How reforestation may impact water quantity

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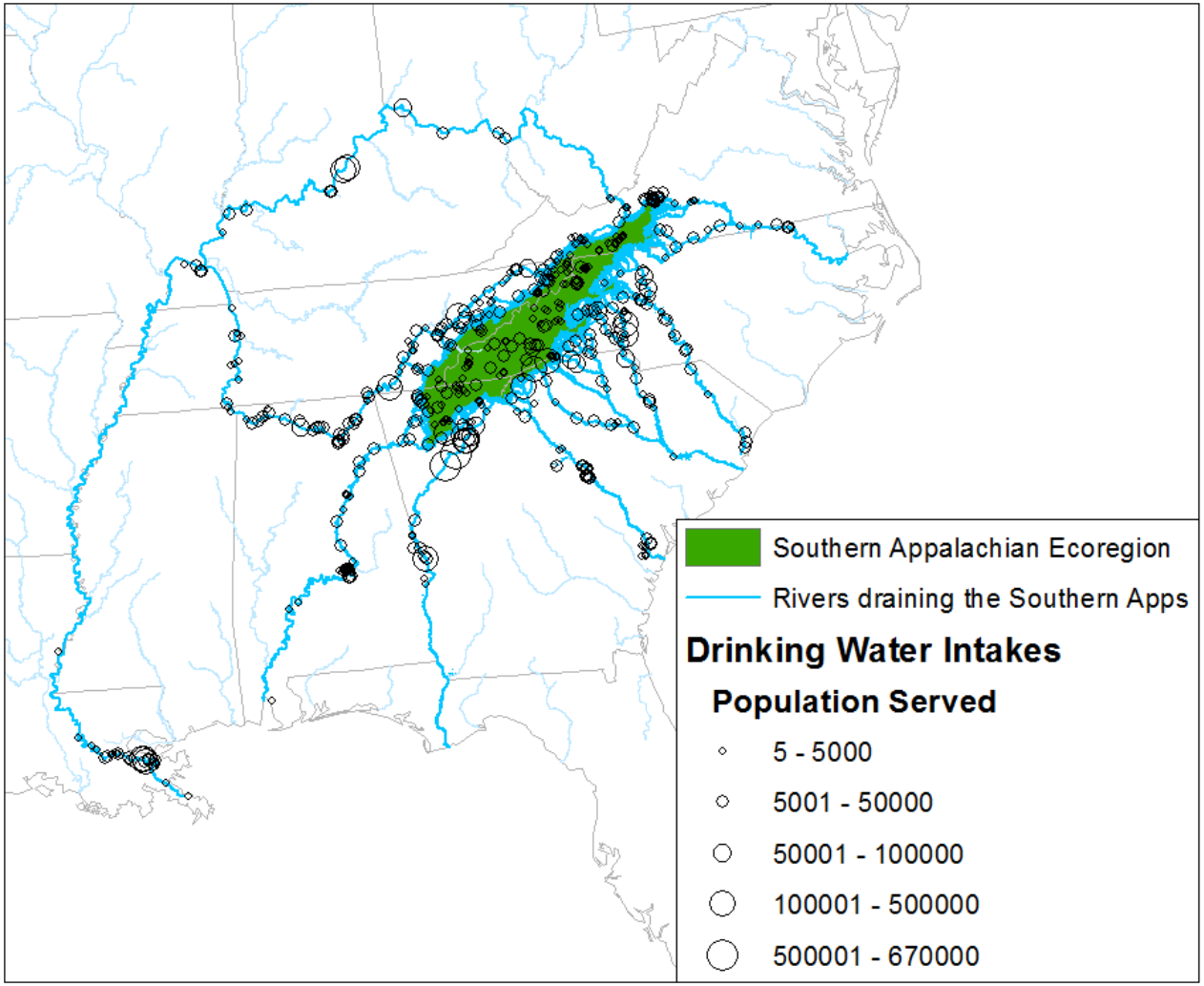
The southern Appalachians: Headwaters for drinking water supply

EPA SDWIS; WaSSI model output



- 81% Forested (24% Nat'l Forest)
- 23 billion m^3/yr
- 588 intakes
- 336 communities
- 10.7 million served (4.9 M get >20%)

Caldwell et al., 2014

Effects of Reforestation on Water Quantity

Direct Effects

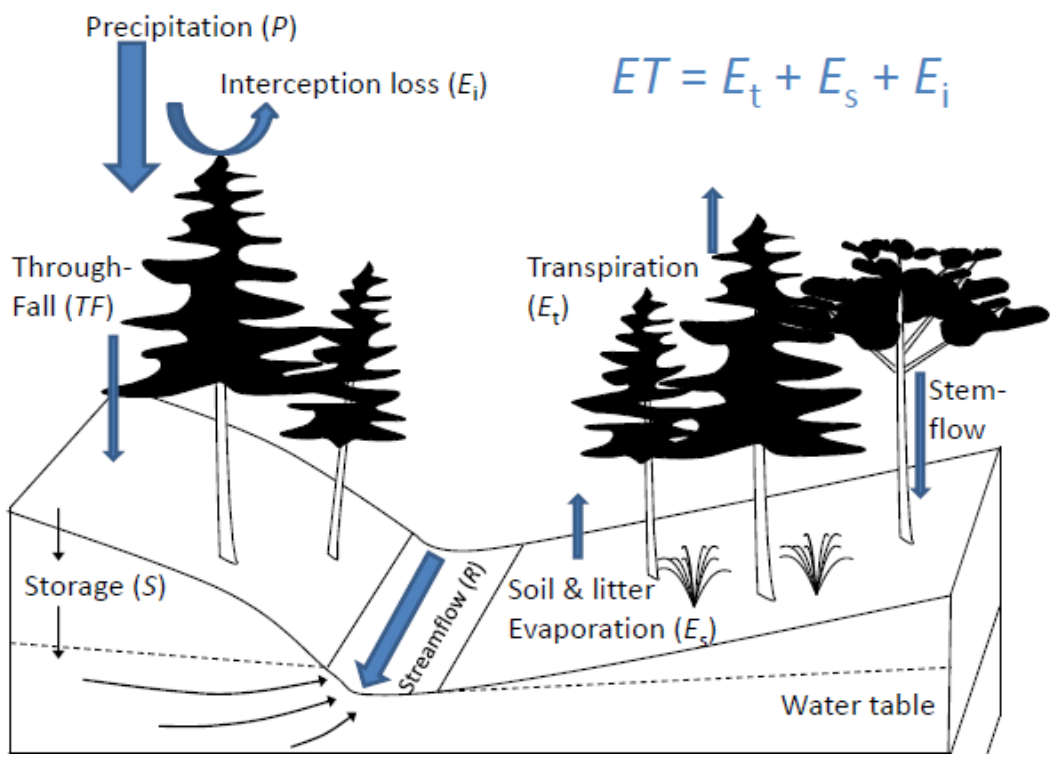
Associated with

- Basal & leaf area (amount)
- Species composition

Indirect Effects

Associated with

- Changes in climate
- Soil moisture & structure
- Disturbance (invasives)



