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Frank Hagedorn,
Snow and Landscape Research
(WSL), Switzerland

*CORRESPONDENCE
Shalom D. Addo-Danso
✉ shalomdanso@gmail.com

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Editorial: Insights into forest ecosystem belowground processes and functioning in a changing environment

Shalom D. Addo-Danso[1]*, Camille E. Defrenne[2], Daniela Yaffar[3] and Laynara F. Lugli[4]

[1]Forests and Climate Change Division, CSIR-Forestry Research Institute of Ghana, Kumasi, Ghana, [2]College of Forest Resources and Environmental Science, Michigan Technology University, Houghton, MI, United States, [3]Functional Forest Ecology, Universität Hamburg, Barsbüttel-Willinghusen, Germany, [4]Land Surface-Atmosphere Interactions, Technical University of Munich, Fresing, Bavaria, Germany

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Editorial on the Research Topic
Insights into forest ecosystem belowground processes and functioning in a changing environment

Introduction

Forests cover an estimated 4.06 billion hectares globally (FAO, 2020), and account for about 70 percent of the world's terrestrial biodiversity (Pillay et al., 2022). Much attention has focused on forest ecosystems aboveground, with little emphasis on the belowground components and processes. Hence, our appreciation of forests functioning belowground lags far behind that of the aboveground. Yet, understanding the roles of plant roots, their associated symbionts, and soil microbes in net primary productivity, nutrient and water cycling are key in mediating the supply of ecosystem services including hosting biodiversity, carbon storage and water infiltration (Cusack et al., 2021; Chen et al., 2022; Xie et al., 2023).

Recent conceptual and technological advances in belowground forest ecology are shedding new light on plant root and belowground processes including root traits, root dynamics, rhizodeposition (exudation), mycorrhizal association, and soil respiration partitioning (Freschet et al., 2021a,b). However, there are still gaps in our knowledge on how to efficiently quantify the roles that plant roots and their associated symbionts play in driving forest ecosystems functioning and their responses to climate change, disturbances, and forest management practices. The goal of this Research Topic in Frontiers of Forests and Global Change was to bring together studies on forest ecosystems from a broad range of biomes including temperate, boreal and the tropics to provide new insights into the driving factors of variations in belowground components and processes at the plant species, community and ecosystem levels.

Root traits and soil carbon turnover in tropical forests

Tropical forests play an essential role in global water, carbon, and nutrient cycling (Cusack et al., 2021), but our understanding of the interspecific and intraspecific variations of root traits, and the main drivers of traits expression in the tropical forest biome is still at the nascent stage (Addo-Danso et al., 2020; Giweta, 2020). In this issue, Lee and Andersen examined the current state of root trait representation in the Paleotropics by compiling 421 publications that captured a wide range of root trait categories. They show that root physiological, architectural, and anatomical traits remain heavily underrepresented in the literature, representing only 25% of all the publications. In addition, they highlight gaps in the current trait coverage, with respect to ecosystems and geographical hotspots, a lack of trait data at the species level, and inconsistencies in how publications distinguish between fine roots and coarse roots. Based on their findings, the authors propose four avenues for future research: (i) measuring root anatomical traits (associated with plant hydraulics), (ii) examining "hard" traits such as mycorrhizal colonization intensity and root longevity, (iii) distinguishing between coarse roots, absorptive fine roots, and transport fine roots, and (iv) using a mix of *in situ* and *ex situ* experimental designs. Consistent with these recommendations, Weemstra et al. measured five morphological and architectural traits of absorptive fine roots of 218 Neotropical tree species in Brazil. They reveal that tree species that possess a combination of highly mycorrhized, thick roots with low tissue densities may dominate in tropical forests—often associated with arbuscular mycorrhizal fungi, and mostly limited by soil phosphorus. The authors' further highlight that shared ancestry is a weak driver of root trait variation in tropical forests, as opposed to tree species of temperate forests.

Tropical forest succession and the associated shifts in plant community composition and ecosystem services and processes are increasingly gaining attention due to the potential impacts on biodiversity conservation, climate change, and landscape restoration (Chazdon, 2017; Rüger et al., 2023). In this Research Topic, Wallwork et al. explored the relationship among tree functional composition, litter mass loss, and soil respiration rates in a chronosequence of tropical forest regrowth in Panama. They demonstrate that tree functional type (light-demanding vs. shade-tolerant species) influenced leaf litter decomposition and soil respiration rates. Specifically, they observed faster decomposition in light-demanding species than shade-tolerant species. Furthermore, the age of forests and the corresponding litter type interacted in a complex way to influence both leaf litter decomposition and soil respiration.

