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Editorial: Nitrogen dynamics and load in soils

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Editorial on the Research Topic
Nitrogen dynamics and load in soils

Among the chemical elements, nitrogen is one of the most abundant elements on Earth, making up approximately 78.1% of the atmosphere. It is also an essential nutrient for life, and it can take many chemical forms in soil. The reactions making possible the transformations among these forms are mainly driven by soil microorganisms. Several nitrogen-containing compounds are also toxic. Soil microbial reactions involving nitrogen, therefore, have the potential to affect human and environmental health, sometimes spatially and temporally far from the microorganisms that originally performed the transformation. During the last decades, anthropogenic activities have also seriously impacted the global biogeochemical nitrogen cycle.

The excessive use of nitrogen for crop production has negatively affected soil biodiversity as well as climate and human health due to increases in N_2O and NO emissions, NH_3 volatilization to the atmosphere, and NO_3^-, NO_2^- and NH_4^+ leaching to the aqua sphere. However, nitrogen shortage limits both the quantity and quality of crops, thereby reducing the ability to meet global food demand. The disturbance of the global biogeochemical nitrogen cycle reveals significant challenges and requires the immediate implementation of strategies for appropriate nitrogen management. Understanding nitrogen transformations and improving the knowledge of soil microbial biodiversity and their metabolic capacities, as well as proper management of nitrogen use for crops, are essential for understanding and managing ecosystem health and productivity.

In this context, this Research Topic is showcasing the relevance of the biogeochemical nitrogen cycle in soils as well as the negative impacts of massive fertilization on this cycle as well as on the quality of the soils used for agricultural purposes. We have encouraged scientists working on all aspects of the Nitrogen cycle in soils, to contribute to this Research Topic to share advanced and updated results in this field of knowledge. Thus, works focused on nitrogen biogeochemical transformation processes, methods, and strategies for mitigation of nitrogen losses in soil, nitrogen gas exchange in soil, soil amendments for nitrogen management, contributions of soil microbes to the global nitrogen balance, biotechnological applications of microorganisms in the soil to improve the growth of the crops or to promote soil bioremediation or soil management and application practices that affect nitrogen cycling, were welcome. The general and applied knowledge that emerges from these studies could be complemented by other research approaches aiming at the characterization of the biogeochemical nitrogen cycle in soils.

Among the main concerns related to the nitrogen cycle in soil, the use of massive amounts of fertilizers affects microbial biodiversity and modifies the main metabolic pathways of the N-cycle driven by microorganisms. Urea is one of the most used N fertilizers all over the world, accounting for approximately 60% of N fertilizer consumption (Glibert et al., 2014). However, urea cannot be absorbed and directly assimilated by plants. Urea must be hydrolysed to NH_3/NH_4 by the enzyme urease (EC 3.5.1.5) to provide bio-assimilated nitrogenous compounds for plants and soil microorganisms (Mobley and Hausinger, 1989). During the last two decades, there have been increasing concerns about relatively low urea-N use efficiency. Biochar has shown the potential to mitigate N loss, but how biochar influences urea hydrolysis and the underlying mechanisms are still unclear. In the work carried out by Zhao et al., long-term biochar-amended upland, paddy, and greenhouse soils were sampled at depths of 0–20 and 20–40 cm in Haicheng City, Northeast China Zhao et al. The authors monitored and quantified soil N concentrations, urea hydrolysis rates (UHRs), total intracellular and extracellular urease activity, as well as the total bacterial and ureolytic microbial gene abundance. The main results obtained in this work stated that the decrease of nitrogen concentrations in soil was accompanied by a higher UHR in upland and greenhouse soils, suggesting that the accelerated UHR caused a negative effect on the soil N content, possibly due to excessive NH_3 volatilization. In paddy soil, where the UHR was not increased, biochar was an effective amendment for simultaneously improving soil urease activity and N content. These results are in concordance with other previous works reported on this Research Topic and reinforce the message that N could be lost from soils. Consequently, a certain percentage of the nitrogen initially added as part of the fertilizer composition is lost for the crops by volatilization (i.e., NH_3, NO, N_2O or N_2) with which great economic losses are produced due to the inefficient use of fertilizers, while the quality of the soil deteriorates in terms of biogeochemical cycles and microbial biodiversity.

Along with rice fields, and wheat crops, corn crops are cultivated globally to meet food demands, and cover large agricultural areas all over the world (USDA, 2022). For this reason, they are usually used as model systems to analyse the effect of fertilizers on the growth of the crops and, on the health of the soils. In this context and, in connection with the research conducted by Zhao et al. described above, Deng et al. have analysed the responses of crop production and soil health to chemical nitrogen fertilization in a maize-wheat rotation system. In this study, the authors tested the effects of chemical nitrogen on crop production and soil health by conducting a 3-year trial with urea and controlled-release fertilizer in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) system shifted from vegetable farmland. They evaluated the effects of N fertilization on crop yields, typical soil properties, and soil bacterial community using 16S rRNA gene sequencing. The results obtained confirm the increase of the crop yield by the additions of the fertilizers, as expected, but after three cropping seasons, the soil N properties were notably altered. For each kg of N applied, significative changes in soil pH values were observed (pH decreased) and the C/N ratio linearly decreased as the N rate increased. Consequently, N application significantly decreased soil bacterial diversity. Thus, at the phylum level, chemical N application significantly depleted members of *Acidobacteria*, *Chloroflexi* and *Nitrospirae*, but the growth of Actinobacteria, *Gemmatimonadetes*, *Firmicutes* and *Patescibacteria* was improved. Compared with urea, the controlled-release fertilizer did not significantly change crop yields, soil bacterial diversity, soil TN and TC content. Overall, this work demonstrated that chemical nitrogen improved crop yields at optimum application rates, but abusive applications of nitrogen resulted in a decline in soil health, specifically accelerated soil acidification, a decrease in soil bacterial diversity, and soil C and N imbalance.

