Editorial: Climate Change and/or Pollution on the Carbon Cycle in Terrestrial Ecosystems

Junjie Lin[1*], Dafeng Hui[2], Amit Kumar[3*], Zhiguo Yu[3], Yuhan Huang[4]

[1] School of Environment and Natural Resources, Zhejiang University of Science and Technology, Hangzhou, Zhejiang 310023, China; email: ybu_lin@126.com (JL)

[2] Department of Biological Sciences, Tennessee State University, Nashville, TN 37209, USA; email: dhui@tnstate.edu (DH)

[3] School of Hydrology and Water Resources, Nanjing University of Information Science and Technology, Nanjing 210044, China; email: amit.agl09@gmail.com (AK); zhiguo.yu@nuist.edu.cn (ZY)

[4] Centre for Green Technology, School of Civil and Environmental Engineering, University of Technology Sydney, NSW 2007, Australia; email: yuhan.huang@uts.edu.au (YH)

*Corresponding author

In terrestrial ecosystems, the carbon (C) cycle involves the uptake of carbon dioxide (CO_2) through photosynthesis and release it primarily through respiration by heterotrophs (bacteria, animals and fungi), autotrophs (photosynthetic bacteria and plants). Other forms of C losses, such as volatile organic compounds, methane (CH_4), and dissolved C, can also be significant (Jiang et al., 2023). However, our understanding of the nutrients, especially C and nitrogen cycling, and their transformation within ecosystems is limited. This makes it challenging to quantify and predict the feedback between nutrient cycle and climate, particularly in soil systems that interact with the overlying atmosphere. Soil serves as a reservoir of C in terrestrial ecosystems, holding about twice in plant C pool and three times in atmospheric C pool. Therefore, even small changes in the soil C pool may lead to strong feedback between the soil and atmospheric C pools. The terrestrial C pools are also one of the potential sources of atmospheric greenhouse gases (GHG; CO_2 and CH_4), which can significantly contribute to future climate change if not mitigated effectively. Besides, other climate factors such as long-term droughts and heavy rainfall, as well as environmental factors such as increased emerging organic pollution, may influence and even dominate the C balance in the global ecosystem (Zhang et al., 2023). Notably, a large amount of C is stored in vegetation and the underlying soil, which can be released into the atmosphere as CO_2 or CH_4 through microbial processes under extreme climate (e.g., temperature, precipitation) and this release of C can have adverse impacts on the environment. Therefore, understanding the feedback between the C cycle and climate change/emerging organic pollution has recently become a significant focus of scientific research. However, there is a lack of a comprehensive and in-depth understanding of climate change and/or pollution in the soil C cycle, hindering our ability to optimize models and take effective action to predict and alleviate climate change. Decomposition of soil organic C (SOC) responds non-linearly to various complex biotic and abiotic factors, such as temperature, precipitation, soil moisture, inputs of fresh organic C and nutrients, and land use and land cover changes. According to the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (UN IPCC AR6), global temperature are projected to rise beyond 1.5 °C between 2021 and 2040 (Zhou, 2021). Continued warming will lead to multiple hazards, long-term adverse effects, and irreversible ecosystem changes (Liu et al., 2023). As of 2020, the remaining C budget to achieve the 1.5 °C temperature control target is only 500 billion tonnes CO_2 (Matthews and Wynes, 2022). Implementing rapid and sustainable C reduction strategies over the next two decades can significantly alleviate the global warming trend.

In recent years, there has been an increase in emerging agricultural organic inputs, such as agricultural plastic film, which can have a significant impact on soil C cycle. Traditional agricultural films, known for their long-lasting stability, take about two hundred years to decompose completely. These films can negatively affect soil pH, pose threats to soil fauna, lead to a decline in farmland fertility, contribute to soil pollution, and even lead to crop yield reduction. As a result, there is a shift towards using degradable agricultural films, mainly produced from plant materials which share similar properties. Degradable plastics, when exposed to solar radiation and weathering, quickly break down into degradable plastic particles of different sizes, including microplastics and nanoplastics. These particles can alter the nutrient cycle in soil (Kumar et al., 2023). On the one hand, they can be considered an important source of SOC, similar to plant residues. However, it is crucial not to overlook their degradability and potential nitrogen deficiency, wich may lead to a large loss of SOC through the priming effect (Zhang et al., 2023). Two hypotheses that can explain the mechanisms of the priming effect are microbial nitrogen mining and co-metabolism (Yang et al., 2023). Further research is needed to better understand the impact of emerging organic C input on soil C cycle.

