Climate and Vegetation Effects on Temperate Mountain Forest Evapotranspiration

H31F-1487

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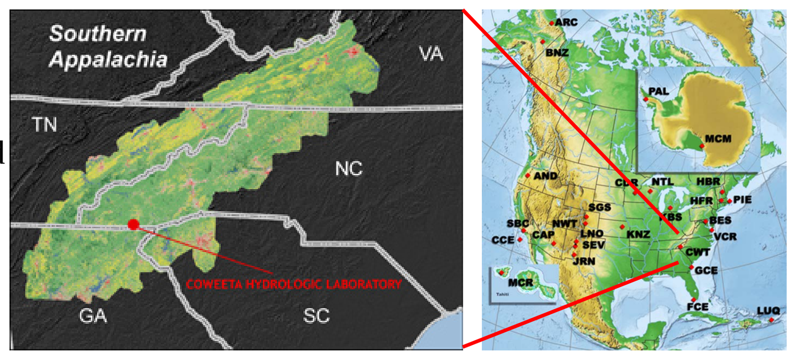
Introduction

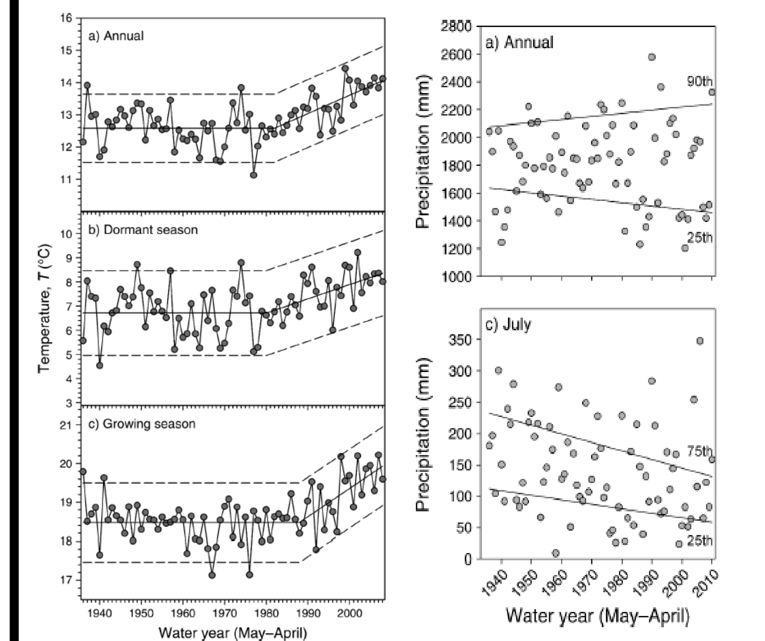
Temperate mountain forests often benefit from abundant water supply from orthographic precipitation. Cove forest stands can receive an additional downslope subsidy from water drainage. However, even within a typical year, a relatively short rain-free period can promote conditions of high atmospheric demand for water, coupled with relatively dry soil. These conditions have been shown to result in decreased net carbon uptake; however, less is known about consequences to the components of the hydrologic cycle.

Study area

- Coweeta Hydrologic Laboratory, North Carolina
- Mature southern Appalachian forest (~85 years since harvesting)
- Deciduous overstory (tulip poplar, sweet birch, red maple, oak), mean canopy height 30 m
- Evergreen understory (rhododendron, mountain laurel)
- Complex topography (base elevation 700 m)
- Mean annual temperature: 12.7º C



Climate trends are increasing likelihood of warmer, drier summers, but forest management and disturbance effects are promoting species with high water use (mesification).

