production. Instead, it addresses phosphorus-related issues, including dewatering improvement, the creation of an internal P-return loop, and stabilizing nutrient removal treatment, resulting in a rapid return on investment. This process is a well-established technology with a proven track record and is ready for expansion.

Circular fertilizer use in organic farming

Organic farming is an agricultural method for producing food and feed using natural substances and processes. It prioritizes environmental, social, and economic benefits over raw yield production. The European Union (EU) promotes organic farming through various means, including direct contributions in the Common Agricultural Policy (CAP) and the objectives outlined in the Green Deal. This commitment includes targets set by the Farm to Fork and Biodiversity strategies, aiming to have 25% of EU agricultural land dedicated to organic farming by 2030.

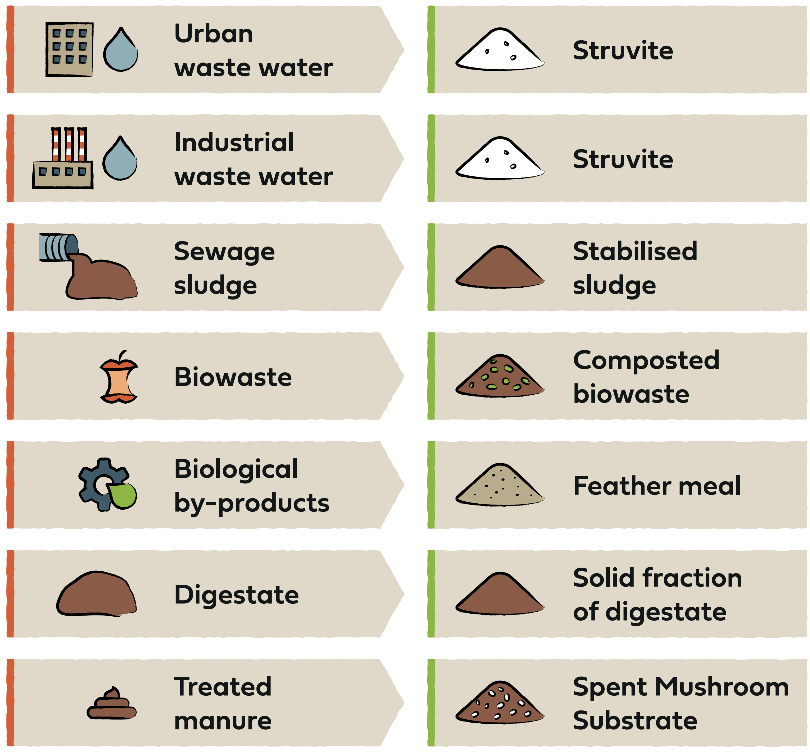
In organic farming, the use of the most common synthetic fertilizers is prohibited. Fertilization is typically carried out through methods such as green manure, crop rotation, or the use of permitted organic fertilizers. Often, a shortage of nutrients is one of the main challenges faced by organic farmers. Fortunately, most circular fertilizers align with EU Regulation 1165/2021, which governs organic farming practices and offers compliance in this regard.

FER-PLAY project: circular fertilizers for healthy soils

The European Commission dedicates special funding to promote collaboration and strengthen the impact of research and innovation in developing, supporting, and implementing EU policies while addressing global challenges. As agriculture holds significant importance for Europe, certain specific calls are allocated to this sector.

One such example of a collaborative project financed by the EU is FER-PLAY, which focuses on circular fertilizers, assessing their benefits in comparison

Figure 3. The seven value chains selected by FER-PLAY, from waste and by-products to circular fertilizers



to conventional ones and facilitating their market adoption. The working group comprises twelve partners representing various entities, including farmers' and local administration associations, fertilizer producer companies, and research centres, all from five EU countries. FER-PLAY has now entered its second year, with 18 months of work ahead. The project has already mapped 61 relevant value chains from seven different waste streams and by-products, including urban wastewater, industrial wastewater, sewage sludge, manure, digestate, biological by-products, and bio-waste. It has also made a public database available to various stakeholders, providing information on these value chains at all levels, including production, distribution, trade, storage, application on soils, product characteristics, costs, and legislative considerations.

Out of these value chains, seven have been selected following a multi-criteria approach for further assessment. In this regard, the partnership is currently engaged on two fronts. Firstly, they are conducting a social, environmental, and economic assessment of these seven value chains to evaluate their performance. Secondly, they are actively engaged in co-creating favourable conditions for the adoption of circular fertilizers. This involves ongoing communication with fertilizer stakeholders, including end users, fertilizer producers, and administrations, to identify and address barriers to the use of these products. They are also preparing guiding documents to assist these categories in making the best use of these resources. ■

For further information on the project visit ***http://fer-play.eu/***
Or contact the project coordinator, ***martin.soriano@cetenma.es***