← Water budget of a watershed

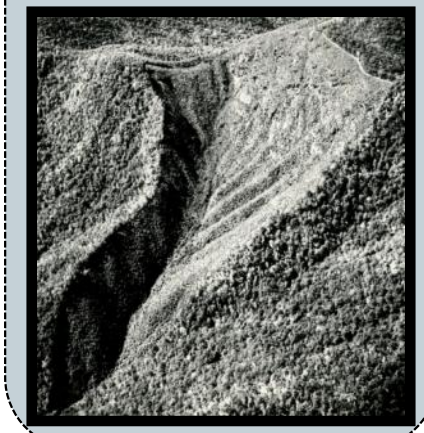
$$P - R = ET$$

Vose, Miniat and Luce et al., 2016

Species conversion to pine

Low elevation clear cut

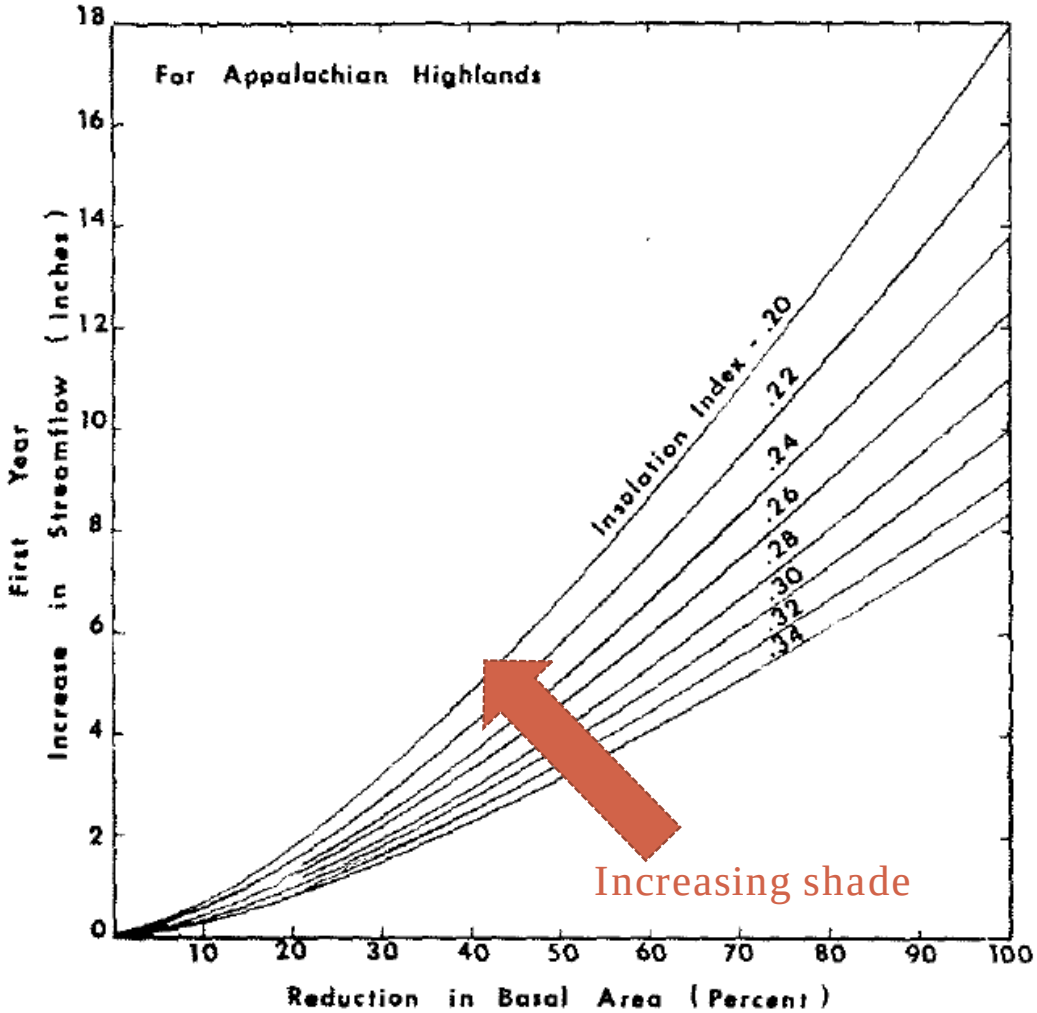
High elevation Clear-cut



Old field succession

Coppice

Effects of Reforestation on Water Quantity



Yield = 0.00224* BA / PI ,

where

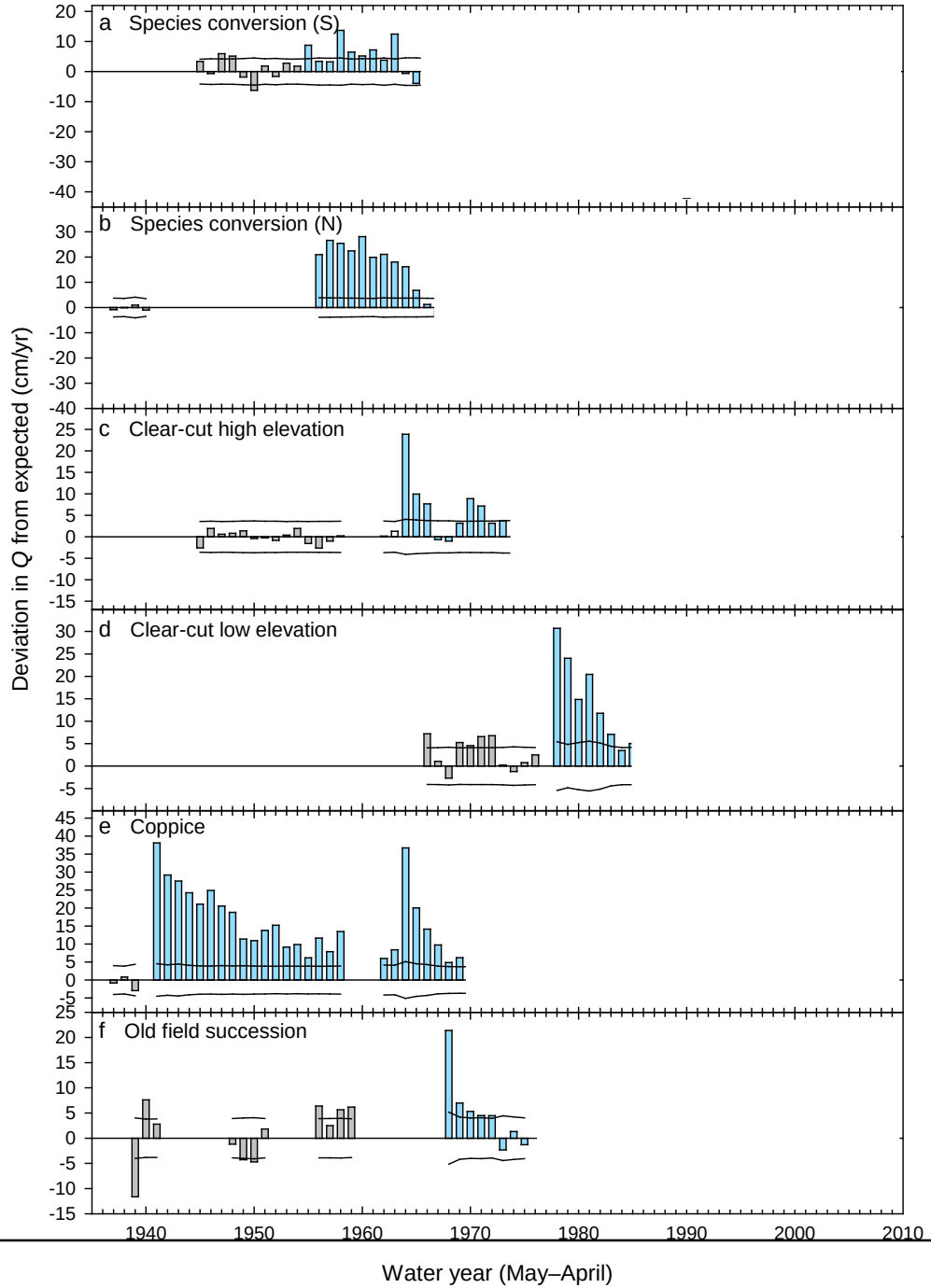
Yield = first year increase in streamflow (cm),

BA = amount of basal area removed (%), and

PI = solar insolation index.

Douglass and Swank 1975

Ford et al. 2011. Ecol Apps



After basal area removal, streamflow recovers quickly.

Panels (a) and (b) illustrate the effect of insolation.