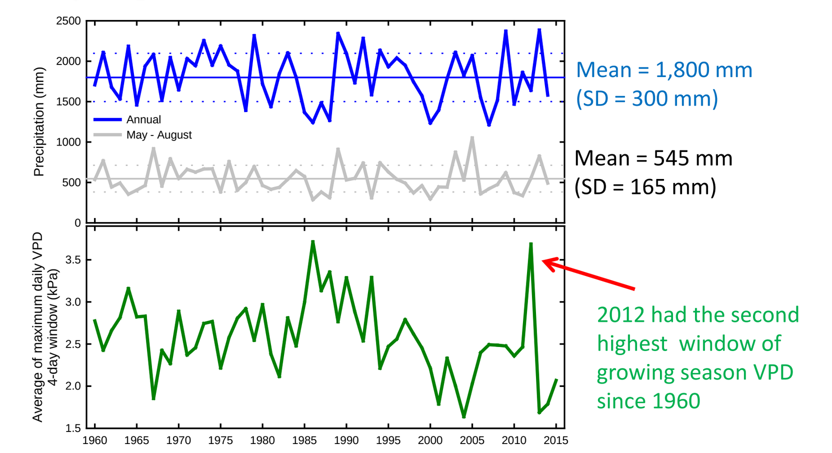


Ford *et al*., 2011, *Ecological Applications*

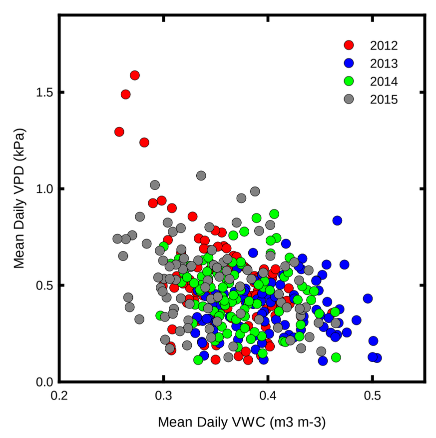
Species	2010 Importance Value	Change Since 1934	Change Since 1970
Ring Porous			
American chestnut (*Castanea dentata*)	1.1	-95%	-77%
Hickory (*Carya* spp.)	5.8	-19%	-18%
Scarlet oak (*Quercus coccinea*)	6.4	-14%	-23%
Red oak (*Quercus rubra*)	4.0	65%	-7%
Chestnut oak (*Quercus prinus*)	14.5	45%	-3%
Evergreen Coniferous			
Eastern hemlock (*Tsuga canadensis*)	1.5	100%	-52%
