frontiers | Frontiers in Forests and Global Change

TYPE Editorial
PUBLISHED 07 August 2023
DOI 10.3389/ffgc.2023.1264354

OPEN ACCESS

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RECEIVED 20 July 2023
ACCEPTED 28 July 2023
PUBLISHED 07 August 2023

CITATION
Brock JMR, Craven D and Morales NS (2023) Editorial: Impacts of climate change on long term viability of tree species with recalcitrant seeds. *Front. For. Glob. Change* 6:1264354. doi: 10.3389/ffgc.2023.1264354

Editorial: Impacts of climate change on long term viability of tree species with recalcitrant seeds

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KEYWORDS

regeneration, resilience to climate change, change in forest composition, cryopreservation, seed provenance, reduced seeding, *ex situ* conservation forest, response to drought

Editorial on the Research Topic
Impacts of climate change on long term viability of tree species with recalcitrant seeds

Globally, climate change represents a significant threat to the resilience and long-term survival of forest ecosystems (Forzieri et al., 2022). Temperatures are increasing above Paleocene norms and precipitation events are becoming more extreme in terms of both drought and flooding (Osman et al., 2021). Further, increased intensity of weather events is driving disease and pest outbreaks and shifts in the disturbance regime including, for example, significant increases in spatial extent and magnitude of fires in global ecosystems (Harvey et al., 2016a). In isolation, such changes in a single environmental parameter represent a challenge for species as suitable regeneration conditions begin to move rapidly across the landscape; however, in combination and across multiple spatial scales, these changes may drive species extinctions (Harvey et al., 2016b).

Cross-scale changes in climate are among the most important factors affecting post-dispersal processes in plants by affecting an individual's reproductive success and potentially jeopardizing the long-term viability of forest communities (Fontúrbel et al., 2021). Climate change is and will continue to drive non-linear changes in fundamental environmental variables such as temperature and moisture availability and continues to influence disturbance regimes affecting seed survival, germination, and seedling establishment (Turner et al., 2013). Climate-driven impacts on seeds will limit colonization of new sites, succession-driven species turnover and ultimately affect forest expansion, recovery, and persistence. Globally, forests are experiencing increased fire events, landslides, pest damage, and wind-throw from storms driving novel extents of both primary and secondary successions. Interactions between unprecedented weather and shifts in environmental conditions are changing the regeneration niche of forest taxa (Harvey et al., 2016b).

Environmental change is considered particularly challenging for tree species with recalcitrant seeds; recalcitrant seeds are unusual as they do not undergo maturation, drying during development, and are rarely capable of dormancy, and therefore have high water content when they are dispersed. As such, recalcitrant seeds are not able to dry and persist

for long periods of time in the landscape surrounding parent trees and are vulnerable to desiccation and fungal infections (Berkak and Pammenter, 2013). Tree species with recalcitrant seeds are especially sensitive to changes in temperature and humidity as these variables affect the short-term viability and germination ability of seeds. Species with recalcitrant seeds are most commonly woody plants, climate change therefore presents a significant risk to seedling establishment of many important forest canopy species.

Changing weather and climactic conditions will drive global shifts in seed viability and successful seedling establishment of tree species influencing forest community composition and successional trajectories. Where recalcitrant-seeded tree species are subject to cross-scale changes in climate it is possible that key forest tree species will decline in frequency across landscapes, with cascading impacts on biotic interactions and filters, and the loss of species-specific functions.

This Research Topic was collated to deepen current understanding of the factors affecting regeneration processes of tree species with recalcitrant seeds under current climate change scenarios This Research Topic includes a number of different case studies of recalcitrant-seeded tree species across a variety of ecosystems where climate change can, or is having, an impact on tree regeneration. Additionally, this issue explores current conservation, restoration, and mitigation strategies that may help in reducing the negative impacts of climate change and examining the long-term viability of recalcitrant-seeded tree species. Yukich Clendon et al. showed that seasonal fruit and seed production in a recalcitrant-seeded canopy dominant tree species responds to changes in annual temperature and rainfall. Once fruit and seed has been produced, changes in environmental conditions will also impact seed germination and recruitment of a new generation of recalcitrant seed species; however, these non-linear patterns suggest that seed viability and seedling resilience to stressors depended on both phenotypic variation and seed provenance (Magni et al.). However, germination and seedling recruitment are not the only stages that plants need to survive in order to reach to adulthood. Seedling survivorship is also dependent on environmental variables such as water availability, which is especially critical in early seedling developmental stages. Nonetheless, the response to stress is not equal among species even in the same family. Ichie et al. showed that seedling survivorship of dipterocarp species can vary under different drought scenarios. The result from the studies included in this Research Topic showed that climate change not only can affect crucial stages of trees' life cycles but also can potentially change forest composition and ultimately the viability of these ecosystems. Such changes can result in local population extinctions and loss of genotypes, which can eventually translate into species extinctions.

Further, the pressures of climate change will create challenges to potential conservation strategies, in particular where *in situ* conservation is no longer possible, leaving *ex situ* conservation as the only option. Off-site storage and conservation of recalcitrant seeds may no longer be possible in the long-term using conventional techniques because of the constraints presented by the high water content of these seeds. Despite this hurdle, cryopreservation of a range of plant tissues with regeneration potential could provide a solution; Fernández et al. reviewed several studies and compiled data from case studies showing that whilst cryopreservation is a possible solution, climate change will impose limitations on the potential for this method to support conservation as (1) vegetative material will be less available as climatic conditions worsen, and (2) changes in environmental conditions may necessitate seed propagation and planting of recalcitrant-seeded species into locations different to those areas where the species originally occurred, but where conditions for seedlings to grow are now suitable ("assisted migration").

The studies included in this Research Topic show that the effects of climate change on regeneration can be significant for recalcitrant-seeded tree species and highlight that responses are species and location specific. Authors highlighted the need for more research to design new methods and give recommendations on how conservation of these species using an *ex situ* approach.

Author contributions

NM: Conceptualization, Writing—original draft, review, and editing. JB: Conceptualization, Writing—original draft, review, and editing. DC: Conceptualization, Writing—original draft, review, and editing.

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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