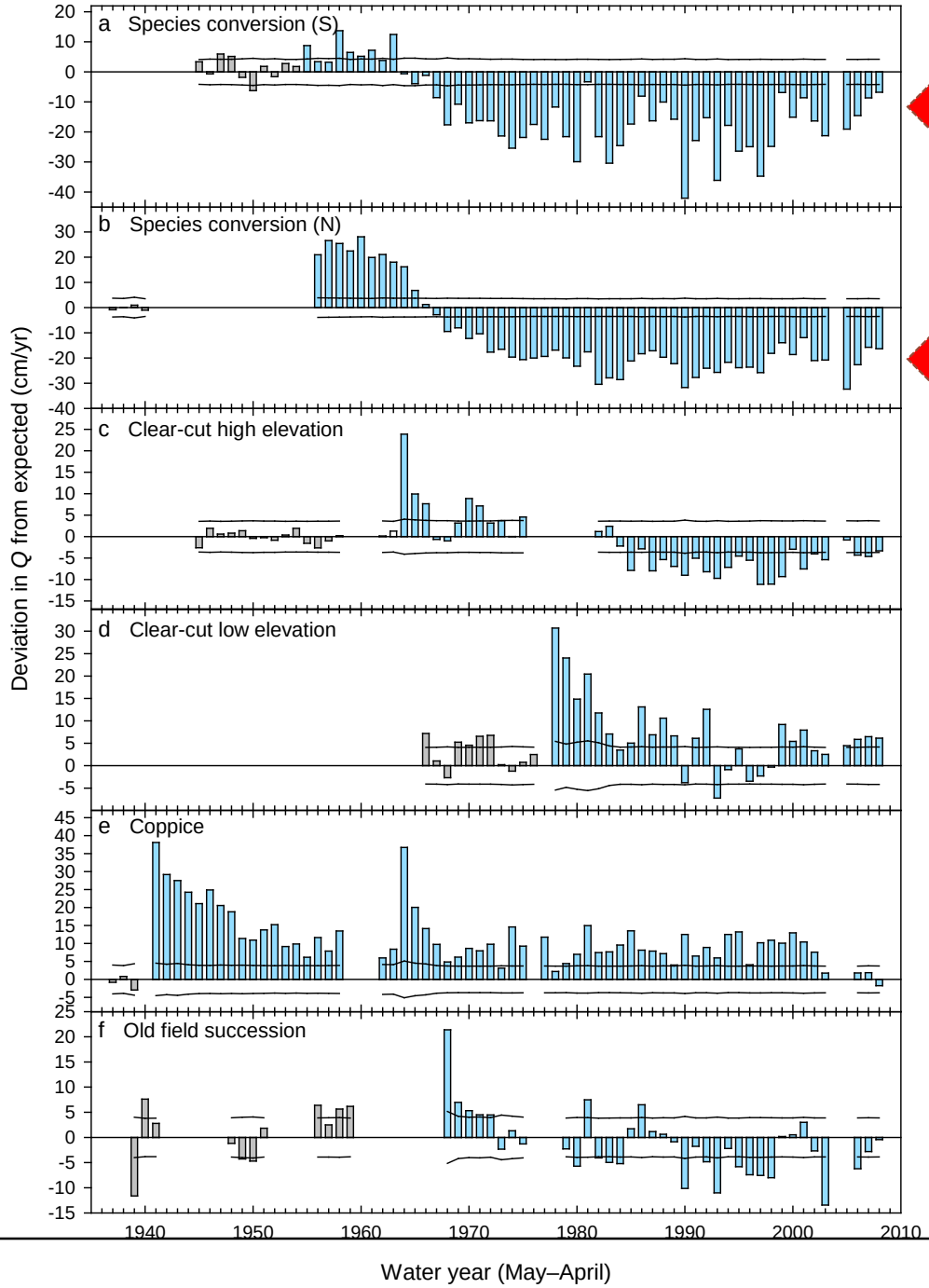
Panel (a) is south-facing

Panel (b) is north-facing

A question that is more difficult to answer is

What happens to streamflow if the vegetation "type" is changed, or if species composition is changed for the long-term?

Ford et al. 2011. Ecol Apps

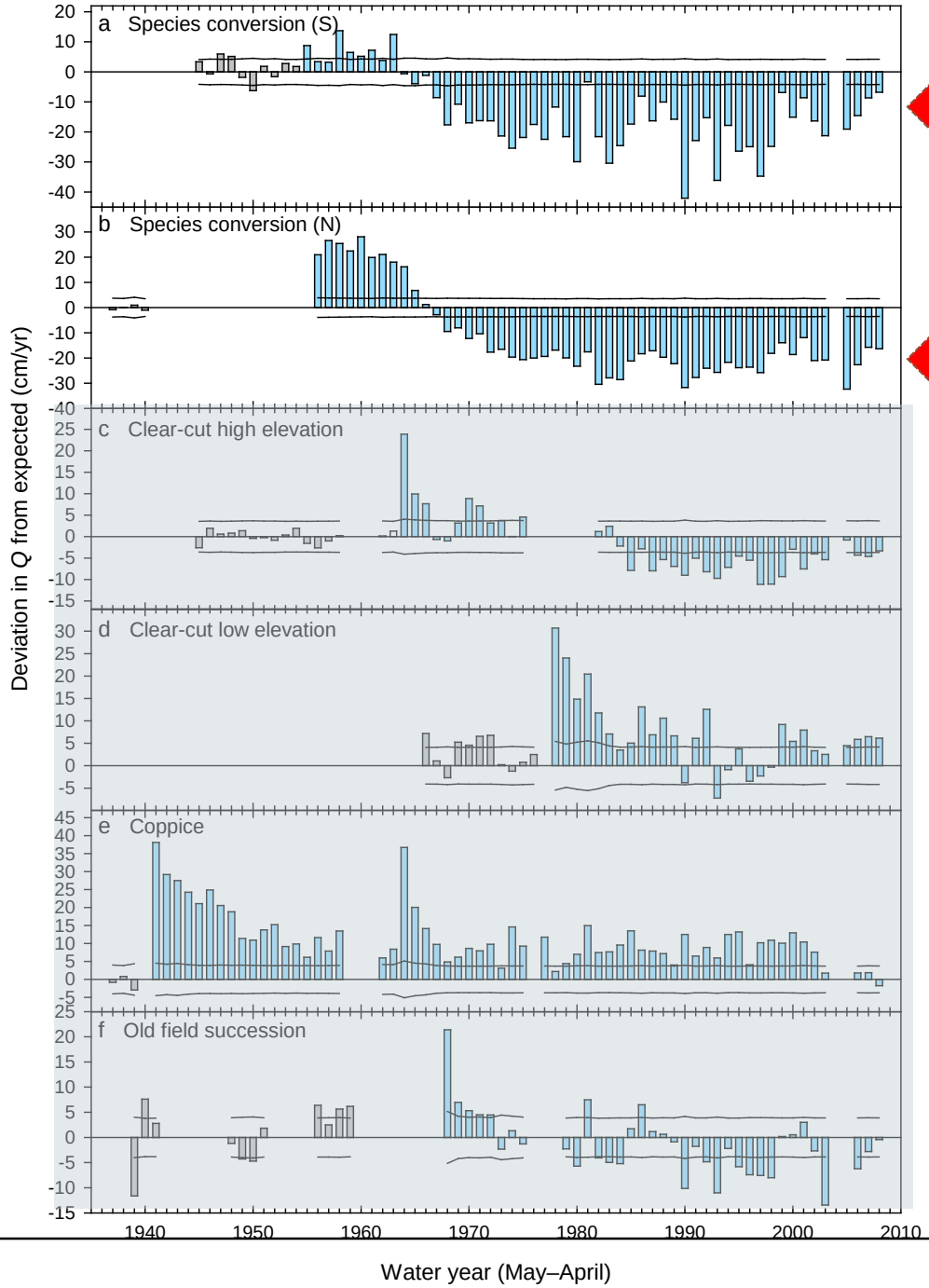


What happens to streamflow if the vegetation "type" is changed, or if species composition is changed for the long-term?