Diffuse Porous			
Red maple (*Acer rubrum*)	18.0	124%	39%
Black birch (*Betula lenta*)	4.2	166%	55%
Tulip poplar (*Liriodendron tulipifera*)	8.8	95%	74%

Importance value is a function of basal area and density.
Elliott and Miniat, unpublished; Elliott and Vose 2011

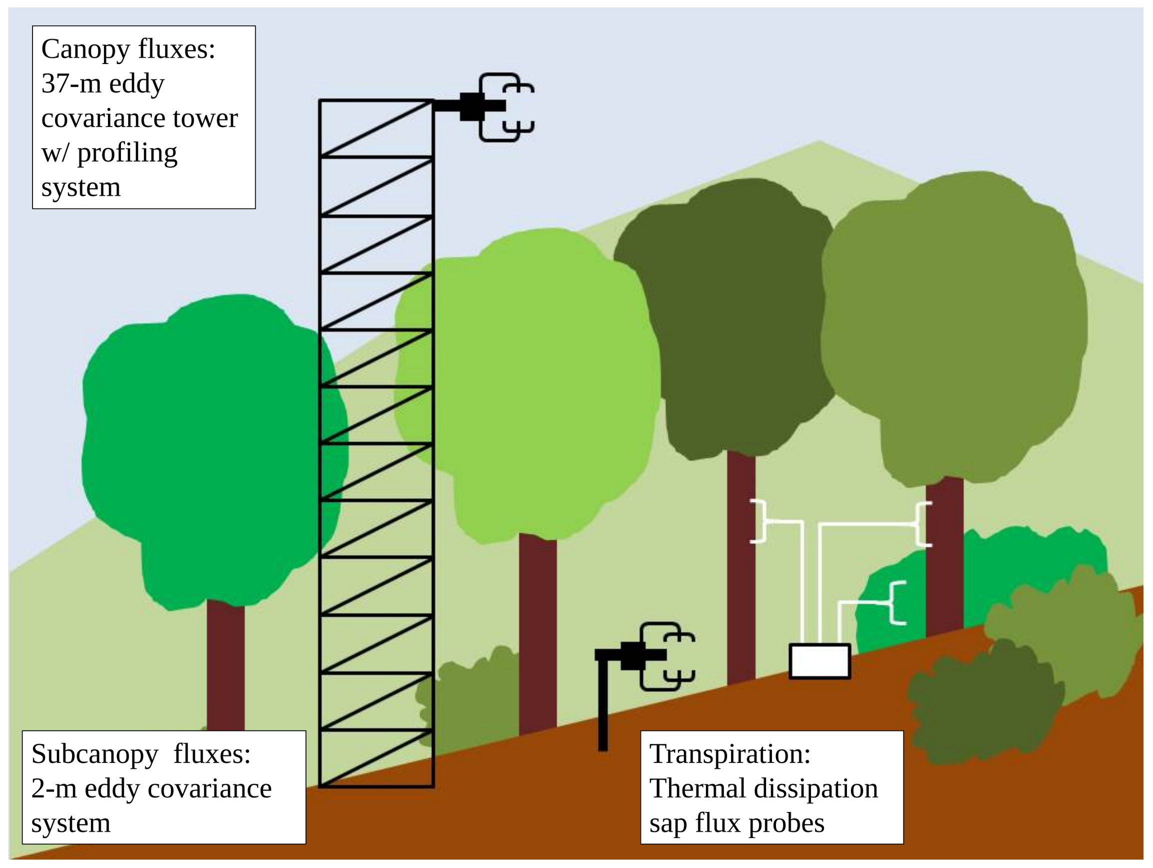
Annual precipitation is typically high and evenly distributed through the year. Average growing season precipitation and evapotranspiration are nearly equal.



