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Long-term increase in forest water-use efficiency observed across ecosystem carbon flux networks

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Terrestrial plants remove CO_2 from the atmosphere through photo- synthesis, a process that is accompanied by the loss of water vapour from leaves. The ratio of water loss to carbon gain, or water-use efficiency, is a key characteristic of ecosystem function that is central to the global cycles of water, energy and carbon. Here we analyse direct, long-term measurements of whole-ecosystem carbon and water exchange. We find a substantial increase in water-use efficiency in temperate and boreal forests of the Northern Hemisphere over the past two decades. We systematically assess various competing hypotheses to explain this trend, and find that the observed increase is most consistent with a strong CO_2 fertilization effect. The results suggest a partial closure of stomata - small pores on the leaf surface that regulate gas exchange - to maintain a near- constant concentration of CO_2 inside the leaf even under continually increasing atmospheric CO_2 levels. The observed increase in forest water-use efficiency is larger than that predicted by existing theory and 13 terrestrial biosphere models. The increase is associated with trends of increasing ecosystem-level photosynthesis and net carbon uptake, and decreasing evapotranspiration. Our findings demonstrate the utility of maintaining long-term eddy-covariance flux measurement sites. The results suggest a shift in the carbon- and water-based economics of terrestrial vegetation, which may require a reassessment of the role of stomatal control in regulating interactions between forests and climate change, and a re-evaluation of coupled vegetation–climate models.