Hardwoods were replaced by pines in panels (a) and (b)

Oaks and hickories were replaced by maple, tulip poplar, birch, and other diffuse-porous species in panels (c) and (f)

Ford et al. 2011. Ecol Apps



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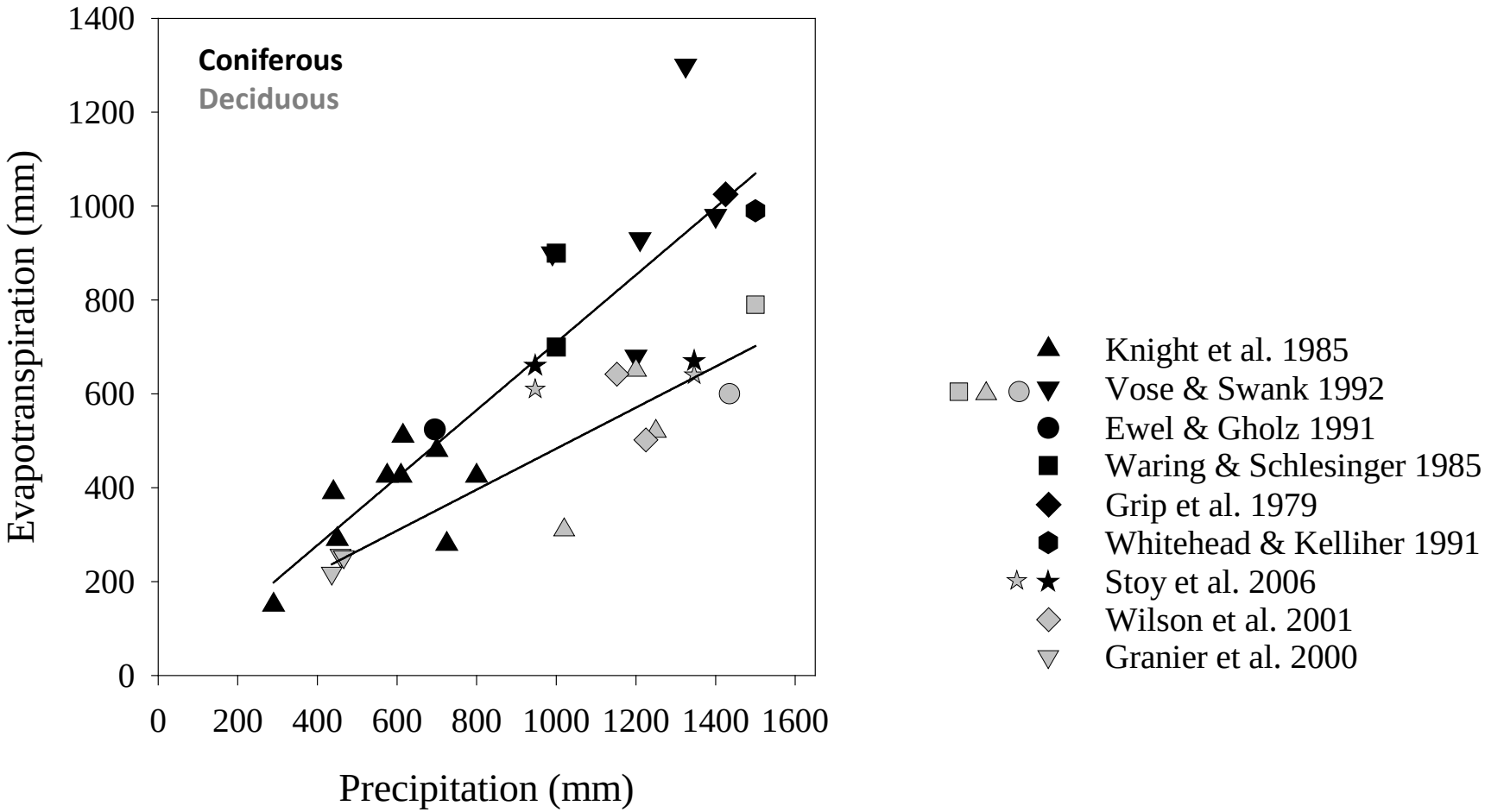
In many studies and biomes, conifers use more water than hardwoods, especially under high rainfall

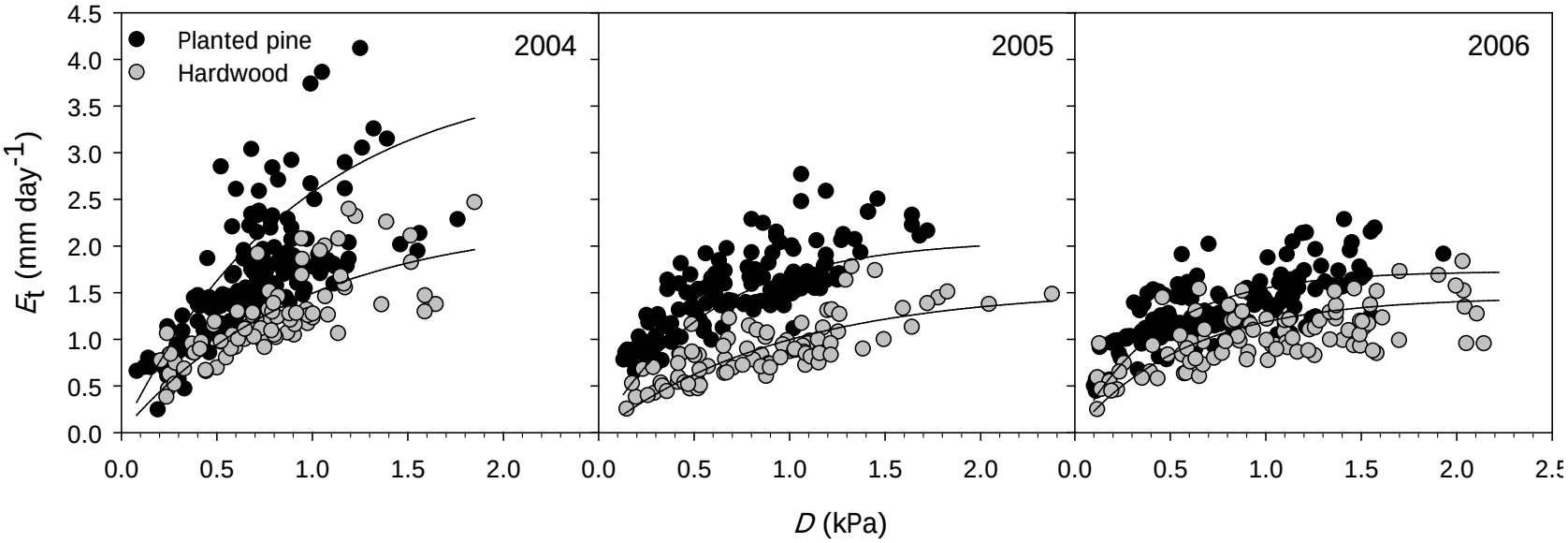


Ford et al. 2011. Ecohydrol

Per unit leaf area, conifers and hardwoods can be relatively similar.

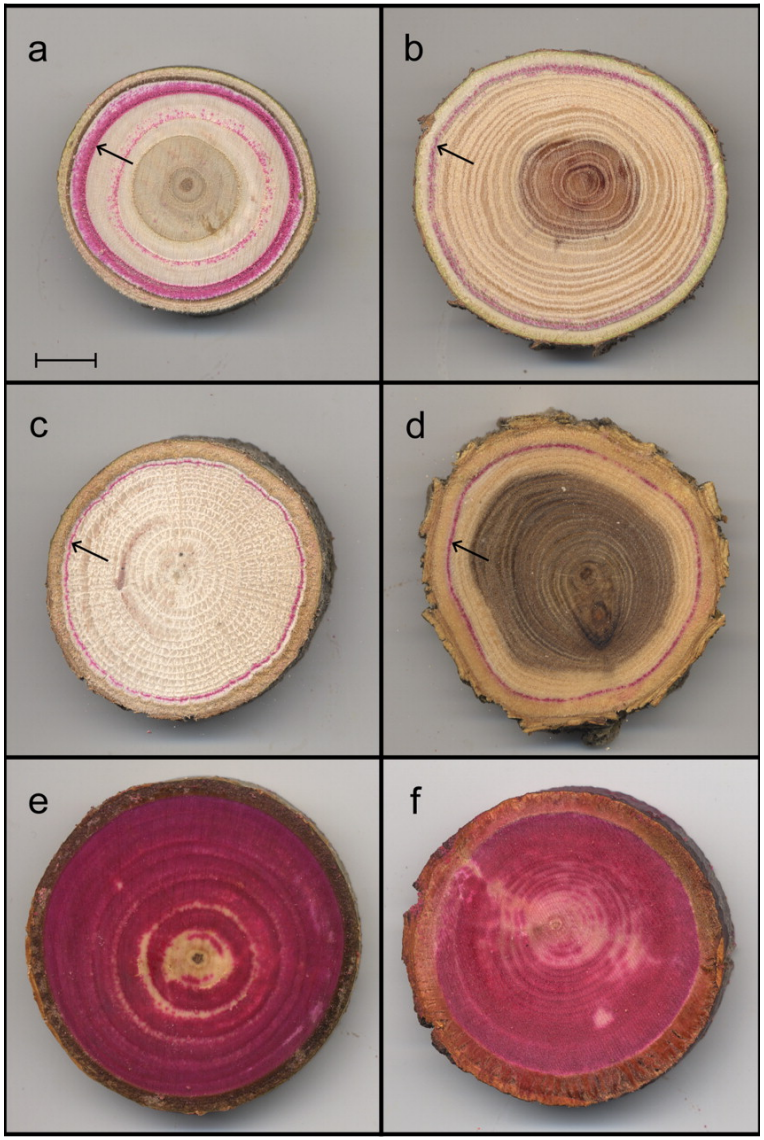
Yet, conifers can have ***more leaves per tree***

