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Editorial

Fertilizer Use, Soil Health and Agricultural Sustainability

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Due to the growing population and consequent pressure of use, agricultural soils must maintain adequate levels of quantity and quality to produce food, fiber, and energy, without falling victim to a negative impact on their balance of nutrients, health, or their ability to function. The use of mineral fertilizers has long been a key tool to offset nutrient outputs and thus achieve increased yields [1–4]. Fertilizer application is believed to have been responsible for at least 50% increase in crop yield in the 20th century [5,6]. According to [5], average corn yields would decline by 40 percent without nitrogen (N) fertilizer application, while long-term studies confirmed a 40–57 percent yield decline in wheat without fertilizer application. Yousaf et al. [6] reported a 19–41% yield increase in rice, and a 61–76% increase in rapeseed with the combined application of NPK fertilizers.

However, due to the inappropriate use of mineral fertilizers (i.e., when used in both excess or deficiency), mostly concerning nitrogenous and phosphate, many productive soils have been thwarted in their ability to function, as shown not only by chemical indicators but also by physical and biological ones. Thus, improper fertilizing technology might have a negative effect on soil health and soil-related ecosystem services. Imbalanced use of chemical fertilizers can alter soil pH, and increase pests attack, acidification, and soil crust, which results in a decrease in soil organic carbon and useful organisms, stunting plant growth and yield, and even leading to the emission of greenhouse gases [7,8]. Soil health is defined as the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal health and productivity, and maintain or improve water and air quality. A major challenge for agricultural sustainability is to conserve ecosystem service delivery while optimizing agricultural yields. This Special Issue addresses the task to find a balance between increasing yields using conventional and novel fertilizers, and the maintenance of soil and environmental health as a basis for the sustainable intensification of the agricultural sector.

The purpose of this issue was to provide new knowledge on fertilizer use, soil health, and agricultural sustainability. We received a total of 13 papers that provided interesting and innovative information. Five of them [9–13] were works on basic studies on the status of nutrients. These studies were based on the reviews of published works, or on experiments under controlled conditions (greenhouse and incubation) referring to nitrogen losses due to volatilization, leaching, denitrification, the distribution of nutrients, the combined or integrated use of mineral and organic fertilizers, bio-based nitrogen, or new findings in sulfur, a largely low-attended nutrient.

In the study of Ning et al. [9], effects of P amendment on nitrification in a fertile agricultural soil were investigated. In soils that received no amendments (control), P only, urea only, and urea plus P amendment, nitrification occurred within the first five days, with an average net nitrification rate of 5.30, 5.77, 16.66 and 9.00 mg N kg^{-1} d^{-1}, respectively. Nitrification in urea-treated soils was retarded by P addition where a N:P ratio seemed to be a key factor impeding nitrification. This was also supported by the response of ammonia-oxidizing bacteria (AOB), which was more sensitive to P addition than ammonia-oxidizing archaea (AOA). The outcome of this study showed that the application of P fertilizer suppressed the nitrification process in urea-amended soil, suggesting that a synergistic aspect of N and P nutrient management should be further explored to retard N losses from agricultural systems.

According to Pan et al. [10], soil nutrient balance is related to the interaction mechanism between soil fertilizer, soil water, climate change, and plant capability. This study confirmed that publication outputs increased exponentially from 1992 to 2020. The synthetic parameter of the sum of normalized data (SND), calculated from the default indicators of the bibliometric software tools, was used to rank the overall contribution of journal/authors/institutions/countries. The results indicated that nitrogen fertilizer, green manure, and soil population have gained close attention from scholars, while the soil amendment of biochar has evolved as a hot topic in recent years.

On the other hand, Skorupka and Nosalewicz [11] revealed that agriculture is responsible for 80–95% of total ammonia emissions to the atmosphere; however, at the same time, it has great potential to reduce them. Fertilization with mineral N (in particular urea) is responsible for 19.0–20.3% of total ammonia emissions emitted from agriculture. Ammonia emissions have a negative impact on the environment and human health; therefore, it is important to minimize the volatilization of ammonia and increase fertilizer use efficiency. This is important due to the need to mitigate the negative impact of anthropogenic pressure on the environment in terms of air pollution and the negative effects on soil and water. The application of urease inhibitors during fertilization with nitrogen fertilizers is one method to reduce ammonia emissions from plant production. The authors [11] also stressed the maximization of energy crops for the production of biofuels.

The results of Wan et al. [12] revealed that chemical fertilizer has been excessively used for the high yield of citrus around the world, especially in China; this has deteriorated the citrus orchard soil environment. To resolve this conflict, the use of organic fertilizer provides a promising solution. The authors concluded that the combined application of both organic and chemical fertilizers, and bioorganic and chemical fertilizers would be beneficial to improve soil fertility and citrus growth physiology, alleviate NO_3^--N leaching, and promote yields.

