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EDITED AND REVIEWED BY
Yuncong Li,
University of Florida, United States

*CORRESPONDENCE
Lanfang Han,
hanlanfang@gdut.edu.cn

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Editorial: Exogenous carbon-based materials in soil ecosystems

Hao Zheng[1], Yuxue Liu[2], Jie Jin[3], Qian Zhao[4] and Lanfang Han[5]*

[1]Institute of Coastal Environmental Pollution Control, College of Environmental Science and Engineering, Ministry of Education Key Laboratory of Marine Environment and Ecology, Frontiers Science Center for Deep Ocean Multispheres and Earth System, Ocean University of China, Qingdao, China, [2]State Key Laboratory for Managing Biotic and Chemical Threats to the Quality and Safety of Agro-products, Institute of Environment, Resource, Soil, and Fertilizer, Zhejiang Academy of Agricultural Sciences, Hangzhou, China, [3]MOE Key Laboratory of Resources and Environmental Systems Optimization, College of Environmental Science and Engineering, North China Electric Power University, Beijing, China, [4]Pacific Northwest National Laboratory, Environmental Molecular Sciences Laboratory, Richland, WA, United States, [5]Key Laboratory for City Cluster Environmental Safety and Green Development of the Ministry of Education, School of Ecology, Environment, and Resources, Guangdong University of Technology, Guangzhou, China

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Editorial on the Research Topic
Exogenous carbon-based materials in soil ecosystems

Various exogenous carbon-based materials (ECMs) such as crop straw, biochar, carbon-based nano-fertilizer, and microplastics have accumulated in soil ecosystems. They exhibit either multiple functions as soil amendments (e.g., soil fertility improvement, soil pollution remediation, and carbon sequestration) or negative effects as emerging contaminants (Li et al., 2021; Gao et al., 2022; Wang et al., 2022). These ECMs may cause direct and indirect impacts on soil properties, processes, productivity, and health, thus potentially changing the function and stability of soil ecosystems (Blanco-Canqui, 2021; Gujre et al., 2021). However, large knowledge gaps still exist on ECMs in soil ecosystems, including their accumulation, interactions with soil components, and potential ecological impacts and risks. Therefore, more efforts are needed to further understand the impacts especially the long-term effects of ECMs in soil ecosystems.

By generating new knowledge, this Research Topic aims to improve the understanding of the effects of ECMs on soil ecosystems, including soil quality, nutrient cycling, microbial ecology, crop growth, environmental health and ecological risk. Eventually, seven original Research were published within this Research Topic, all involving biochar. Figure 1 illustrated the specific topics of different papers published in this special issue.

With focuses on the response of soil phosphorus (P) mobility to biochar, Wu et al. investigated the influences of doping ratios of the biochar, phosphate concentration,

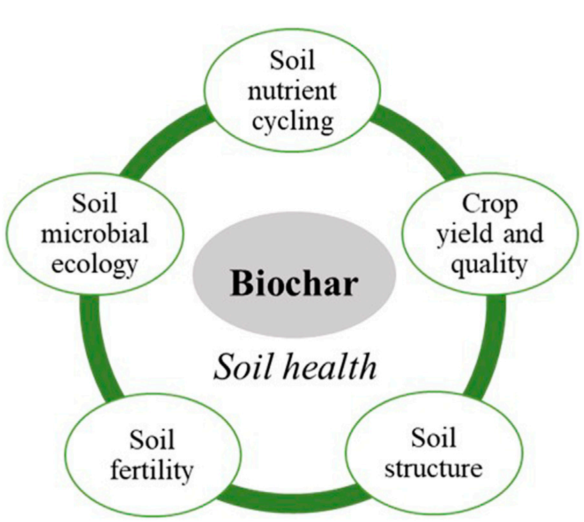

FIGURE 1
The thematic concepts of topics involved in this special issue.

solution pH, and biochar-derived dissolved black carbon (DBC) on P sorption in red soil to verify the hypothesis that adding biochar to the red soil could affect P mobility. The results show that bioavailable P content in biochar-amended red soil increased by 255% compared with the un-amended soil. The amount of P sorption decreased was mainly due to electrostatic repulsion resulted from the increased soil pH and released DBC containing P following biochar addition. Moreover, authors found that the humic acid-like substances in DBC can compete with P for soil sorption sites, leading to a decrease in P absorption. They highlighted that the addition of biochar affected P sorption by the red soil not only by directly releasing DBC to occupy the sorption sites but also indirectly changing soil physicochemical properties, which should be carefully considered in practical application of biochar amendments.