& canopies that are more coupled to the atmosphere



Ford et al. 2011. Ecohydrol

Structural effects:
All else equal, trees with more sapwood area use ***more*** *water*

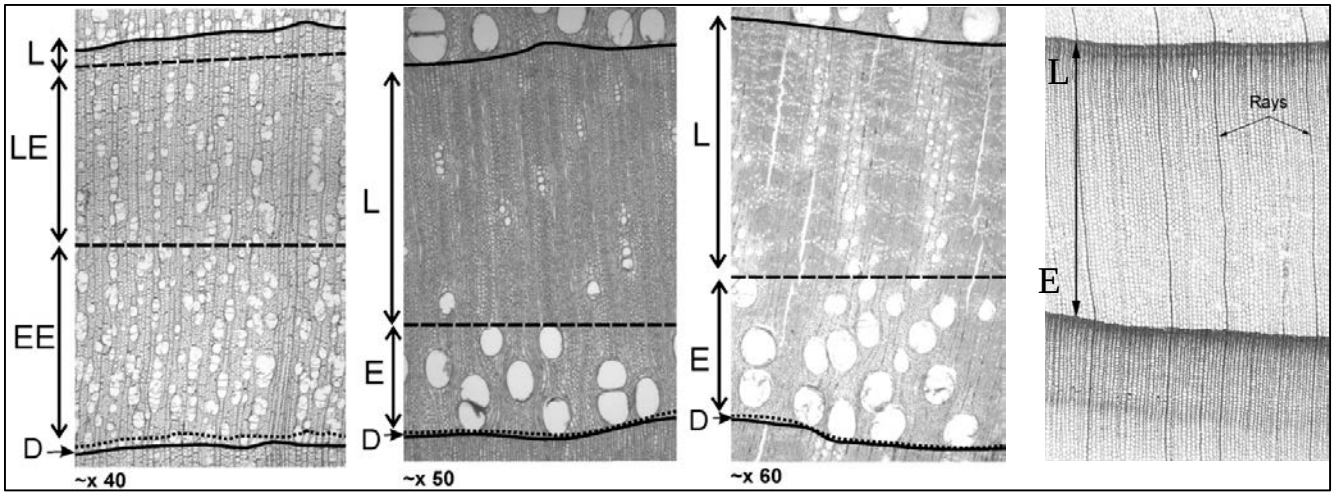


Bush et al. 2010

Xylem conduits & vulnerability

Three main xylem anatomical types have varying efficiencies for flow rate & vulnerability to embolism, which affects cumulative hydroactive sapwood area & water use

