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Editorial: Plant litter decomposition: patterns, processes, and element cycling

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Editorial on the Research Topic
Plant litter decomposition: patterns, processes, and element cycling

Litter accretion and its decomposition are key ecosystem processes that drive biogeochemical element cycling, the formation and build-up of soil organic matter, support biodiversity, and regulate energy flows within ecosystems (Berg and McClaugherty, 2020; Prescott, 2010; Spohn and Berg, 2023; Gautam et al., 2024; Robin et al., 2025). The newly shed leaf-to-humus continuum drives a cascade of ecological processes that provide rich refuge to support soil-inhabiting biota (Prescott and Vesterdal, 2021). The decomposition niches developed thereafter, driven by diverse microbial and invertebrates communities, bring complexity to the decomposition process and rates (Kielak et al., 2016; Tuo et al., 2024; Zeng et al., 2024).

The feedback relationship between litter-based biota and overall decomposition direction is central to the development of humus, which forms the foundation of soil health (García-Palacios et al., 2013; Berg and McClaugherty, 2020). The transition of litter to soil organic matter or humus has been followed and studied for a wide range of ecosystems, particularly in the context of carbon biogeochemistry as carbon sources or sinks, affecting global climate change (Mayer et al., 2020; Chen et al., 2024; Piazza et al., 2024). Studies on litter decomposition, humus formation as well as carbon and its stability have explored the huge potential of long-term carbon storage in the organic phase of soils. Over the years we have gained a deeper insight into the effects of plant species, litter types, environmental conditions, ecosystem types and management strategies on litter dynamics including carbon (Hobbie, 2015; Berg and McClaugherty, 2020; Latterini et al., 2023; Joly et al., 2023). Studies have evidenced that the functional feedback from this complex is crucial for cycling other elements as well, including nutrients, which are essential for maintaining soil fertility and ecosystem sustainability. In nutrient-deficient systems where inputs are low, such as arctic, arid, and intensive agricultural, nutrients' recycling through decomposition is important for maintaining productivity and function. It's significance becomes particularly critical in nitrogen- or phosphorus-deficient ecosystems.

This Research Topic of *Plant Litter Decomposition: Pattern, Processes, and Element Cycling* brings together diverse research contributions that explore the intricate relationships between these factors. Several key insights emerge from these studies, underscoring the complexity of the concept litter decomposition across different biomes and environmental conditions. Below is given summaries of the novel findings into the processes governing litter breakdown and element dynamics across different ecosystems.

Wang et al. and team showed that in arid environments, where biological activity is limited by extreme conditions, the role of photodegradation is related to the intensity of UV exposure, but not to precipitation or temperature. Their study demonstrates that ultraviolet (UV) radiation, rather than plant species differences, is the dominant factor controlling litter decomposition in hyper-arid desert ecosystems. The results highlight the importance of abiotic drivers in litter breakdown in deserts, where microbial and invertebrate activity is constrained by harsh conditions, providing important insights into decomposition processes under extreme environmental stress.

Qi et al. and group investigated the effect of rubber tree intercropping with native trees on litterfall and the nutrient return of essential elements like nitrogen, phosphorus, and potassium. The authors found that intercropping systems enhanced litter production and nutrient return compared to monoculture rubber plantations. The findings suggest that integrating native trees into rubber plantations can improve soil fertility and ecosystem sustainability, offering a pathway for more sustainable agricultural practices in tropical ecosystems.

The unresolved question of bacterial or fungal participation in litter decomposition is an ongoing debate over which microbial community—bacteria or fungi—plays a more dominant role in breaking down plant litter and driving its dynamics. A *Phragmites australis* litter decomposition experiment conducted by Ping et al. across coastal wetlands in China revealed that decomposition of these coastal species was driven by different fungal guilds, particularly symbiotrophic fungi, rather than bacterial communities. These differences became more pronounced at later decomposition stages and correlated with fungal dissimilarities between habitats. They identified symbiotrophic fungi as a key factor influencing litter breakdown by interacting with saprotrophic fungi.

While carbon, nitrogen and base elements (Ca, Mg, and K) are in the focus of decomposition studies, the investigation on trace and rare earth elements can provide a broader perspective on their cycling, highlighting the complexity of element dynamics during litter decay. The study presented by Gautam et al., explored the long-term dynamics of 33 trace and rare earth elements (REEs) in a boreal forest over 4 years. Their study particularly provides new understanding of how these often-overlooked elements are retained in organic matter due to chelation, especially in the later stages when decomposition is predominated by recalcitrant compounds.

The papers in this Research Topic contribute significantly to our understanding of plant litter decomposition by offering diverse perspectives from a range of ecosystems, from tropical forests to coastal wetlands and arid deserts. Together, these studies provide a richer understanding of how biotic and abiotic factors interact to influence decomposition and element cycling.

Despite significant advances in recent years, several gaps persist in our understanding of litter decomposition. Among these, a key challenge is the limited cross-biome comparisons, which are essential for comprehending how decomposition dynamics varies across diverse ecosystems. Future research can greatly benefit from including other less studied ecosystems like aquatic, arid, agricultural and agroforestry ecosystems. Currently we have a too limited understanding of litter dynamics tied to these ecosystems to develop a generalization about the processes. Particularly long-term decomposition processes are under-researched. Understanding the dynamics over decadal timescales is crucial for accurately modeling processes and fluxes. Additionally, untangling the factors that drive decomposition in different ecosystems requires global integrative approaches of combining cross-biome field studies with decomposition modeling. As global environmental changes accelerate, understanding of how altered precipitation patterns and intensities (i.e., drought), soil warming, UV radiation, and land degradation are expected to affect decomposition processes, rates and element cycling become increasingly important. In the context of element cycling, while a limited number of studies have explored the trace and rare earth dynamics tied to decomposition, their sporadic nature makes it difficult to establish a comprehensive understanding or to develop general models. Litter decomposition studies should prioritize the dynamics of trace and rare earth elements, as their human footprints are significantly increasing in ecosystems today. Further, there is a notable imbalance in research focus, with, for example, coarse woody litter receiving significantly less attention and being less studied than leaf litter. A significant gap in decomposition studies is their focus on a few dominant tree species, often overlooking the diversity of plant functional types found across different ecosystems, especially in (sub-) tropical regions. This bias limits the ability to generalize the associated processes. Focusing on a few dominant tree species introduces a significant limitation to the field of decomposition studies, as it prevents a comprehensive understanding of the processes across diverse ecosystems. By not accounting for the diversity of plant functional types, studies often overlook critical interactions and variations that can affect decomposition rates, process and element dynamics including carbon. Performing decomposition studies on woody litter and incorporating overall plant diversity will enhance our understanding of this crucial ecological process that links above-ground productivity with on- or below-ground productivity.

In the end, we hope the insights presented here will inspire further research into these fundamental ecological processes.

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MG: Conceptualization, Resources, Supervision, Writing–original draft, Writing–review and editing. BB: Conceptualization, Writing–original draft, Writing–review and editing.

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