Are Plants Using Less Water These Days?

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Plant responses to increasing CO₂ reduce estimates of climate impacts on drought severity
Abigail L. S. Swann\textsuperscript{a,b,1}, Forrest M. Hoffman\textsuperscript{d}, Charles D. Koven\textsuperscript{c}, and James T. Randerson\textsuperscript{f}

Intensifying drought eliminates the expected benefits of elevated carbon dioxide for soybean
Sharon B. Gray\textsuperscript{a}, Ori E. Paul\textsuperscript{b}, David M. Ro A. Ainsworth\textsuperscript{a,1}, Carl E. Parmelee\textsuperscript{b}, Stephanie P. Klein\textsuperscript{a}, Anna M. Lark\textsuperscript{b}, Justin M. McGrath\textsuperscript{a}, Rachel E. Paul\textsuperscript{b}, and Michael D. L. Allen\textsuperscript{a,1}

Warm spring reduced carbon cycle impact of the 2012 US summer drought
Sebastian Wolf\textsuperscript{a,b,1}, Trevor F. Keenan\textsuperscript{c,2}, Joshua B. Fisher\textsuperscript{d}, Dennis D. Baldocchi\textsuperscript{a}, Ankur R. Desai\textsuperscript{a}, Andrew D. Richardson\textsuperscript{d}, Russell L. Scott\textsuperscript{d}, Beverly E. Law\textsuperscript{d}, Marcy E. Litvak\textsuperscript{e}, Nathaniel A. Brunsell\textsuperscript{f}, Wouter Peters\textsuperscript{g}, and Ingrid T. van der Laan-Luijkx\textsuperscript{h}

Well are they?

Relationships between individual-tree mortality and water-balance variables indicate positive trends in water stress-induced tree mortality across North America
RNER A. KURZ\textsuperscript{2} and NICHOLAS C. COOPS\textsuperscript{1}

Stomatal response to humidity and CO₂ implicated in recent decline in US evaporation
ANGELA J. RIGDEN and GUIDO D. SALVUCCI

Department of Earth and Environment, Boston University, 675 Commonwealth Ave., Boston, MA 02215, USA
Outside air $\Psi = -100.0\,\text{MPa}$

Leaf $\Psi$ (air spaces) $= -7.0\,\text{MPa}$

Leaf $\Psi$ (cell walls) $= -1.0\,\text{MPa}$

Trunk xylem $\Psi = -0.8\,\text{MPa}$

Root xylem $\Psi = -0.6\,\text{MPa}$

Soil $\Psi = -0.3\,\text{MPa}$

Water potential gradient

Xylem sap
Mesophyll cells
Stoma
Water molecule
Atmosphere
Transpiration

Xylem Adhesion cells
Cohesion, by hydrogen bonding

Cohesion and adhesion in the xylem

Water molecule
Root hair
Soil particle
Water

Water uptake from soil

https://www.emaze.com/@AWQQLQIL/Transpiration
Global mean temperature near-term projections relative to 1986–2005

Warmer and intensified hydrologic cycle

Temperature anomaly [°C]

-0.5  0.0  0.5  1.0  1.5  2.0  2.5

1990 2000 2010 2020 2030 2040 2050

Historical ← RCPs

Observations
Historical (42 models)
RCP 2.6 (32 models)
RCP 4.5 (42 models)
RCP 6.0 (25 models)
RCP 8.5 (39 models)

http://www.climate-lab-book.ac.uk/comparing-cmip5-observations/
Recent trends in U.S. evapotranspiration show both, driven by changes in surface

Plant transpiration ~60% of global terrestrial water flux (Wei et al., 2017)!
SO:

Are Plants Using Less Water These Days?

Or in the future?
YES

• Higher CO$_2$ means less need to keep stomata open
  – Evidence: *Increasing water use efficiency*

• Increased atmospheric demand for moisture in warmer climates leads to stomatal closure
  – Evidence: *Higher vapor pressure deficit*

• Longer growing seasons lead to earlier depletion of plant available water
  – Evidence: *Soil moisture deficiency in summer*
Wolf et al., 2016

Decreased transpiration

Energy Fluxes

Baseline
LE 2012
H Baseline
H 2012

Spring: 84±16 MJ
Summer: -202±32 MJ
Fall: -52±7 MJ

Baseline
2012

EF

Baseline
2012
relative heating
relative cooling

Increased vegetation activity
Reduced vegetation activity

SWC

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec
-12% | -30% | -9%
NO

- Higher CO$_2$ fertilizes growth, plants trade water for carbon to maximize this, and as a result have limited change in stomatal response
  - Evidence: *Increased transpiration, reduced baseflow, decreases in water use efficiency*

- Longer growing seasons leads to longer actively transpiring period
  - Evidence: *Plant phenology shifts, earlier use of soil moisture*
Answer

• It depends
  – On plasticity of species response (isohydric/anisohydric continuum)
  – Either way, plant water use will change in response to intensifying hydrological cycles, which will influence global water budget and local land-atmosphere feedbacks
  – Implications for management of water for agriculture, forestry, drought
  – Multi-scale, long-term experiments and observations are needed (Ameriflux, NEON, LTER)
* Climate effects on ecosystem carbon fluxes are shown only in qualitative terms. Individual fluxes might be affected differently by climate extremes (see text).

Sippel et al., 2016
Thanks!

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Photo by J Thom