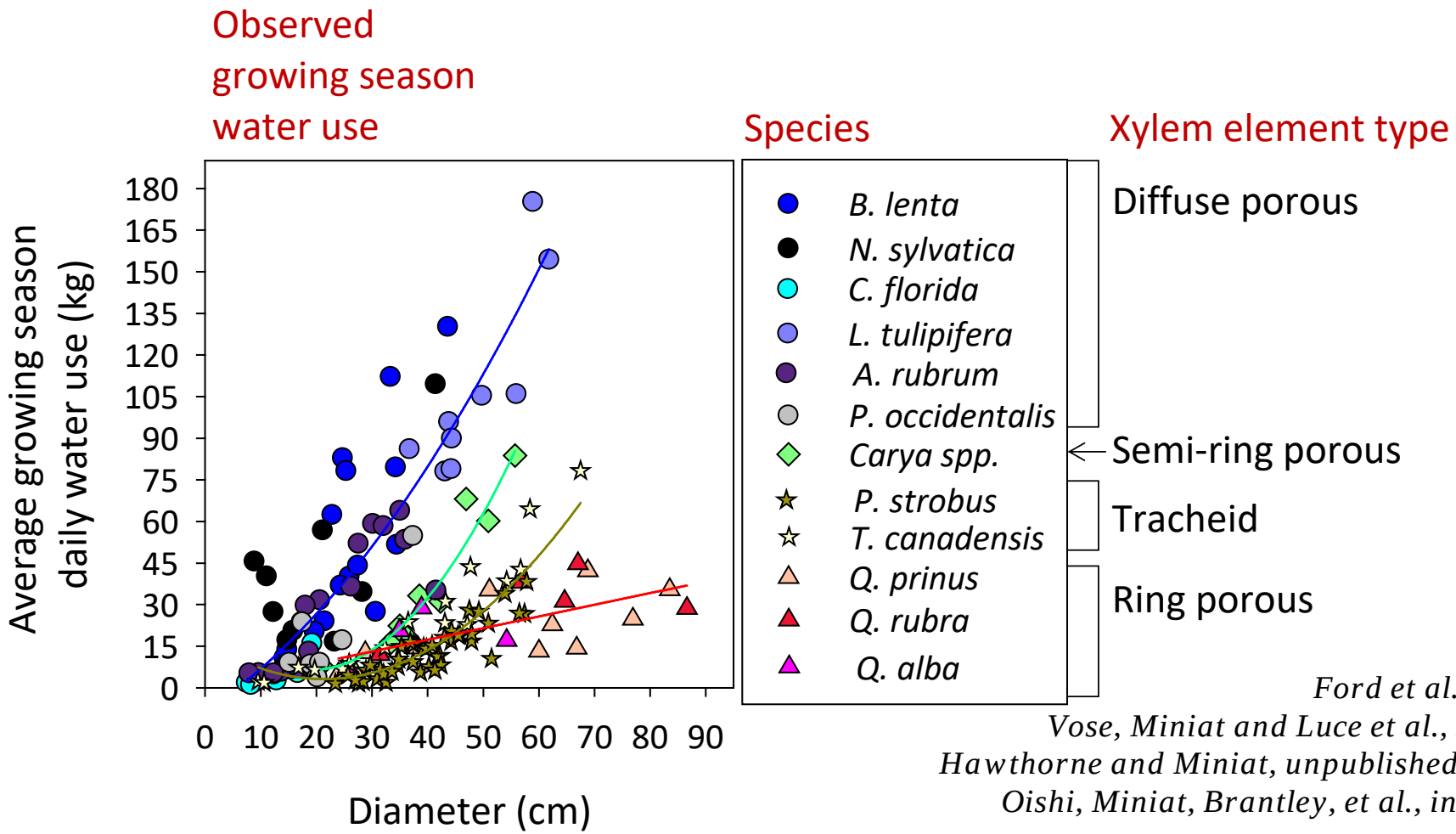
Diffuse-porous Ring-porous Tracheid



Ballesteros et al. 2010

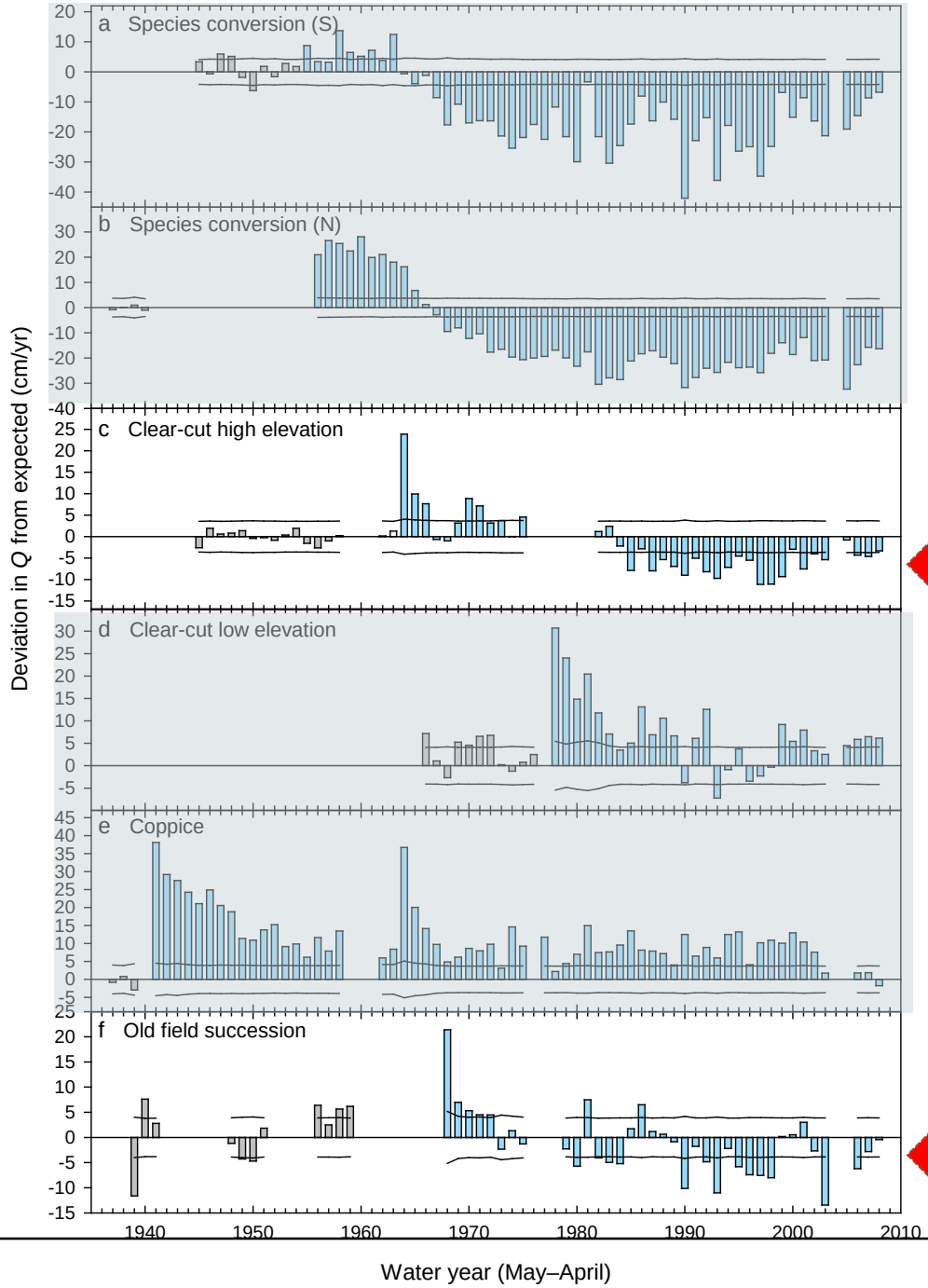
Whole tree water use by species

Even within the same forest, growing season transpiration rates among species can vary by as much as 4-fold, and co-occurring species can differ in their responsiveness to climatic variation.



Ford et al. 2011
Vose, Miniat and Luce et al., 2016
Hawthorne and Miniat, unpublished data
Oishi, Miniat, Brantley, et al., in prep

Ford et al. 2011. Ecol Apps



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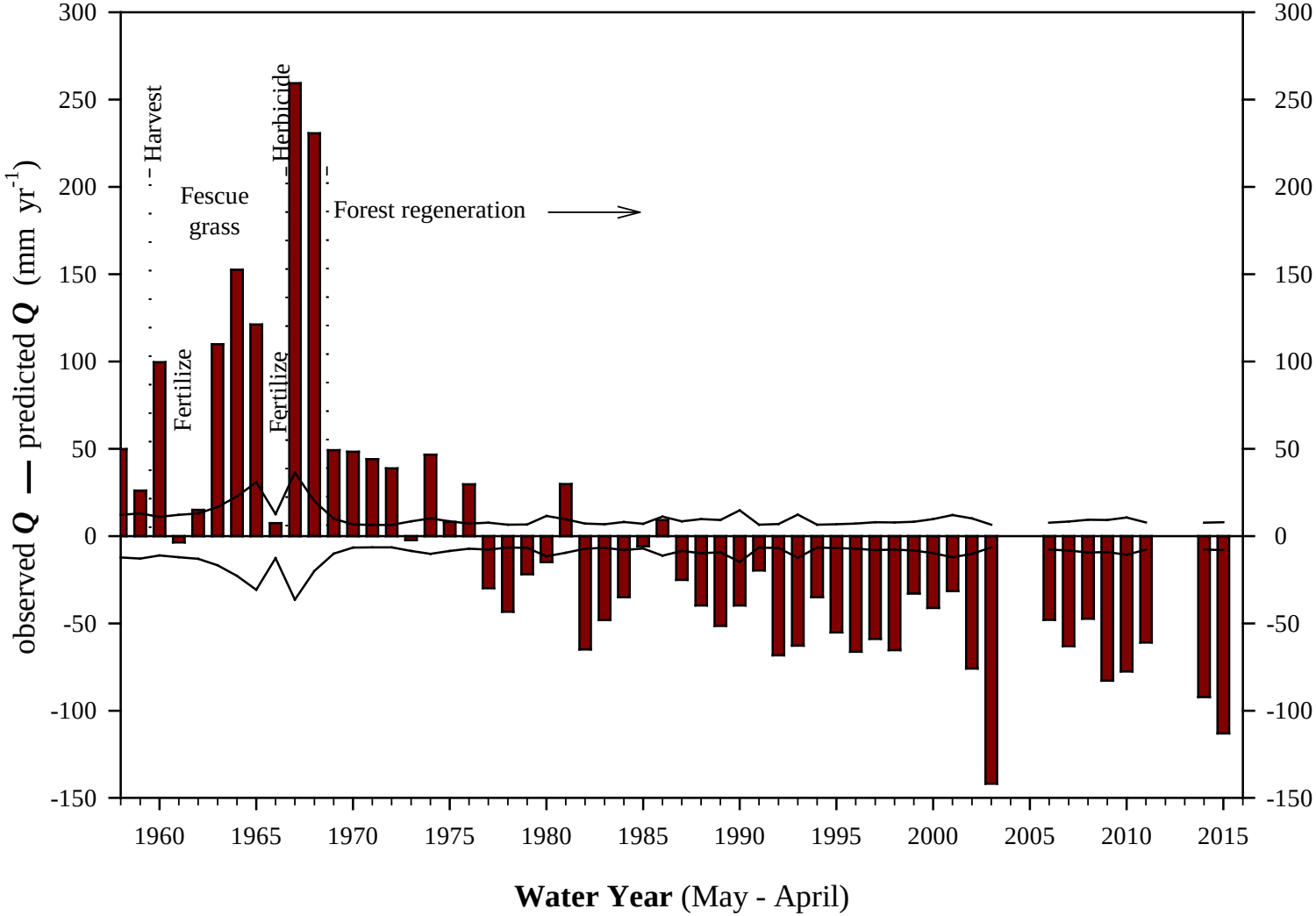
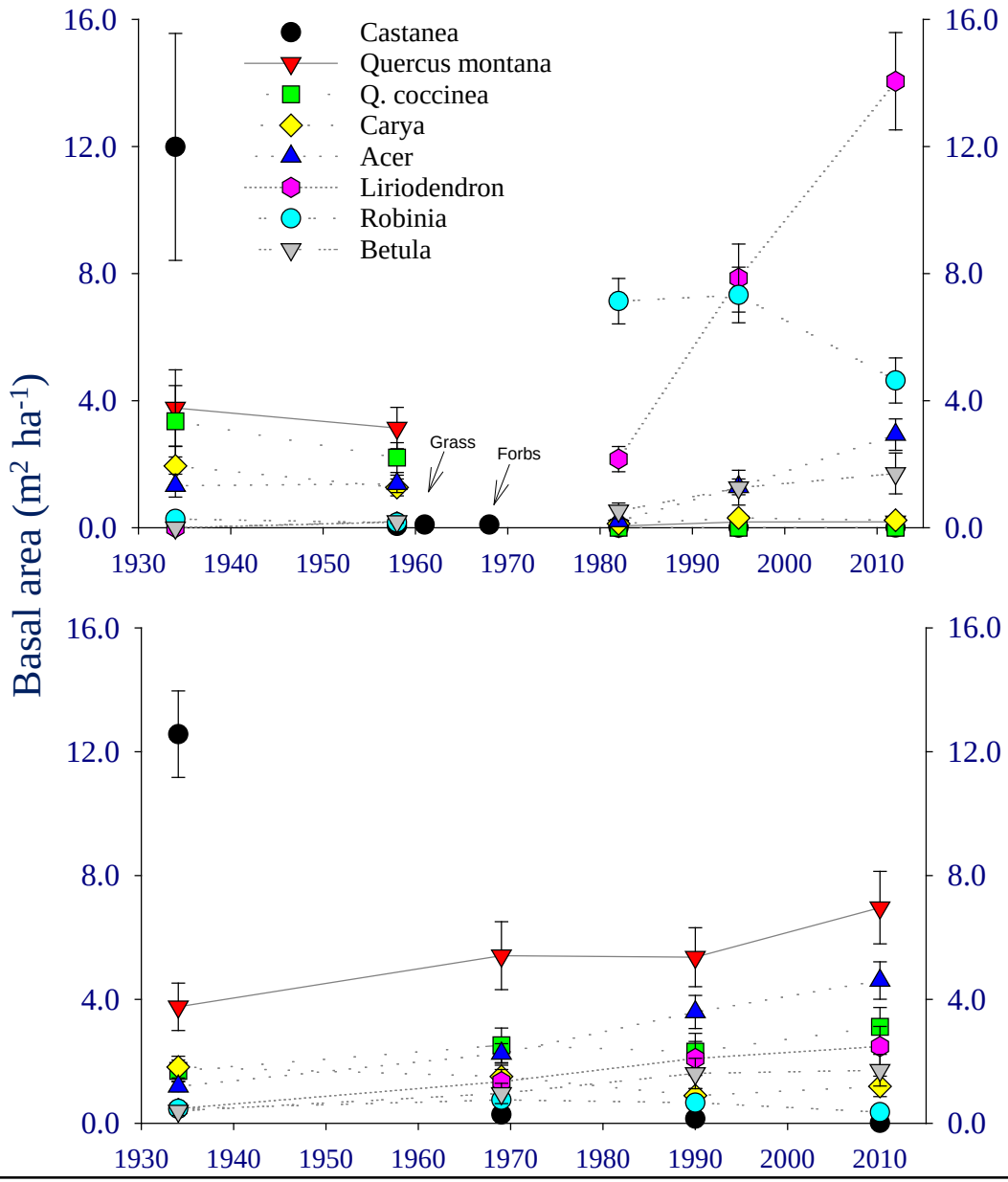
Water yield (Q) for the grass-to-forest transition



