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CONCERTO Graphical Summary

Increased efficiency of water use does not stimulate tree productivity

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Journal Nature Climate Change

Funded by the European Union

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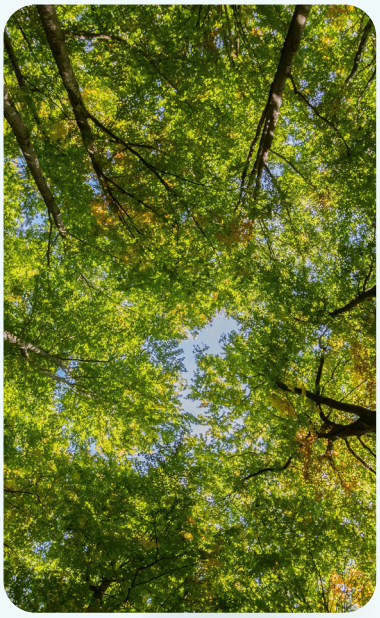
Research brief

Higher water-use efficiency does not always translate into greater tree productivity
New study shows that rising forest water-use efficiency does not necessarily lead to greater tree growth or carbon storage.

Background

Trees are becoming more water-use efficient as atmospheric carbon dioxide concentrations increase. This increase in intrinsic water-use efficiency (iWUE) is often interpreted as evidence that forests will grow faster and store more carbon under future climate conditions. However, observations from many forests worldwide have shown that increases in water-use efficiency do not always coincide with increases in tree growth. This raises important questions about how forests will respond to rising atmospheric CO_2 and whether improved water-use efficiency can be used as a reliable indicator of future carbon sequestration.



Objective

This study investigated whether increases in intrinsic water-use efficiency can be expected to lead to proportional increases in tree growth and forest productivity. The researchers combined optimality theory, tree-ring isotope records, experimental observations, and global datasets to develop a theoretical framework linking water-use efficiency, atmospheric CO_2, atmospheric dryness, plant hydraulics, and tree growth.

Results

The study found that although rising atmospheric CO_2 generally increases intrinsic water-use efficiency, these gains are unlikely to translate into proportional increases in tree growth.

The analysis identified several mechanisms that weaken the link between water-use efficiency and productivity

- Increasing atmospheric dryness, measured as vapour pressure deficit (VPD), reduces the growth benefits associated with higher water-use efficiency.
- Hydraulic constraints linked to tree size and height increase the cost of transporting water, further limiting growth responses.
- Carbon-use efficiency and respiration processes reduce the fraction of assimilated carbon that can be converted into biomass growth.

The study further showed that increases in water-use efficiency frequently overestimate increases in tree productivity because environmental and physiological constraints become increasingly important under climate change.

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Stakeholders

- Researchers
- Forest ecologists
- Earth system modellers
- Forest and land managers
- Environmental policymakers
- Climate mitigation practitioners

Key messages

Rising atmospheric CO_2 generally improves water-use efficiency, but does not lead to proportional increases in tree growth.

Increasing atmospheric dryness reduces the growth benefits of improved water-use efficiency.

As trees grow larger, hydraulic constraints make water transport more costly and further limit growth.

Respiration and carbon-use processes mean that only part of the assimilated carbon contributes to biomass growth.

Under climate change, water-use efficiency may increasingly overestimate tree productivity due to environmental and physiological constraints.

Practical value

This research improves forest carbon projections and Earth system models by accounting for structural and environmental constraints that limit future tree growth and climate mitigation capacity.

https://www.nature.com/articles/s41597-025-05773-4

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