Returning crop straw in the form of biochar into agricultural soils is considered as an effective strategy to regulate carbon cycling and achieve carbon sequestration and thus mitigate climate change. Kalu et al. studied the effects of biochar on greenhouse gas (GHG) emission and N dynamic through long-term field experiments, where biochars were applied 2–8 years before. They found that wood-based biochar increased crop yield and reduced yield-normalized emissions of CH_4 and N_2O even after 7 years of application in one field experiment with a coarse-textured soil. They further interlinked these effects with soil and biochar properties. The results showed that spruce biochar increased N use efficiency and crop yield after 2-year application in a clay soil due to the increase of soil nitrate retention. Using an 8-year field study, Sun et al. investigated how different straw management practices (i.e., straw returning to field and straw derived biochar amendment) affect soil aggregate structure and humic substances which were of great significance for carbon cycling in soils (Guber et al., 2009; Ju et al., 2011). They found that both biochar and straw improved soil aggregate stability. Particularly, the biochar treatment enhanced humic carbon both in bulk soil and different aggregate fractions. They further confirmed that the biochar increased the proportion of aromatic C, the ratios of alkyl C/O-alkyl C, aromatic C/aliphatic C, and hydrophobic C/hydrophilic C in the aggregates using solid-state ^{13}C cross-polarization magic-angle-spinning nuclear magnetic resonance. This study highlighted that biochar may improve soil health in terms of soil structure and carbon pools for long term.

For the two research articles, dealing primarily with the co-application of biochar with chemical fertilizers, Gu et al. studied the effects of biochar combined with different doses of chemical fertilizer on paddy soil properties and *japonica* rice production through a 5 year field experiment in Northeast China. They found that soil available nutrients, bulk density, total and capillary porosity, macroaggregates, pH, and soil organic matter were improved by the co-application, which may be directly related to the increase of effective panicles, grains per panicle and seed setting rate. They suggested that biochar combined with chemical fertilizer can reduce the demand amount of chemical fertilizer, providing a new approach to green and low-carbon circular development for rice production. The second study by Gu et al. performed a field trial to reveal the response of halophyte (*Mesembryanthemum cordifolium*) growth, soil physicochemical factors, and rhizospheric microorganisms to different particle sizes of bio-organic fertilizer (BOF) and biochar. The combined application significantly improved the aerial biomass of salt-tolerant *M. cordifolium* in a saline–alkali soil. They demonstrated that the combined application of biochar and BOF can be an effective way of reclaiming saline–alkali land. These two studies suggested that biochar combined with fertilizer can provide a new approach to green and low-carbon circular development in soil health conservation and sustainable agriculture.

Soil microorganisms, one of the most important components of soil ecosystems, play important functions by fixing carbon and N, and mineralizing organic matter in maintaining the basis of soil food webs and global carbon and nutrient cycling (Coban et al., 2022). Research by Xu et al. and Sun et al. investigated the impact of biochar amendment on microbial communities. The first one reported that long-term successive biochar application reduced the richness indexes of the soil bacterial community. By contrast, soil pH, available potassium, total organic carbon, total nitrogen, and cation exchange capacity were significantly increased. They identified that soil pH and C/N were the two major environmental factors affecting the composition of the soil bacterial community according to a redundancy analysis. Furthermore, biochar significantly increased the functions of the metabolism of terpenoids and polyketides, metabolism of other amino acids, and biosynthesis of other secondary metabolites. The second one further focused on the influence of biochar addition rate and demonstrated that the amendment of biochar at low dose not only improved the abundance of some beneficial bacteria but also increased the complexity, modularity index, and competitive interactions of the bacterial co-occurrence network. By contrast, biochar applied at high dose decreased the modularity index and competitive interactions, which might account for the decreased peanut yield. These authors highlighted that the interaction among microorganisms needs to be comprehensively considered when evaluating the effects of biochar amendments on soil health.

Hopefully, this Research Topic will encourage more researchers to fill in the gaps in our knowledge on the impacts especially long-term effects of ECMs (not limited to biochar) in soil ecosystems, and that eventually this knowledge will enable us to achieve scientific application or development of ECMs.

Author contributions

Writing-original draft preparation, HZ, YL, JJ, and QZ; writing-review and editing, LH. All authors have read and agreed to the published version of the manuscript.

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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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