Elliott et al. 2017, HESS

Species changes following reforestation

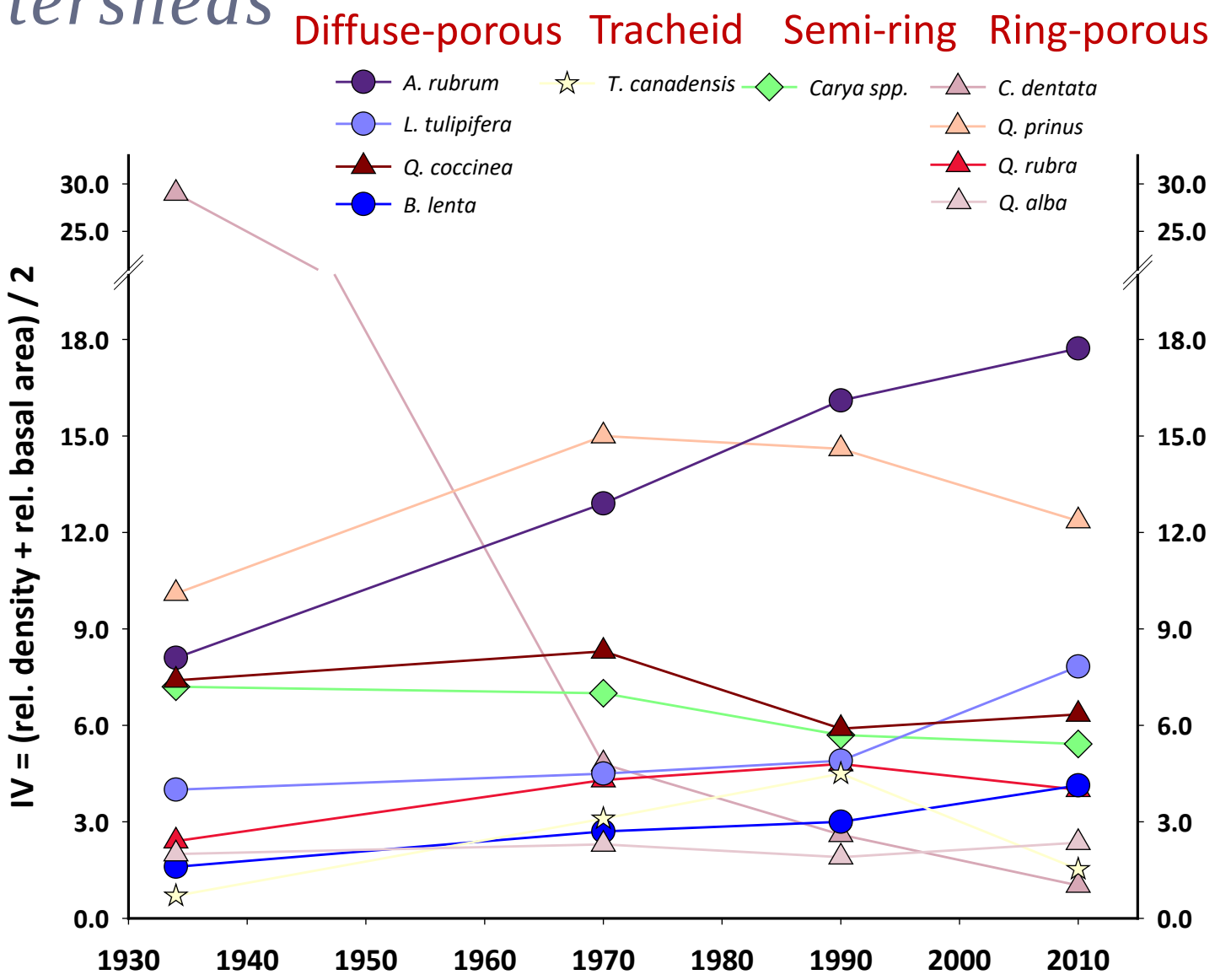


Treatment watershed had more mesic species (less conservative water use)