Periods of high atmospheric demand for water are brief, infrequent, and often coupled with lower soil volumetric water content (VWC).



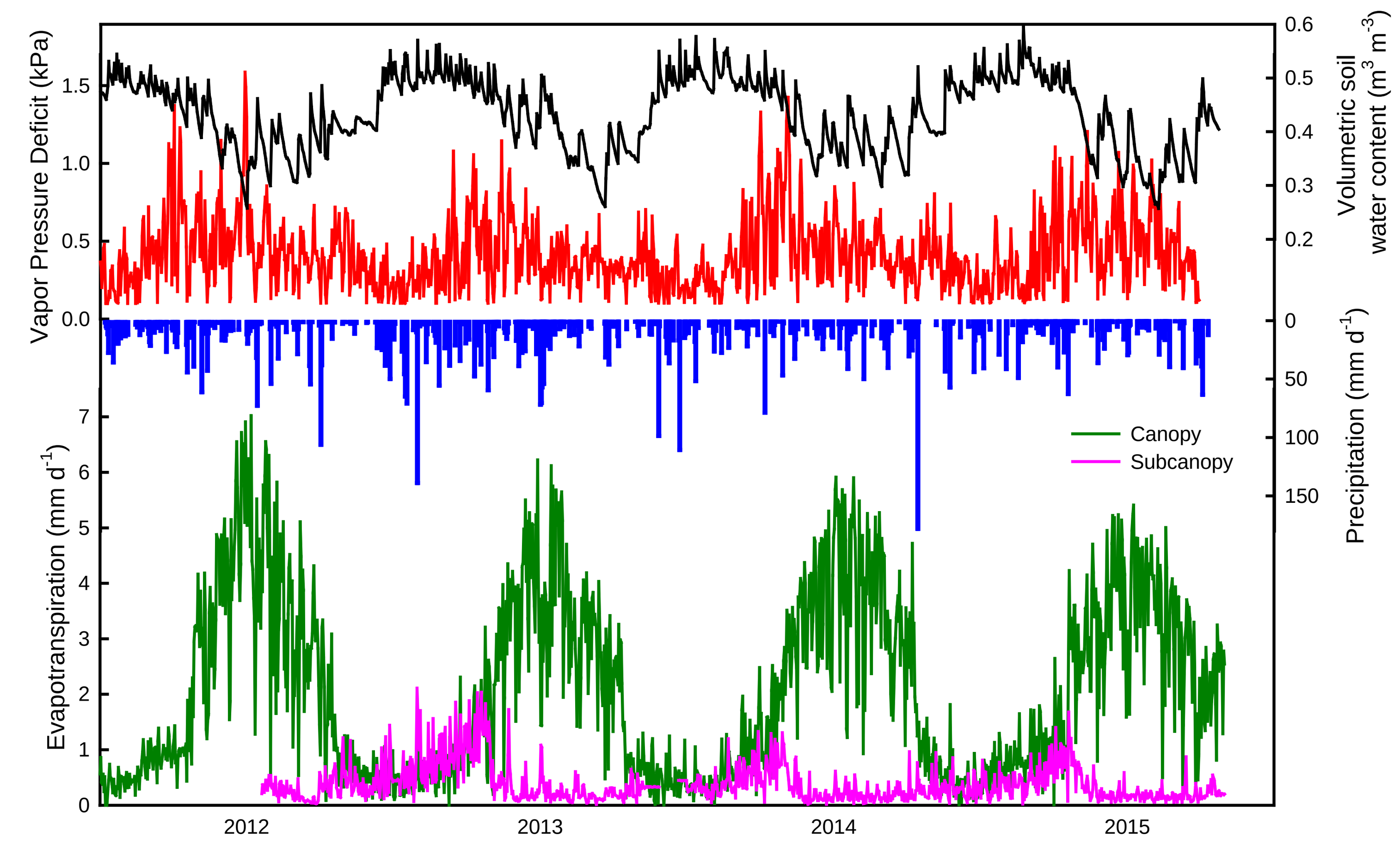
Methods and instrumentation



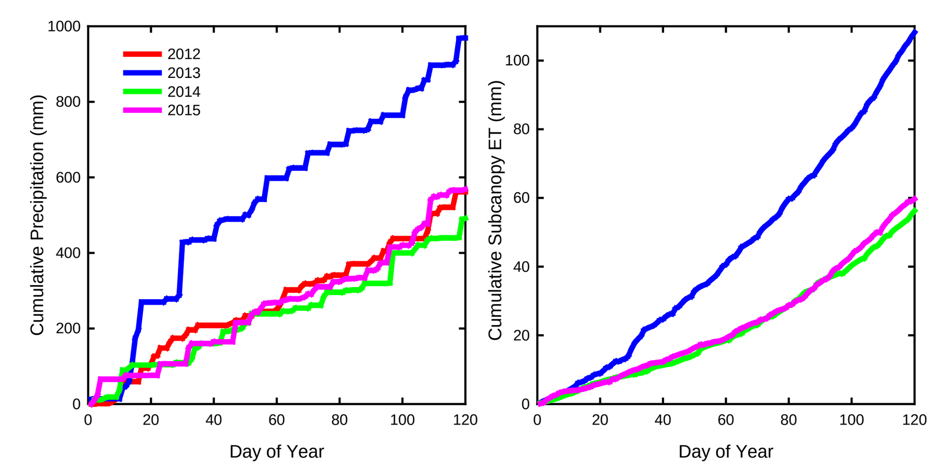
Meteorological measurements include PAR, Rnet, air and soil temperature, relative humidity, soil heat flux, volumetric water content, precipitation, and throughfall. Leaf area index estimated using polynomial relationship between springtime, ground-based, optical measurements (LI-COR, LAI-2000) and PhenoCam photos (http://phenocam.sr.unh.edu/webcam/sites/coweeta/) (r^2=0.96).