Roots, mycorrhizal fungi, and environmental changes in boreal forests

Boreal peatlands store large amounts of carbon in the peat layers (Beaulne et al., 2021) and are regarded as critical ecosystems for climate change mitigation (Eyvindson et al., 2023). Information on fine root dynamics and controlling factors of forested peatlands is limited, despite the belowground components contribute over 30% of the total net primary productivity (Xie et al., 2023). In this issue, Lampela et al. examined the effect of persistent water-table level drawdown in forested boreal peatlands, and called attention to the context dependency of fine-root biomass and production responses to drought. In particular, in forested fens, drainage decreased fine-root biomass, whereas in forested swamps, drainage increased fine-root biomass. The authors emphasize that both site wetness and nutrient regime should be accounted for when assessing the impact of drought on belowground plant traits in boreal peatlands. Bucher et al. went further to conduct a meta-analysis on root responses to water level drawdown and warming considering three plant functional types (tree, shrub, and graminoid) common in boreal peatlands. From the 65 observations, they showed an increase in fine root growth with both warming and water drawdown. When they considered the individual plant functional types, trees showed the greatest response (approximately +375% for warming and +867% for water level drawdown) and graminoids the least (approximately +60% for warming and −60% for water level drawdown), but these responses were mediated by topographic differences within sites.

Roots, mycorrhizal fungi, root exudation, and environmental changes in temperate forests

Most of the data and information that have shaped our understanding of root dynamics and belowground ecosystems have come from temperate forest ecosystems. However, there are still knowledge gaps when it comes to the responses of the belowground components of dominant tree species of temperate forests to changing climatic conditions, particularly drought and climate warming (Zwetsloot and Bauerle, 2021; Brunn et al., 2022; Kengdo et al., 2022). In this issue, Danzberger et al. rewetted beech and spruce forest stands, after subjecting them to 5 years of experimental summer drought, to explore the recovery of belowground plant roots and their associated fungal communities. One of their major findings was that the soil fungal community was more resilient to drought in mixed stands, as opposed to monocultures. In particular, ectomycorrhizal fungal species richness and relative abundance were higher in mixed stands within 3 months after rewetting.

Root exudates are key belowground components that determine plant interactions within the soil environment (Prescott et al., 2020), but how exudates change in response to increasing temperature remains unclear (Brunn et al., 2022). Heinzle et al. addressed this by delving into this crucial belowground component using an *in-situ* incubation method set up in a long-term soil warming experiment to measure carbon exudation rates from roots of spruce-dominated forests. The authors did not find any changes in root exudation per unit root dry mass in the warmed plots over a 15-year period when contrasted with control plots. Nevertheless, owing to increased root biomass stocks, the overall fine root carbon exudation experienced a 30% increase in the warmed plots. However, a +10°C increase in soil warming within 4 days led to a rapid increased root exudation. They demonstrate that root carbon exudation is temperature-sensitive in the short term.

Outlook

This Research Topic of papers represents the belowground component dynamics of forests in the boreal, temperate, and tropical biomes. The papers show that there are still knowledge gaps that need to be filled, especially on species-level root trait expression from diverse tropical forest ecosystems and sites. Furthermore, there is the need to shift attention to less studied belowground traits including those that are associated with root anatomy, architecture and physiology such as root exudation rate, specific root respiration and mycorrhizal colonization intensity, which often have direct link with plant and ecosystem functioning. Focusing on the belowground processes of peatland forests is critical for improving our understanding on the management practice of draining peatlands, and potential consequences on the long-term storage of carbon. Furthermore, expanding studies on exudation will help us to better understand how exudates mediate the interactions among above- and belowground ecosystem components, and their interactions with rhizosphere microbes. Finally, considering changes in forest community composition and structure during forest regrowth recovery could help us understand belowground dynamics of these forests, and predict their succession trajectory. Together, this Research Topic shows new research on some of the driving factors of belowground processes in different forest ecosystems and their responses to changing environmental conditions, and it serves as an avenue toward filling gaps for a more holistic view of the belowground component.

Author contributions

SDA-D: Conceptualization, Writing – original draft, Writing – review & editing. CED: Conceptualization, Writing – original draft, Writing – review & editing. DY: Conceptualization, Writing – original draft, Writing – review & editing. LFL: Conceptualization, Writing – original draft, Writing – review & editing.

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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.