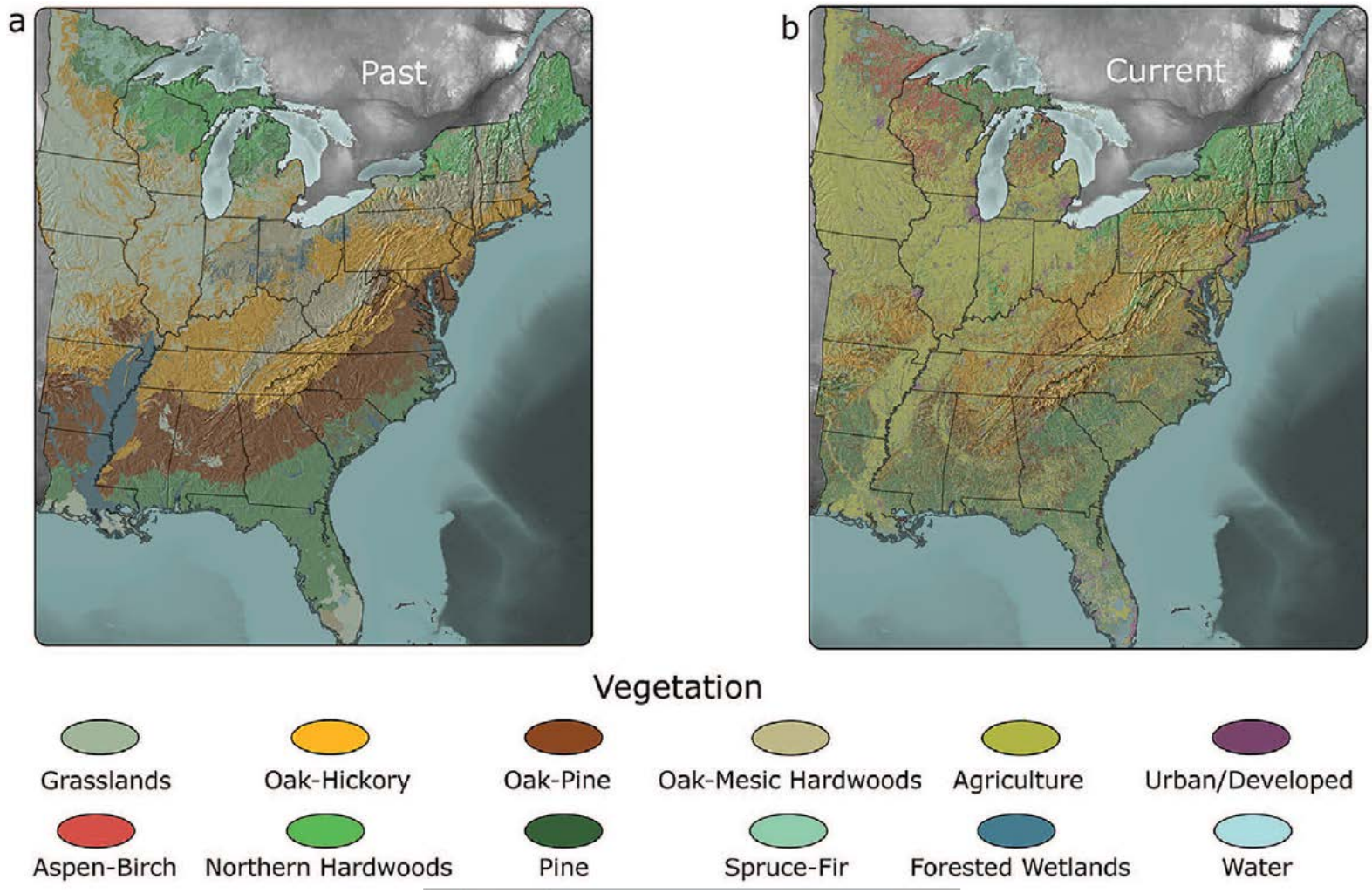
Reference watershed still dominated by ring-porous *Quercus* (more conservative water use)

Elliott et al. 2017, HESS

Species change over time in "reference watersheds"



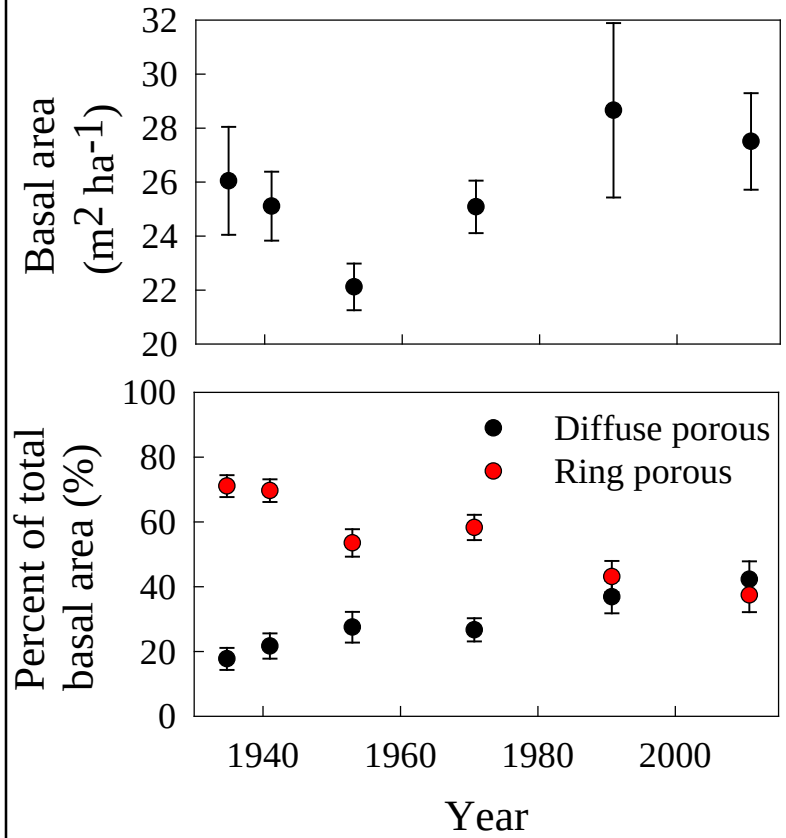
"Mesophication" of forests in the Eastern US



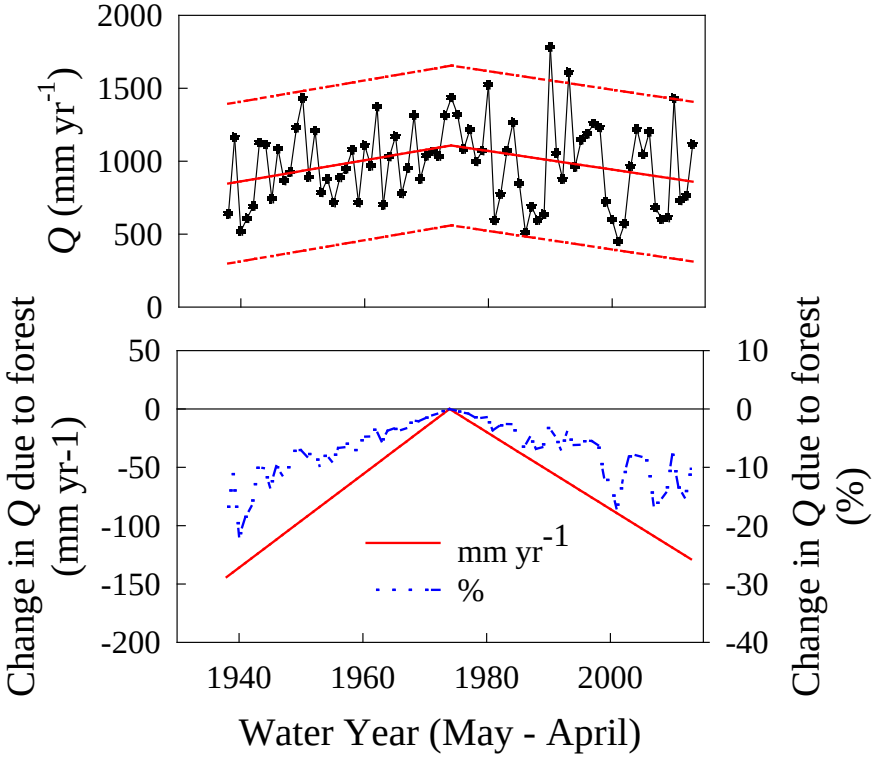
Nowacki and Abrms, 2008

Forest species and structure impacts water yield (Q) in reference catchments

Changes in forest structure and species composition



Changes in water yield



Caldwell et al., 2016, GCB

Key Points

- The balance of water not used by forests is important in the SE as almost half the SE population receives >20% of their drinking water from streams
- Forest area and water yield are fundamentally linked. Reforestation decreases yield
- Large differences exist among species' water use
- Conifer plantations use more water than hardwood forest
- Among hardwoods, mesophytic species (deep functional sapwood) use more water than oaks and hickories

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