frontiers | Frontiers in Forests and Global Change

TYPE Editorial
PUBLISHED 05 February 2024
DOI 10.3389/ffgc.2024.1356686

OPEN ACCESS

EDITED AND REVIEWED BY
Pedro Álvarez-Álvarez,
University of Oviedo, Spain

*CORRESPONDENCE
Xianliang Zhang
✉ lxzhxl@hebau.edu.cn

RECEIVED 16 December 2023
ACCEPTED 25 January 2024
PUBLISHED 05 February 2024

CITATION
Zhang X, Manzanedo R, Xu G and Lapenis AG (2024) Editorial: Achieving sustainable development goal 13: resilience and adaptive capacity of temperate and boreal forests under climate change.
Front. For. Glob. Change 7:1356686.
doi: 10.3389/ffgc.2024.1356686

Editorial: Achieving sustainable development goal 13: resilience and adaptive capacity of temperate and boreal forests under climate change

Xianliang Zhang[1]*, Ruben Manzanedo[2], Guobao Xu[3] and Andrei G. Lapenis[4]

[1]College of Forestry, Hebei Agricultural University, Baoding, China, [2]Plant Ecology, Institute of Integrative Biology, D-USYS, ETH-Zürich, Zurich, Switzerland, [3]Shaanxi Key Laboratory of Earth Surface and Environmental Carrying Capacity, College of Urban and Environmental Sciences, Northwest University, Xi'an, China, [4]Department of Geography and Planning, State University of New York at Albany, Albany, NY, United States

KEYWORDS

boreal forest, temperate forest, resilience, drought, climate warmer and raider

Editorial on the Research Topic
Achieving sustainable development goal 13: resilience and adaptive capacity of temperate and boreal forests under climate change

Global climate change has led to a significant decline in tree growth and increased tree mortality worldwide (Trumbore et al., 2015). Temperate and boreal forests, distributed in regions experiencing water stress, may be particularly vulnerable to increasing temperatures (Gauthier et al., 2015; Millar and Stephenson, 2015; Mirabel et al., 2023), despite initial expectations that increasing temperature would result in increased tree productivity, particularly in cold-limited boreal ecosystems (D'orangeville et al., 2018). Only recently we have started to understand the complex effects that climate change may exert in these highly valuable trees, including aspects such as interaction between drought, snowmelt, diurnal temperature ranges, and phenology, which are greatly influential but yet understudied (Zhang et al., 2019, 2022, 2023). Yet, better understanding the intricate effects of these changes in climate and their effects on temperate and boreal trees is crucial for achieving sustainable development in these forest regions.

Siberian wildfires have resulted in extensive forest loss in boreal forests, leading to increased emissions of greenhouse gases in the Northern Hemisphere. To estimate the variability in Russia's wildfires, Lapenis and Yurganov found a remarkable link with between fire dynamics and the Arctic Oscillation, which could serve as a highly valuable predictive variable for Russia's wildfire emissions. Remarkably, in the year 2021 alone, wildfires in Russia emitted the exceptionally high volume of 1,700 Tg CO_2eqv, surpassing carbon emissions generated by the country's fossil fuel consumption. As a result, carbon emissions caused by wildfires nearly offset the carbon assimilation by Russian forests. Projecting future wildfire emissions based on the Arctic Oscillation can help evaluate the carbon balance of Russian and other boreal forests.

It is well established that temperature plays a significant role in driving tree growth in boreal forests, with the general expectation that warming would promote tree growth in many northern boreal forests. However, Moreau et al. brings nuance to this relationship, highlighting the need to consider tree responses across the whole growing season. They reported that, while the growth of black spruce in the southern regions of the boreal forest-tundra ecotone generally benefitted from warmer spring temperatures, these positive warming effects were offset by late-spring frosts in the northern regions, resulting in a lack of a net effect of climate across the whole study area. Considering time- and space- dependent responses is hugely important to provide a real world test to our models, check their underlaying assumptions, and cross-ecotone applicability.

Acclimation to extreme climate events is remarkably important for forest persistence. In this issue, Ravn et al. assessed how cold-adapted boreal forest tree species acclimate to future warming and droughts. They conducted experiments with balsam fir seedlings, subjecting them to 12 temperature treatments and five drought treatment intensities. They found that tree seedlings exhibit high phenotypic plasticity in root-to-shoot ratio and photosynthesis, which enables them to endure considerable heat and drought in the future. These results show the power of experimental settings to reveal species responses to warming and drought in boreal forests.

Similarly, Cholet et al. address the effects of drought stress and warming on temperate forest, but focused on the underexplored soil component of this interaction. They demonstrate that the severity and duration of soil water stress have increased with climate warming in eastern North American temperate forests. The severity of soil water stress increased the most in areas that had previously experienced short periods of soil water stress, while the duration of soil water stress increased the most in areas with a history of long periods of soil water stress. These changes in soil water stress pose a significant risk to tree growth. To understand how daily drought affects interannual tree growth in temperate forests, Li et al. monitored daily stem radial growth changes using point dendrometers for *Larix principisrupprechtii*. They found that vapor pressure deficits (VPD) were the major limiting factor influencing tree intra-annual growth during the growing season. Daily stem growth showed a linear reduction with VPD when VPD ranged from 0.5 kPa to 0.6 kPa. Daily tree growth reached a relatively stable maximum value when VPD was below 0.5 kPa (indicating wet conditions) and a minimum value when VPD exceeded the range of 0.8–0.9 kPa (indicating dry conditions). It is projected that daily stem growth will be increasingly limited by water deficits as VPD values are expected to remain above the 0.8 kPa level from 2,051 to 2,100 in the future.

This Research Topic sheds light on how climate change has impacted forest, wildfires and soil water stress, it provides insights into how trees adapt to warming and droughts in temperate and boreal forests, and bring much needed nuance and a diversity of approaches to the study of boreal and temperate forest as they adapt to a warming World. Black spruce exhibits distinct growth patterns between southern and northern forest-tundra ecotones due to the interactions between frosts and warming (Moreau et al.). In temperate forests, larch is more influenced by atmospheric droughts (Li et al.), whereas balsam fir can adapt to warming and droughts by altering their phenotype (Ravn et al.). Our Research Topic has highlighted that the impacts of warming and drought on tree growth vary by species and region, emphasizing the importance of considering the interaction between different climate variables. In addition, drought often driven the occurrence of pests and diseases, and some species were influenced more by drought-induced insects and diseases than droughts (Hajek et al., 2022). The interaction of drought and insects may lead to increased insect populations, resulting in higher tree mortality than being only influenced by droughts (Anderegg et al., 2015). The variability in responses and limiting factors across these forests and the need to consider them holistically to reach meaningful and useful scientific results. Further studies are needed to gain a comprehensive understanding of how different species adapt to future warming and drought conditions, and the urgent need for further data and theoretical development in one of the World's most influential ecosystems in terms of ecosystem services, particularly carbon sequestration.

Author contributions

XZ: Conceptualization, Writing—original draft. RM: Writing—review & editing. GX: Writing—review & editing. AL: Writing—review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

We would like to thank the authors, reviewers, and Frontiers Editorial Office for contributing to this Research Topic.

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.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

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