Considering that nitrogen transformations in soils are dynamic and highly dependent on the microbial biodiversity inhabiting those environments apart from climates, cropping systems, and management practices, it is important to obtain information from experiments in which all these parameters are considered to monitor nitrogen chemical transformations, not only in natural soils (not affected by anthropogenic activities) but also in soils for agricultural practices. There is a lack of knowledge in this sense, which makes it difficult to provide general N recommendation rates, advice or policies for fertilization in a specific region, state, or even in country. Regarding the connections between nitrogen transformations and all the mentioned parameters, the work here presented by Raza and Singh Farmaha includes a study aiming at the optimization of N fertilization rates for corn (*Zea mays* L.). To achieve the objective, eight field trials were conducted on different controlled fields at the Edisto Research and Education Centre of Clemson University in 2018–2021. The soils varied in physicochemical parameters like pH, inorganic N, management practices (irrigate, dryland, cover, and no-cover crop), and climatic conditions (temperature and precipitation). As expected, the corn yields generally increased with N fertilization rates; however, a significant variation existed at each N level among different fields. Based on yield responses, the eight field trials were divided into two categories to better understand the efficiency of the N treatments in connection with the physicochemical parameters integrated into the study. Thus, baseline inorganic N, pH values, and precipitation rates were identified as the major factors controlling corn yield responses to N fertilization. The yield variations driven by several factors make N management challenging, highlighting the need for site-specific N management and policies for the extensive cultivation of corn in the southeast United States. The main message from this research is that N management for crops and the efficiency in the use of fertilizers are affected by environmental parameters, climate and water availability, soil structure and chemical composition, microbial biodiversity, and the chemical composition of the fertilizers. Consequently, there is a need for specific programs in terms of N addition and management for each specific location to be used for agricultural purposes.

To improve the efficiency in the use of fertilizers on a large scale and minimize the negative impacts that the use of fertilizers has on the environment, the management of models that integrate all the environmental, physicochemical, and biological parameters reveals useful tools to establish predictions under different conditions, at large scale and for long periods. In this sense, the work carried out by Xia et al. faces one of the main concerns related to direct emissions of soil nitrous oxide (N_2O) during crop growing seasons. N_2O has a global warming potential that is 265 times greater than one of the better-known greenhouses gas, carbon dioxide (CO_2) (IPCC, 2014). The production of N_2O and NO in soil from fertilizers is mainly possible due to microbial organisms showing metabolic capacities as denitrifiers (partial denitrifiers are microorganisms favouring the production of NO or N_2O from nitrate or nitrite as part of the chemical composition of fertilizers) (Martínez-Espinosa, 2020). Microorganisms able to perform complete denitrification can fully reduce nitrate/nitrite to N_2, thus acting as a sink of nitrogenous gases, but also removing nitrate from soils as part of the fertilizers (Torregrosa-Crespo et al., 2018). Xia et al. contribute to the improvement of knowledge on this Research Topic by using an adapted "parameterized CENTURY/DAYCENT-model" (pCENTURY) calibrated with crop growth and soil organic matter decay coefficients at the county level for the estimation of N_2O emissions in the United States Corn Belt. The model considers interactions between management, climate, and soil moisture when key data are available (in this case from a meta-summary of field observations related to 55 studies). The preliminary evaluation done about regional soil moisture estimates showed a correlation between monthly soil moisture estimates and the North American Soil Moisture Dataset during the growing season. However, the overestimation of soil moisture in winter–spring can influence the estimates of annual N_2O emissions. Consequently, more work must be done to calibrate accurate model parameters correlated to soil moisture. Even though, the model and the methods developed in this research provided scenario-based estimates of climate and management impacts on soil nitrous oxide emissions during a growing season (N_2Ogs) together with valuable spatial insights into emission factors that will be improved by more accurate information of fertilizer inputs and more temporally refined model evaluation.

The works presented in this Research Topic illustrate different facets of the great concern about the N-cycle in soils and the consequences of anthropogenic activities affecting this cycle. The continuous progress in the methodologies that are becoming more affordable for agricultural practises, N-cycle modelling and physiological/metabolically characterization (involving plants and microbes) will allow us to explore and understand new scenarios in order to develop sustainable agricultural practices, keeping safe the health of the soil.

Author contributions

RM-E conceptualized and drafted the editorial, MS, RH, and YW provided critical review and insight to improve the writing. All authors approved the final paper.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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