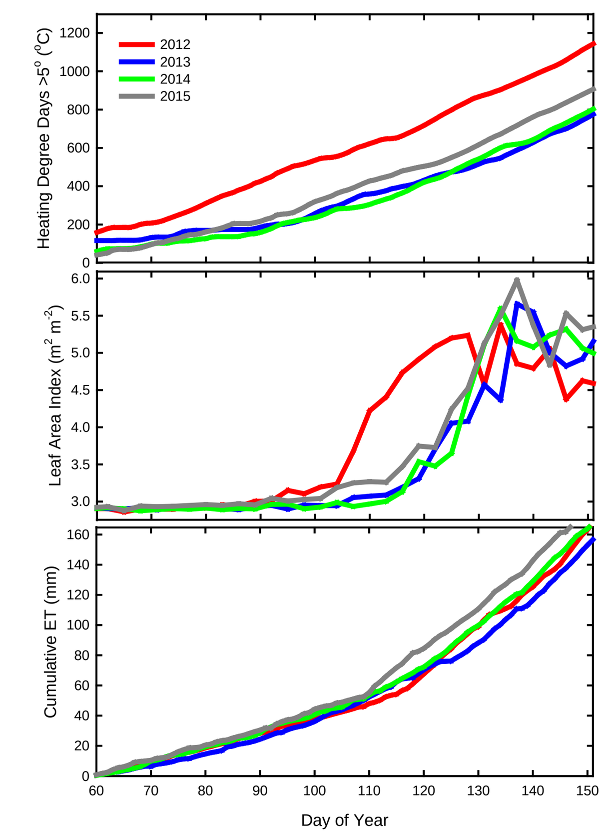
Results

Canopy and subcanopy evapotranspiration (ET) exhibit large seasonal variability



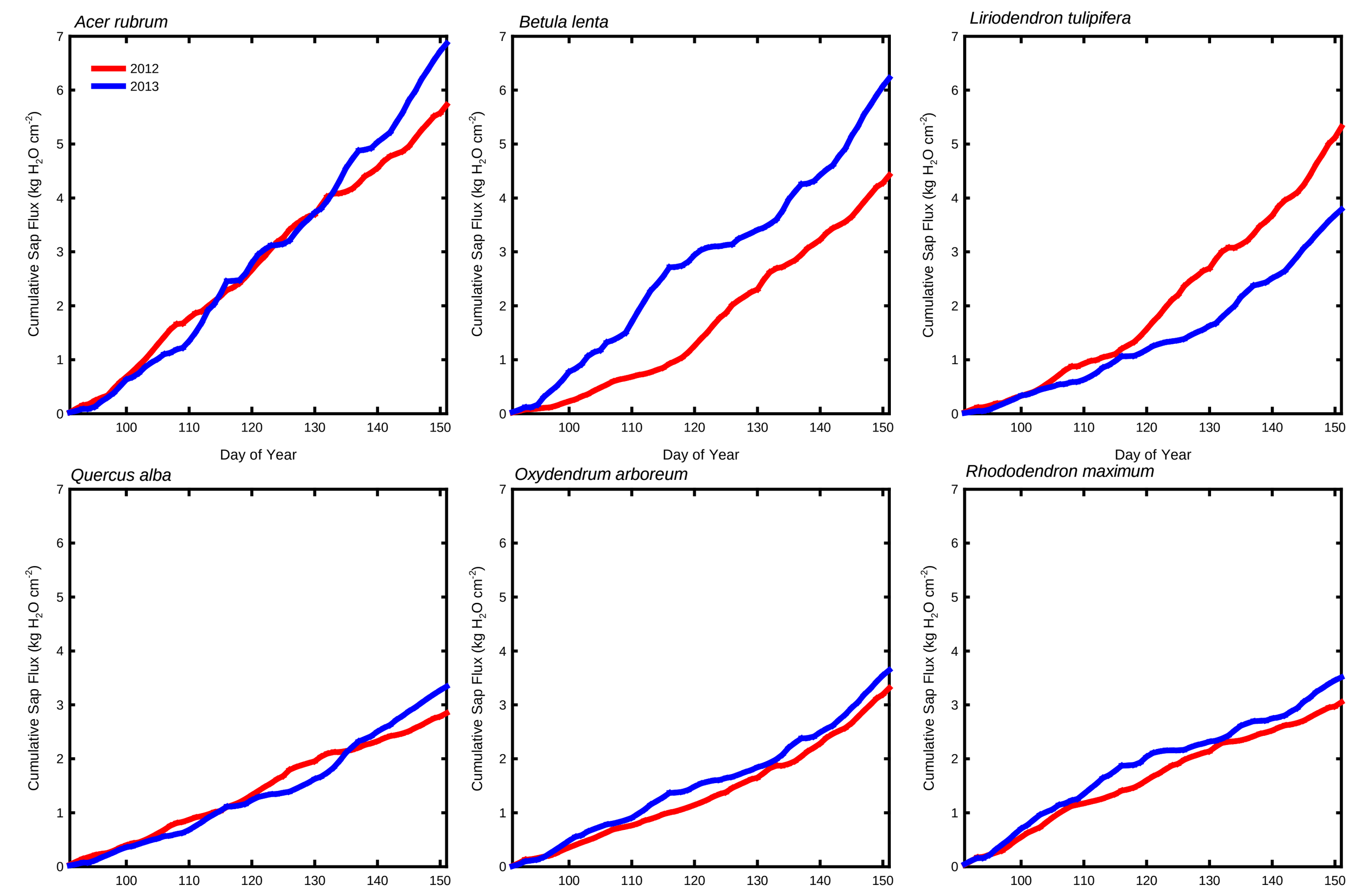
Variability in dormant season ET is driven by litter water availability.





Left - Warm early spring temperature in 2012 resulted in earlier leaf expansion. However, canopy evapotranspiration did not follow patterns in deciduous leaf phenology.

