

COMMENTARY ARTICLE OPEN ACCESS

Deciduous tree species are losing their ability to recover from drought stress

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ABSTRACT

Climate change is driving more intense droughts, threatening global forests. This commentary highlights a pivotal study revealing an alarming trend: deciduous trees, long assumed to be resilient due to fast recovery, are losing this critical ability. Analysis of Canadian forests shows a century-long decline in deciduous drought recovery, while evergreens remain stable. This suggests a major shift in forest composition is underway, with profound implications for biodiversity, carbon storage, and ecosystem services. Urgent action is needed to integrate these findings into climate models and conservation strategies to safeguard our forests for the future.

Keywords: Drought recovery | Deciduous species | Evergreen species | Forest resilience | Climate-driven drought

Anthropogenic greenhouse gases emissions have significantly affected the ecosystem, exposing plants to various abiotic stresses ^[1]. This global warming drives climate changes that cause recurring drought episodes ^[2], which are becoming more frequent, severe, and widespread, posing a major threat to the integrity and functioning of global forest ecosystems. Forests play a pivotal role in regulating the Earth's carbon cycle, maintaining biodiversity, and providing essential ecosystem services ^[3]. However, research increasingly documents tree mortality, canopy dieback, and declines in forest productivity linked to drought stress ^[4,5]. As climate extremes intensify, understanding how different tree species respond to drought stress and whether their resilience is increasing or declining is crucial for predicting future forest dynamics. Previous studies have highlighted the importance of tree functional traits, such as leaf phenology, wood anatomy, and water-use strategies in shaping drought responses ^[6]. Yet, findings have been inconsistent, especially regarding differences between deciduous and evergreen species across varying biomes. Additionally, many studies have been limited spatially or taxonomically, leaving critical knowledge gaps in large-scale forest responses to drought.

The recent study by Marchand et al ^[7], published in *Global Change Biology*, provides valuable new insights into the long-term evolution of drought resilience in Canadian forests. Drawing on an exceptional dataset of 40,147 trees across 4,558 plots and 23 species, the authors deliver a nuanced analysis of how growth resistance, recovery, and overall resilience have changed over the past century. By combining dendroecological methods with high-resolution climate data and mixed-effects modeling, the study explores how leaf habit (deciduous vs. evergreen), prior drought exposure, and environmental gradients shape tree responses to drought. Their findings reveal a notable temporal divergence in resilience trajectories: while evergreen species exhibited low but stable drought resilience, deciduous species experienced a sharp

and sustained decline in recovery and resilience throughout the 20th century. These patterns suggest that deciduous trees, long thought to be more resilient due to faster recovery, may be more vulnerable than previously believed under intensifying drought regimes.

One of the most consequential insights of this study is the differential temporal trajectory of post-drought recovery. Deciduous trees initially exhibited stronger recovery than evergreens; however, this advantage steadily diminished between 1901 and 2017, with recovery values dropping from 1.53 to 1.27. The resilience (the ability to return to pre-drought growth) of deciduous species also declined significantly, while evergreens remained consistently low but stable. This temporal divergence raises urgent questions about future forest composition and productivity, particularly in mixed forests where deciduous species have historically dominated. The analysis further shows that drought resistance declined more steeply with tree age in evergreen species, suggesting that mature conifers may become increasingly susceptible to mortality under repeated drought exposure. Importantly, the authors identify a strong negative correlation between resistance and recovery in both groups, pointing to an inherent trade-off in drought response strategies.

Marchand et al ^[7] also provide compelling evidence that resilience dynamics are strongly modulated by spatial and climatic gradients. Elevation, temperature, and precipitation emerged as dominant predictors of resilience indices, with high-elevation forests showing greater resistance and overall resilience to drought. Interestingly, the positive effect of elevation was more pronounced in deciduous species, suggesting possible topographic refugia for vulnerable broadleaf trees. Meanwhile, prior drought exposure emerged as a critical factor: trees that had experienced more drought events in the past tended to show improved resistance and recovery, pointing to a form of ecological memory or adaptive acclimation. However, this benefit was not

uniform across species or regions, and in older, previously unexposed forests, resilience remained particularly low. These results underscore the complex interplay between intrinsic traits, environmental context, and disturbance history in shaping tree drought resilience.

Despite its broad scope and robust methodology, the study is not without limitations. The analysis, while spatially extensive, is constrained to Canadian forests and may not capture the full variability of resilience responses in other forested biomes. Extrapolating the findings to other global regions should be done cautiously, given differences in ecosystem types, climate regimes, and disturbance histories that may influence resilience trajectories. Additionally, while tree-ring data offer powerful insights into long-term growth trends, they do not fully capture belowground processes, hydraulic failure, or mortality mechanisms associated with drought stress. Furthermore, the potential role of biotic agents (e.g., pests, pathogens) in mediating post-drought resilience was not addressed, although such interactions can significantly affect recovery outcomes. Nonetheless, Marchand et al.^[7] effectively mitigate many methodological concerns by using rigorous filtering criteria for drought events and modeling approaches that account for confounding variables such as tree size, age, and site-level variation. However, some limitations remain, including potential biases from site selection or uneven species representation. Moreover, the statistical models, while sophisticated, rely on assumptions that may not fully capture ecological complexity.

The findings of this study have far-reaching implications for forest management, conservation planning, and Earth system modeling. The long-term decline in deciduous tree resilience suggests that forest composition could gradually shift toward more drought-tolerant evergreen species. This shift may have important implications for forest productivity and biodiversity. Moreover, the study's insights into spatial and temporal variability in resilience can inform region-specific adaptation strategies. For instance, the identification of high-elevation zones as potential climate refugia provides a basis for targeted conservation efforts. The study also questions the adequacy of current forest models and carbon accounting frameworks, many of which do not incorporate time-dependent shifts in resilience or the legacy effects of repeated droughts.

Building on Marchand et al.^[7] work, we propose several research priorities. First, expanding tree-ring and drought resilience studies into tropical, Mediterranean, and Southern Hemisphere forests would help assess whether the patterns observed in Canada are globally consistent. Second, integrating physiological measurements, such as non-structural carbohydrate reserves, xylem embolism thresholds, and root depth, with dendroecological data could elucidate the mechanisms underlying resilience trajectories. Third, long-term monitoring across drought-prone gradients, especially in mixed or transitional forest zones, is essential to detect early-warning signals of functional decline. Fourth, developing standardized resilience metrics and protocols across biomes will facilitate more accurate model parameterization and inter-site comparisons. Lastly, engaging local and Indigenous communities in forest monitoring and resilience research can enhance the social relevance and ethical grounding of climate adaptation strategies.

Overall, Marchand et al.^[7] make an important contribution to advancing our understanding of forest responses to climate-induced drought. Their comprehensive analysis reveals not only a decline in deciduous tree resilience but also broader implications for forest composition, carbon dynamics, and biodiversity in a

warming world. As droughts grow more intense and forests face compounding stressors, such work may inform updates to resilience models, support adaptive management, and contribute to protecting ecosystem services across boreal and temperate regions.

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AUTHOR CONTRIBUTIONS

Conceptualization: F.M. and M.B.S. | Writing – original draft: F.M. and M.B.S. The authors confirm their contributions to the paper as follows.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The author has nothing to report.

LINKED ARTICLE

This article is a Commentary on Marchand et al., <https://doi.org/10.1111/gcb.70330>

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