CONCERTO

CONCERTO Graphical Summary

Higher optimal temperature for vegetation transpiration than for photosynthesis

Haoyu Xia, Fangyue Zhang, Philippe Ciais, Josep Peñuelas and colleagues

Journal Nature Plants

Funded by the European Union

CONCERTO receives funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101185000. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the EU nor CINEA can be held responsible for them.

Research brief

Plants keep losing water after photosynthesis starts to decline under heat stress. New global study shows that vegetation can tolerate higher temperatures for transpiration than for photosynthesis.

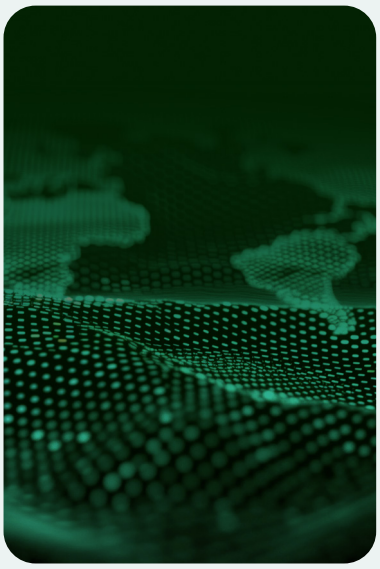
Background

Plants regulate both the global carbon and water cycles. Through photosynthesis, vegetation removes carbon dioxide from the atmosphere, while transpiration releases water vapour and helps cool leaves. As heatwaves become more frequent and intense, understanding how plants balance carbon uptake and water loss becomes increasingly important. While the temperature optimum of photosynthesis has been widely studied, much less is known about the temperature response of transpiration at ecosystem scale.

Objective

This study investigated whether vegetation reaches peak water loss (transpiration) and peak carbon uptake (photosynthesis) at the same temperature. The study combined measurements from more than 300 ecosystem monitoring sites worldwide, tree sap-flow observations, and Earth system model simulations to determine whether photosynthesis and transpiration reach their thermal limits at the same temperature.

Results



Across ecosystems worldwide, the optimal temperature for transpiration was consistently higher than that for photosynthesis. On average, transpiration continued increasing until temperatures were about 1.8°C higher than those at which photosynthesis reached its peak. This suggests that plants continue using transpiration to cool their leaves even after photosynthesis has begun to decline under heat stress. The pattern was observed across forests, grasslands, croplands, and different climate zones, and was confirmed using multiple independent datasets and analytical approaches.

The study further showed that:

Maximum growing-season temperature is the main factor controlling the thermal optima of both transpiration and photosynthesis.

Ecosystems with greater vegetation water content show larger differences between the temperature optima of water loss and carbon uptake.

Current Earth system models reproduce the general pattern but significantly underestimate the temperature thresholds and their differences.

Funded by the European Union

CONCERTO receives funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101185000. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the EU nor CINEA can be held responsible for them.

Stakeholders

Researchers

Earth system modellers

Water and land managers

Environmental policymakers

Climate adaptation practitioners

Key messages

Plant water loss remains high at temperatures where carbon uptake is already declining.

Under warming conditions, photosynthesis becomes constrained before transpiration.

During heat stress, plants appear to prioritize leaf cooling over carbon gain.

Current climate and ecosystem models do not fully capture this behaviour and may underestimate ecosystem responses to extreme heat.

Practical value

The findings improve risk assessment by enabling more accurate predictions of forest carbon sink–source transitions, enhance water security through better forecasting of soil moisture depletion during heatwaves, and support more reliable Earth system models by reducing the underestimation of ecosystem collapse under global warming.

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

Funded by the European Union

CONCERTO receives funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101185000. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the EU nor CINEA can be held responsible for them.