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LATEST NEWS

Increasing the resilience of agricultural farms with declining fertility

Modern agriculture has achieved remarkable productivity gains; however, heavy reliance on synthetic fertilizers, driven by intensified farming technologies, has heightened the economic and ecological vulnerability of cropping systems. In the European Union, the consumption of nitrogen- and phosphorus-based mineral fertilizers reached 9.8 million tons in 2024-an increase compared to the previous year, yet below the 11.6 million-tons mark recorded in 2017. In Romania, fertilizer use increased by 137.5 thousand tons in total nitrogen-based fertilizer consumption between 2014 and 2024, and by 35 thousand tons for phosphorus-based fertilizers.

Today, Romanian farmers face significant economic pressures due to the massive rise in chemical fertilizer costs, driven by natural gas price fluctuations and geopolitical disruptions along international trade routes. Reduced domestic fertilizer production and increased imports have affected NPK fertilizer application rates per unit of cultivated land. This adjustment reflects farmers' efforts to absorb price shocks and volatility in international input markets. At the same time, reliance on imports heightens the financial risks Romanian farms face. In this context, optimizing fertilizer application rates becomes critical for maintaining farm profitability and resilience.

Soil fertility is the soil's fundamental capacity to provide plants with necessary nutrients continuously and in a balanced manner, closely linked to water availability and biological activity. A common misconception in practice is that increasing fertilizer rates automatically leads to proportional increases in yield. In reality, crop response follows the law of diminishing returns, meaning yield gains from each additional unit of nutrient gradually decrease. Furthermore, exceeding optimal rates becomes economically inefficient and can lead to toxicity issues. Nutrient Use Efficiency (NUE) is the key indicator for monitoring sustainability and the rational application of fertilizers. Optimizing this process shows that rationalizing fertilizer rates enables high, stable yields while using fewer resources.

Soil microorganisms are responsible for the natural transformation and release of nutrients. When chemical fertilizers are applied in excess, the soil's biological balance suffers, disrupting the beneficial relationship between plants and the microbial community. Soil microflora contribute significantly. On the one hand, nitrogen-fixing bacteria can supply significant amounts of atmospheric nitrogen through symbiosis with legumes. On the other hand, soil bacteria mineralize organic matter and release nutrients that plants can assimilate, while mycorrhizal fungi and specialized bacteria transform phosphorus reserves that are otherwise inaccessible to plants. The impact of fertilizers on soil microbiota depends directly on the dosage, type, and balance of the applied nutrients. The rational application of mineral fertilizers stimulates microbial activity in the short term by supplying essential nutrients and increasing root mass and rhizosphere exudates, thereby providing a rich carbon source for microorganisms. Conversely, unbalanced or excessive application of synthetic fertilizers (particularly those based on ammoniacal nitrogen and urea) can severely inhibit microbial activity. An excess of mineral salts increases the osmotic pressure of the soil solution, disrupting microbial cells. Furthermore, heavy and repeated nitrogen fertilization accelerates soil acidification-a process that inhibits nitrifying and nitrogen-fixing bacteria, reduces the functional diversity of microbial communities, and promotes the proliferation of pathogenic fungi. Additionally, the excessive availability of mineral nitrogen from synthetic sources can suppress the natural symbiosis between leguminous plants and nitrogen-fixing bacteria, as well as the colonization of roots by mycorrhizal fungi in the case of phosphorus.

Against this backdrop, interest is growing in developing and using biofertilizers-preparations based on living microorganisms that enhance beneficial microbial processes, increase nutrient availability for plants, and reduce reliance on chemical inputs. Biofertilizers support a diverse range of soil functions and maintain the flow of biogeochemical cycles. They convert insoluble forms of phosphorus, potassium, and trace elements in the soil into forms easily assimilable by plants through the secretion of organic acids and enzymes. They supplement atmospheric nitrogen input without a carbon footprint or the risk of leaching, while also producing phytohormones that stimulate root growth and enhance water and nutrient absorption capacity. From a crop protection perspective, these inputs secrete antimicrobial substances and induce systemic plant resistance, thereby protecting the rhizosphere and increasing drought tolerance. When integrated with rational mineral fertilization and organic sources, biofertilizers allow reduced synthetic fertilizer application rates, preserve soil structure and fertility, and provide sustainable biological support for high agricultural yields.

Optimizing fertilizer application rates is also essential for protecting water resources and combating environmental degradation. Excess nitrogen is not retained by the soil complex and easily leaches into groundwater and surface water, causing eutrophication. Compliance with environmental regulations-such as the Nitrates Directive and the Code of Good Agricultural Practice-imposes clear limits on nitrogen application and mandates the establishment of buffer strips along watercourses. Beyond environmental benefits, the use of organic fertilizers and conservation practices enhances farm resilience to drought. Increasing organic matter content improves soil structure and the capacity to retain precipitation, while also stimulating deep root development.

The transition to integrated nutrient management entails implementing practical measures at the farm level. A primary measure is conducting periodic agrochemical mapping-every 3-4 years-to determine economically optimal application rates. Incorporating legumes into crop rotations and using cover crops benefit nitrogen fixation and soil health. Applying organic fertilizers, supplemented by split applications of mineral fertilizers, enhances soil fertility and nutrient use efficiency. Techniques such as localized row application or fertigation are beneficial for increasing the nutrient utilization rate by plants.

A lack of fertilization leads to severe soil depletion, caused by the massive removal of nutrients through the harvest. A wheat yield of 6 t/ha extracts 180 kg N, 96 kg P_2O_5, and 192 kg K_2O from the soil; a maize yield of 10 t/ha removes 300 kg N, 140 kg P_2O_5, and 300 kg K_2O; and a rapeseed yield of 4 t/ha consumes 220 kg N, 160 kg P_2O_5, and 220 kg K_2O. In the long term, failing to replenish these nutrient losses reduces soil fertility and leads to declines in humus content, structural changes, acidification, and depletion of plant-available nutrients, resulting in yield losses of up to 70–80%.

To coordinate these measures, a globally adopted international reference framework is the 4C Principle (adapted from the "4R Nutrient Stewardship" concept developed by the International Plant Nutrition Institute – IPNI, in collaboration with The Fertilizer Institute and the International Fertilizer Association). The 4C Principle promotes best management practices through:

(1) The right type (source), involving the selection of the appropriate fertilizer based on soil properties and crop requirements;

(2) The right rate, to optimize the quantity of nutrients applied in relation to the plants' actual needs;

(3) The right time, ensuring nutrient availability during the crop's critical uptake phases;

(4) The right method (placement), involving the application of fertilizer where the plant can absorb it with maximum efficiency.

Adopting the 4C approach directly improves the nutritional and technological quality of the harvest while preventing the unwanted accumulation of chemical compounds (such as nitrates) in agricultural products intended for human consumption and animal feed.

Conclusion

Soil is the only non-renewable resource on a human timescale and serves as the fundamental basis for agricultural production and global food security. Under current conditions, a key objective is to ensure food supplies for a constantly growing population while simultaneously preserving the soil's physical and chemical properties and its biological fertility. Understanding and applying these principles is a shared responsibility for all stakeholders in the agri-food chain-from farmers and the academic and research communities to input manufacturers and processors.

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