The aforesaid studies emphysize the challenges in quantifying and predicting the terrestrial C cycle under climatic extremes, mainly due to a limited understanding of the processes involved in C and nutrients transformation and recycling in ecosystems. This editorial aims to highlight some of the most pressing issues regarding the feedback between global change, emerging organic inputs, and the soil C cycle. Several uncertainties exist in assessing the soil C budget from terrestrial ecosystems in a warming world with rising CO_2, including: (i) Temperature sensitivity and influencing factors: The magnitude of temperature sensitivity and influencing factors on different stability of soil C pool in various ecosystems remain poorly understood. This knowledge gap hampers the accuracy of the earth system model in predicting the feedback between climate change and soil C pool. (ii) Birch effect caused by dry-wetting cycles. The understanding of the birch effect caused by drying-wetting cycles is very limited, especially under extreme precipitation events and long-term drought conditions. The mechanisms of birch effect on soil C decomposition through soil physical and chemical protection at the ecosystem scale are still lacking. This limits our ability to accurately assess soil C loss. (iii) Priming effect and emerging organic pollutants: The priming effect, especially resulting from the input of emerging organic pollutants, is a topic of intense global scientific discussion. However, its undelying mechanisms and the overall impact on the soil C balance have rarely been studied, leaving it as a mystery.

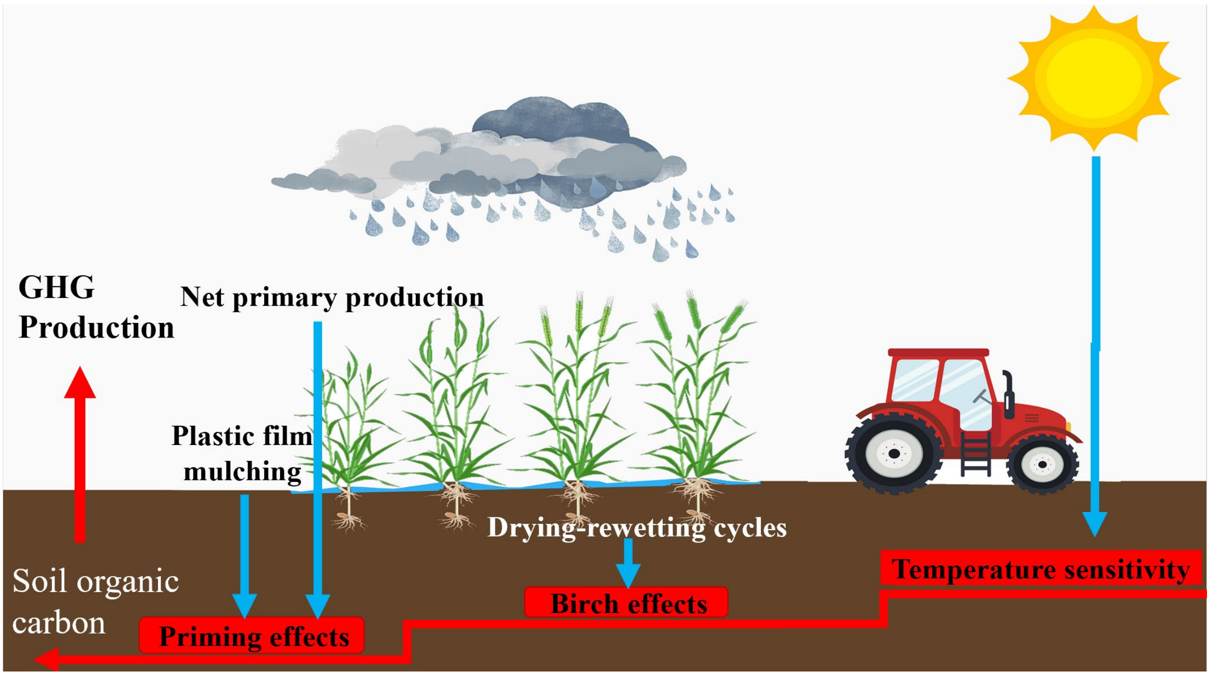

Fig. 1: Schematic of climate change and/or pollution on soil carbon cycle.