Below - Transpiration followed earlier leaf expansion in 2012 for tulip poplar. Other species showed negligible differences, whereas birch exhibited lower transpiration in 2012.

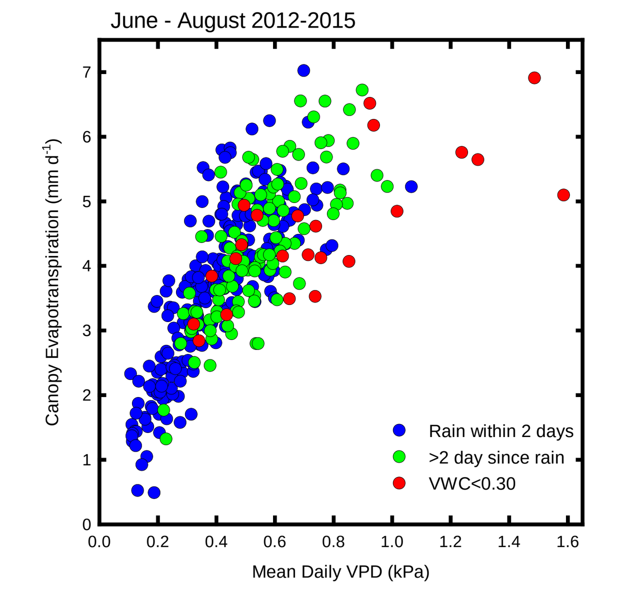


Canopy evapotranspiration increases with VPD to the point at which stomatal control and intercepted precipitation become limiting.

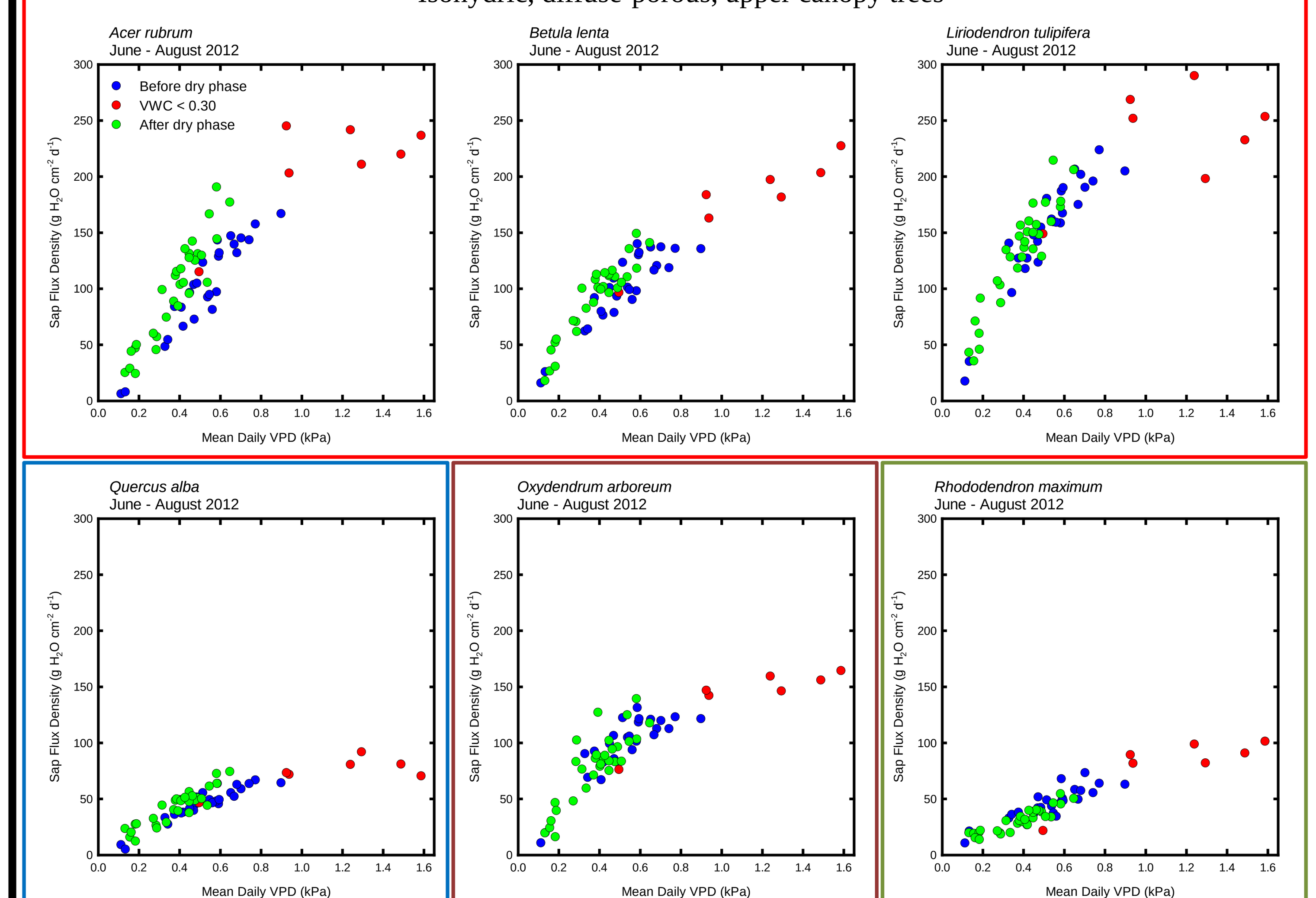
Days following rain events are associated with lower VPD.