Publisher's note

References

Addo-Danso, S. D., Defrenne, C. E., McCormack, M. L., Ostonen, I., Addo-Danso, A., Foli, E. G., et al. (2020). Fine-root morphological trait variation in tropical forest ecosystems: an evidence synthesis. *Plant Ecol.* 221, 1–13. doi: 10.1007/s11258-019-00986-1

Beaulne, J., Garneau, M., Magnan, G., and Boucher, E. (2021). Peat deposits store more carbon than trees in forested peatlands of the boreal biome. *Sci. Rep.* 11:2657. doi: 10.1038/s41598-021-82004-x

Brunn, M., Haifner, B. D., Zwesloot, M. J., Weikl, F., Pritsch, K., Hikino, K., et al. (2022). Carbon allocation to root exudates is maintained in mature temperate tree species under drought. *New Phytol.* 235, 965–977. doi: 10.1111/nph.18157

Chazdon, R. (2017). Landscape restoration, natural regeneration, and the forests of the future. *Ann. Missouri. Bot. Gard.* 102, 251–257. doi: 10.3417/2016035

Chen, Y., Leung, L. R., Huang, M., Koven, C., Detto, M., Knox, R., et al. (2022). Modelling the joint effects of vegetation characteristics and soil properties on ecosystem dynamics in a Panama tropical forest. *J. Adv. Model. Earth. Syst.* 14:e2021MS002603. doi: 10.1029/2021MS002603

Cusack, D. F., Addo-Danso, S. D., Agee, E. A., Andersen, K. M., Arnaud, M., Batterman, S. A., et al. (2021). Tradeoffs and synergies in tropical forest root traits and dynamics for nutrient and water acquisition: field and modeling advances. *Front. For. Glob. Chang.* 4:704469. doi: 10.3389/ffgc.2021.704469

Eyvindson, K., Launianen, S., Leppa, K., Repo, A., Salmivaara, A., and Lehtonen, A. (2023). Trade-offs between greenhouse gas mitigation and economic objectives with drained peatlands in finnish landscapes. *Can. J. For. Res.* 53, 444–454. doi: 10.1139/cjfr-2022-0101

FAO (2020). *Global Forest Resources Assessment 2020: Main Report*. Rome: FAO.

Freschet, G. T., Pagès, L., Iversen, C. M., Comas, L. H., Rewald, B., Roumet, C., et al. (2021b). A starting guide to root ecology: strengthening ecological concepts and standardizing root classification, sampling, processing and trait measurements. *New Phytol.* 232, 973–1122. doi: 10.1111/nph.17572

Freschet, G. T., Roumet, C., Comas, L. H., Weemstra, M., Bengough, A. G., Rewald, B., et al. (2021a). Root traits as drivers of plant and ecosystem functioning: Current understanding, pitfalls and future research needs. *New Phytol.* 232, 1123–1158. doi: 10.1111/nph.17072

Giweta, M. (2020). Role of litter production and its decomposition, and factors affecting the processing in a tropical forest ecosystem: a review. *J. Ecol. Environ.* 44:11. doi: 10.1186/s41610-020-0151-2

Kengdo, S. K., Peršoh, D., Schindlbacher, A., Heinzle, J., Tian, Y., Wanek, W., et al. (2022). Long-term soil warming alters fine root dynamics and morphology, and their ectomycorrhizal fungal community in a temperate forest soil. *Glob. Chang. Biol.* 28, 3441–3458. doi: 10.1111/gcb.16155

Pillay, R., Venter, M., Arajon-Osejo, J., González-del-Pliego, P., Hansen, A. J., Watson, J. E. M., et al. (2022). Tropical forests are home to over half of the world's vertebrate species. *Front. Ecol. Environ.* 20, 10–15. doi: 10.1002/fee.2420

Prescott, C. E., Grayston, S. J., Helmisaari, H.-S., Kaštovská, E., Körner, C., Lambers, H., et al. (2020). Surplus carbon drives allocation and plant-soil interactions. *Trends Ecol. Evol.* 35, 1110–1118. doi: 10.1016/j.tree.2020.08.007

Rüger, N., Schorn, M. E., Kambach, S., Chazdon, R. L., Farrior, C. E., Meave, J. A., et al. (2023). Successional shifts in tree demographic strategies in wet and dry Neotropical forests. *Global Ecol. Biogeogr.* 32, 1002–1014. doi: 10.1111/geb.13669

Xie, L., Wang, G., Chang, J., Chen, Y., Guo, X., Mao, X., et al. (2023). Global depth distribution of belowground net primary productivity and its drivers. *Global Ecol. Biogeogr.* 32, 1435–1451. doi: 10.1111/geb.13705

Zwetsloot, M., and Bauerle, T. (2021). Repetitive seasonal drought causes substantial species-specific shifts in fine-root longevity and spatio-temporal production patterns in mature temperate forest trees. *New Phytol.* 231, 974–986. doi: 10.1111/nph.17432