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MODELLING PRODUCTIVITY AND FUNCTION (M BATTAGLIA, SECTION EDITOR)

Warming and Elevated CO_2 Have Opposing Influences on Transpiration. Which is more Important?

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Abstract

Plant transpiration is a key component of the terrestrial water cycle, and it is important to understand whether rates are likely to increase or decrease in the future. Plant transpiration rates are affected by biophysical factors, such as air temperature, vapour pressure deficits and net radiation, and by plant factors, such as canopy leaf area and stomatal conductance. Under future climate change, global temperature increases, and associated increases in vapour pressure deficits, will act to increase canopy transpiration rates. Increasing atmospheric CO_2 concentrations, however, is likely to lead to some reduction in stomatal conductance, which will reduce canopy transpiration rates. The objective of the present paper was to quantitatively compare the importance of these opposing driving forces. First, we reviewed the existing literature and list a large range of observations of the extent of decreasing stomatal conductance with increasing CO_2 concentrations. We considered observations ranging from short-term laboratory-based experiments with plants grown under different CO_2 concentrations to studies of plants exposed to the naturally increasing atmospheric CO_2 concentrations. Using these empirical observations of plant responses, and a set of well-tested biophysical relationships, we then estimated the net effect of the opposing influences of warming and CO_2 concentration on transpiration rates. As specific cases studies, we explored expected changes in greater detail for six specific representative locations, covering the range from tropical to boreal forests. For most locations investigated, we calculated reductions in daily transpiration rates over the twenty-first century that became stronger under higher atmospheric CO_2 concentrations. It showed that the effect of CO_2-induced reduction of stomatal conductance would have a stronger transpiration-depressing effect than the stimulatory effect of future warming. For currently cold regions, global warming would, however, lengthen the growing seasons so that annual sums of transpiration could increase in those regions despite reductions in daily transpiration rates over the summer months.

Keywords CO_2 · Evaporation · Evapotranspiration · Global change · Penman-Monteith · Stomata · Temperature

Introduction

Climate change is now well recognised as an important environmental change that will shape our future. The most certain change is an increase in the atmospheric CO_2 concentration ([CO_2]). While most attention has been focused on the radiative consequences of increasing [CO_2] in the atmosphere [1], [CO_2] also has direct effects on plant growth and function [2–4]. This can be seen in short-term photosynthetic responses [5], growth responses in short-term experiments [6••], growth responses in the field under artificially increased [CO_2] [7, 8] and in global patterns, such as reductions in river runoff [9].

CO_2-response studies most commonly provide plants with adequate access to soil water. Under water-limited conditions, however, relative plant growth responses to elevated [CO_2] can potentially be even greater because increases in photosynthesis and decreases in stomatal conductance can together enhance water use efficiency to a numerically greater extent than the photosynthetic enhancement alone. This has led to the theoretical consideration that water plants grown with a limited water supply should respond more strongly to elevated [CO_2] than plants grown with adequate soil moisture [10].

This article is part of the Topical Collection on *Modelling Productivity and Function*

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