The effect of organic waste products was studied on sugarcane yield for four years by Feder [13]. The treatments included control mineral fertilization treatment with mulch (MCM) or without mulch (MC), and were compared with two organic waste treatments, a pig slurry with mulch (PSM) and without mulch (PS), and a sugarcane vinasse with mulch (SVM) and without mulch (SV). The results revealed that sugarcane yields obtained with the different treatments differed each year. Soil pH in the different treatments increased with the treatments including organic waste products (PS, PSM, SV and SVM), but remained constant with the treatments including only mineral fertilization (MC and MCM). With the exception of PS and PSM, which were significantly higher in year 4, soil organic carbon content was not modified by the treatments. Soil cation exchange capacity increased only slightly with the PS and PSM treatments from year three onwards. The differences in yields and soil properties can be explained by the nature of the organic waste products, the accumulation of nutrients after several applications, and the specific characteristics of the sugarcane crop. The improvement in soil properties from the third year was not reflected in the yield of sugarcane because it was too weak, and the crop explored a much larger volume of soil.

The other five contributions to our Special Issue [14–18] focused on organic fertilizers as their main subject of study. The addition of different kinds of residues and wastes is an extremely interesting option to pursue the objective of a circular economy based on recycling. Gao et al. [14] reported that cucumber monoculture could cause soil salinization and acidification, soilborne diseases, and eventually yield loss. They investigated how the soil abiotic and biotic properties, in addition to soil rhizosphere microbial community structure in the greenhouses, could still sustain plant growth after such long-term monoculture production. These results indicated that maintaining soil abiotic and biotic properties using organic fertilizers and balanced chemical fertilizers, especially improving potassium fertilizer application, could be useful measurements for the sustainable development of greenhouse vegetable production. In addition, appropriate management strategies should be considered to reduce the potential risk of soil salinization.

Li et al. [15] reported that the rapid development of cities in the last 10 years has caused a reduction in cultivated land area, which only accounts for 14% of the total land area in China. Land development and reclamation have been regarded as an effective way to compensate farmland occupation. The results from this study indicated that the soil quality (organic matter content) was ameliorated by chemical and organic fertilizers, in particular commercial organic fertilizers, which caused a 9.35–16.35% increase in moisture content, a 11.56–18.72% increase in pH, a 1.73–2.15-fold increase in organic matter content, a 338.44–491.41% increase in available P, a 36.80–48.14% increase in total N, a 95.32–128.34% increase in alkaline hydrolysis N, a 92.57–178.38% increase in total bacterial numbers, and a 7.57–20.87-fold increase in microbial biomass carbon compared with control.

According to Luo et al. [16], biobased nitrogen fertilizer derived from animal manure can substitute synthetic mineral N fertilizer and contribute to more sustainable methods of agriculture. This study compared the estimates for pig slurry (PS) and liquid fraction of digestate (LFD) using laboratory incubation and plant-growing experiments. A no-N treatment was used as the control, and calcium ammonium nitrate (CAN) as the synthetic mineral fertilizer. After 100 days of incubation, the addition of PS and LFD resulted in a net N mineralization rate of $10.6 \pm 0.3\%$ and $20.6 \pm 0.4\%$ of the total applied N, respectively. The addition of CAN showed no significant net mineralization or immobilization (net N release $96 \pm 6\%$). In the pot experiment under vegetation, all fertilized treatments caused N immobilization with a negative net N mineralization rate of $-51 \pm 11\%$, $-9 \pm 4\%$, and $-27 \pm 10\%$ of the total applied N in CAN, PS, and LFD treatments, respectively. Compared to the pot experiment, the laboratory incubation without vegetation may have overestimated the N value of biobased fertilizers.

According to Orden et al. [17], onion production in the low valley of Río Colorado (Buenos Aires) generates between 12,000 and 20,000 Mg year^{-1} of vegetal wastes (i.e., leaves, stems, skins, roots) from harvesting, cleaning and classification of the bulbs, causing many problems with their management. The results showed that the highest dose of compost caused the highest effects on soil pH, electrical conductivity, and nutrient content. Soil enzymatic activities were already high in the soil before the compost was applied, which may have contributed to the small effect caused by any dose on soil activity. A significant positive effect on bulb weight and organic onion yield was found as a result of the amendment and growing season. They concluded that the agroecological production of onions with the addition of a 300 kg N ha^{-1} as onion manure compost (OMC) and onion manure compost tea (OMCT) guarantees yields comparable to those of conventional fertilization.