The primary goal of this special issue is to foster a comprehensive and in-depth understanding of the interaction between climate change, pollution, and the soil carbon cycle. It amis to investigate how various factors, such as increased atmospheric CO_2 concentration, warming, long-term droughts, heavy rainfall, as well as increased pollution, influence the C balance of the global ecosystem. All guest editors of this special issue anticipate that the original research articles published herein will provide valuable insights for ecologists, soil scientists, environmentalists, climate change scientists, and policymakers seeking to understand the feedback between the terrestrial C cycle and climate change and pollution. The guest editors emphysize that intensified climate change, such as continuous warming and recurrent drying-wetting cycles, coupled with emerging organic inputs such as the extensive application of degradable agricultural films in agricultural production, may lead to a significant reduction in soil C storage and an increased contribution to atmospheric CO_2 concentration (Hou et al., 2023). Therefore, more attention needs to be paid to ecological management and control measures that scientifically address the exacerbation of climate change and pollution. Long-term in-situ and laboratory-controlled experiments are critical for optimizing models and elucidating the effects of climate change and pollution processes on the soil C cycle. Therefore, a multidisciplinary approach encompassing agronomy, soil science, plant science, environmental science, and ecology is urgently required to comprehensively address the challenges associated with the terrestrial C cycle in relation to climate change and soil pollution. By integrating knowledge and expertise from various disciplines, we can gain a more comprehensive understanding of the intricate dynamics and formulate effective strategies to mitigate the impacts of climate change and pollution on the soil C cycle.

Author contributions

All listed authors have made direct and substantial contributions to the work and have approved its publication.

References

Kumar, A. et al. (2023). Microplastics in terrestrial ecosystems: Un-ignorable impacts on soil characterises, nutrient storage and its cycling. TrAC Trends in Analytical Chemistry, 158, 116869.
Matthews, H.D., Wynes, S (2022). Current global efforts are insufficient to limit warming to 1.5 ºC. Science, 376, 1404-1409.
Yang, Z. et al. (2023). Degradable microplastics induce more soil organic carbon loss via priming effects: a viewpoint. Plant and Soil. https://doi.org/10.1007/s11104-023-06141-0
Zhang, G. et al. (2023). Priming effects induced by degradable microplastics in agricultural soils. Soil Biology and Biochemistry, 180, 109006.
Zhou, T. (2021). New physical science behind climate change: What does IPCC AR6 tell us? The Innovation, 2.
Liu D, Zhang W, Xiong C and Nie Q (2023) Warming increases the relative change in the turnover rate of decadally cycling soil carbon in microbial biomass carbon and soil respiration. Front. Earth Sci. 10:1089544. doi: 10.3389/feart.2022.1089544
Hou J, Li F, Wang Z, Li X, Cao R and Yang W (2023) Seasonal dynamics of sediment organic carbon storage for the upper streams of the Yangtze River. Front. Ecol. Evol. 11:1093448. doi: 10.3389/fevo.2023.1093448.
Zhang Y, Niu J, Wei Z, Zhou X, Wu L, Li X, Ma S, Shi, G (2023) Spatial distribution characteristics, source analysis and risk assessment of polycyclic aromatic hydrocarbons in topsoil of a typical chemical industry park. Front. Environ. Sci., 11. doi: 10.3389/fenvs.2023.1209137.
Jiang Y, Yao Y, Liu H, Zhang S, Bai X, Ma X, Wang Y and Ren Q (2023) Volatile organic compounds conversion pathways and odor gas emission characteristics in chicken manure composting process. Front. Ecol. Evol. 11:1192132. doi: 10.3389/fevo.2023.1192132.