Species with highest water use are increasing in abundance and basal area.

All species showed recovery in transpiration rates after high VPD period.



Isohydric, diffuse-porous, upper canopy trees



Anisohydric, ring-porous
Upper canopy trees

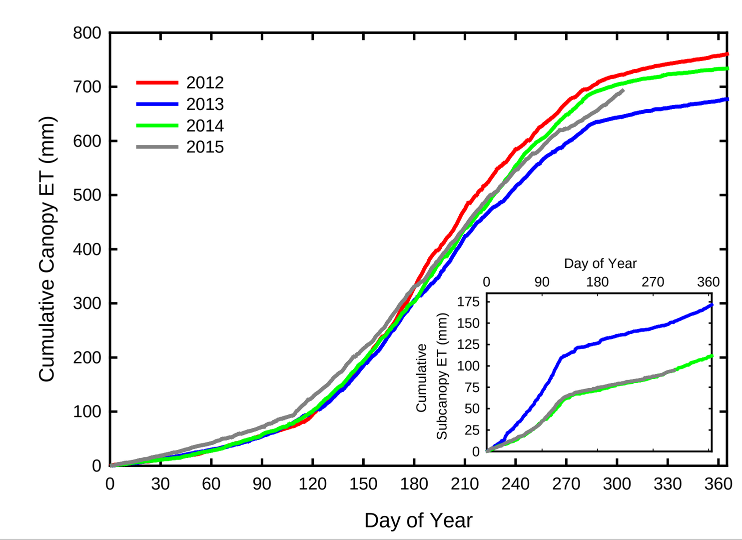
Isohydric, diffuse-porous
Mid-canopy trees

Evergreen
Sub-canopy shrubs

Daily sap flux density as a function of mean daily vapor pressure deficit. Data shown from June 1 through August 31, 2012.

Overall, interannual variability of total canopy evapotranspiration was low.

The subcanopy eddy covariance system captured evaporation intercepted by the litter layer, which was high prior to leaf expansion. However, this footprint is primarily a sparsely vegetated area and may not be characteristic of the entire tower footprint.



Conclusions

Rainless conditions that do not lead to soil drought can still produce atmospheric drought, affecting water use.

Advancing deciduous leaf phenology in a mixed-species forest may not translate to greater stand-level transpiration.

Current forest composition may be resilient to typical climatic variability; however, climate trends, combined with projected changes in species composition, may increase tree vulnerability to water stress.

- Diffuse-porous species are the largest water users and are becoming increasingly dominant.
- Oaks are conservative water users and are declining in many forests.
- Rhododendron is also expanding and can be an important user of water in early spring.

Consistent annual evapotranspiration will cause variability in precipitation to primarily affect streamflow.

This ongoing research is made possible with support from:
USDA Agriculture and Food Research Initiative Foundational Program (AFRI), award number 2012-67019-19484; EPA agreement number 13-IA-11330140-044; National Science Foundation, Long-Term Ecological Research (LTER) program, award #DEB-0823293
We thank, Christine M. Sobek, Stephanie Laseter, Michael Benson, Valerie Bruchon, and Sander Denham for assistance with data collection.