In their study, Oueriemmi et al. [18] reported that farmyard manure, an amendment traditionally used for improving the fertility of sandy soils in arid climates, is becoming scarce and expensive. A field trial was established to analyze the effects of a single application of three organic residues on barley yield and nutrient uptake and selected soil properties after two consecutive harvests. Municipal solid waste compost (MSWC), sewage sludge compost (SSC), and farmyard manure (FYM) were tested at rates of 0, 20, 40, and 60 t ha^{-1}. Adding all three organic amendments increased organic matter, cation exchange capacity, and available P, Ca, Mg, and K in the soil, the grain yield (up to 51%), and the barley plants' nutrient contents. After the second harvest, a positive residual effect of the amendment was observed in plant yield (up to 77%) and nutrient content. MSWC and SSC induced slight increases in the extractable fractions (BCR protocol) of Co, Cu, and Ni, relative to the unamended soil. The results demonstrated the positive immediate and residual effect of the amendments evaluated as fertilizers for agricultural purposes [18]. In the next paper of Zenda et al. [19], the role of sulfur in crop production is discussed in detail. Sulfur application not only increases crop productivity and its quality, but also enhance plant resistance to abiotic stresses. Sulfur plays crucial roles in plant growth and development, with its functions ranging from being a structural constituent of macro-biomolecules to modulating several physiological processes and tolerance to abiotic stresses.

There are also papers dedicated to specific aspects of the effect of fertilizers on the microbiological activity of soils [20] and the spatial distribution of soil properties [21]. According to Ivanova et al. [20], soil biological activity is an integral characteristic reflecting the state of soil fertility, biodiversity, and the activity of soil processes carried out by soil organisms. In their paper [20], the authors assessed the multiple biochemical and microbiological properties of soil from an agricultural field located in the African tropical savanna. They determined basal respiration, substrate-induced respiration, C of microbial biomass, the potential activity of denitrification, nitrogen fixation activity, and estimated prokaryotic components in the soil microbial complex by quantitative PCR. The basal respiration of the soils ranged from 0.77 ± 0.04 to 1.90 ± 0.23 μg C-CO_2 g^{-1} h^{-1}, and substrate-induced respiration ranged from 3.31 ± 0.17 to 7.84 ± 1.04 μg C-CO_2 g^{-1} h^{-1}. The C reserves of microbial biomass averaged 403.7 ± 121.6 μg C g^{-1} of soil. The N_2O emission from the upper layer amounted to 2.79 ng N-N_2O g^{-1} day^{-1}, and the potential denitrification activity reached 745 ± 98 ng N-N_2O g^{-1} h^{-1}. The number of copies of bacterial genes varied from $(0.19 \pm 0.02) \times 10^8$ to $(3.52 \pm 0.8) \times 10^8$ copies g^{-1}, and of archaea, from $(0.10 \pm 0.01) \times 10^7$ to $(0.29 \pm 0.01) \times 10^7$ copies g^{-1} of soil.

Wang et al. [21] reported that soil nutrients are essential factors that reflect farmland quality. Nitrogen, P, and K are essential elements for plants, while silicon is considered a "quasi-essential" element. In this study, the spatial distribution of plant nutrients in soil from a hilly region of the Pearl River Delta in China was investigated. A total of 201 soil samples were collected from farmland topsoil (0–20 cm) for the analysis of total nitrogen (TN), available phosphorus (AP), available potassium (AK), and available silicon (ASi). The coefficients of variation ranged from 47.88% to 76.91%. The nugget-to-sill ratio (NSR) of TN, AP, AK, and ASi were 0.15, 0.07, 0.12, and 0.13, respectively. The NSRs varied from 0.02 to 0.20. All variables exhibited weak spatial dependence ($R2 < 0.5$), except for TN ($R2 = 0.701$). The uniform spatial distribution of AK and TN showed an overall trend of increasing from northeast to southwest, and the overall spatial distribution of AP and ASi showed that the northeast was higher than the southwest. This study provides support for the delimitation of basic farmland protection areas, the formulation of land-use spatial planning, and the formulation of accurate farmland protection policies.

The works received for this Special Issue demonstrate great variability in terms of geography, landscape and soil (East Africa, North Africa and the volcanic islands of the Indian Ocean, the Liaoning province in China, young valley soils in Argentine Patagonia, sandy aridic soils in Tunisia), and in crop and productive systems. Unlike largely studied synthetic fertilizers, such as urea and phosphates, organic fertilizers (animal manures, plant residues, farmyard manure) and bio-fertilizers (beneficial microbes) not only increase crop productivity, but also increase soil carbon stocks, and improve soil physical and biological properties [22–24]. In addition to demonstrating the recognized usefulness of these products as a source of nutrients to improve soil quality, these different works showed original results on different kinds of organic fertilizers (agricultural and animal waste, municipal waste and treated human waste), showing the impact on different soils and crop, and offering comparative analysis between them. These technical and socioeconomic aspects are crucial to make decisions for the better management of soil and crops, and to ensure the provision of healthy soil and healthy food in a sustainable manner.

Conflicts of Interest: The authors declare no conflict of interest.

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