Drought Ecophysiology and Implications for Douglas-fir

Matt Powers

Department of Forest Engineering, Resources and Management

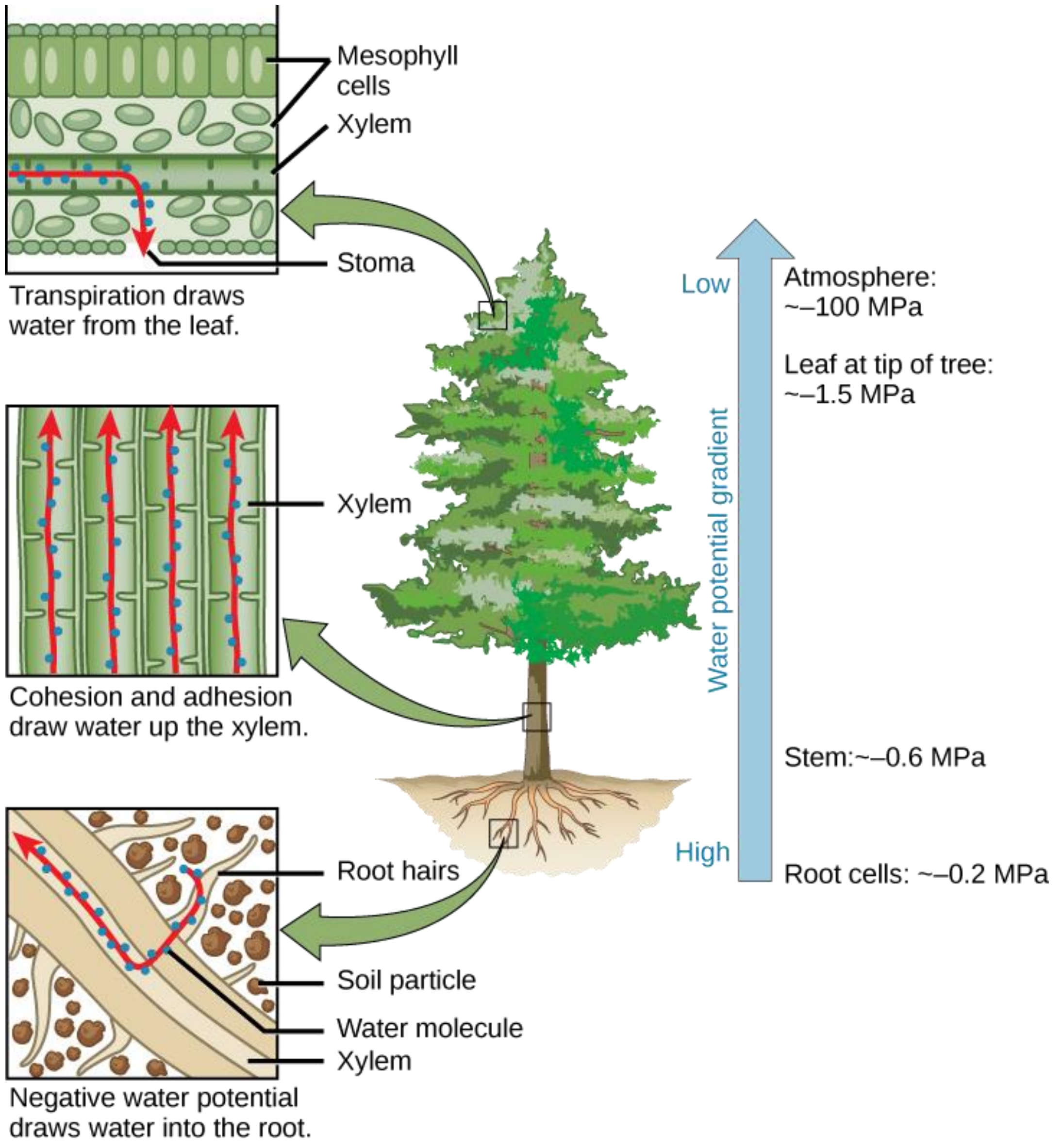
Oregon State University

Overview

- Basics of water uptake and transport in trees
- Drivers of cavitation
- Effects of site conditions on moisture stress
- Stomatal response and carbon starvation
- Drought adapted species vs Doug-fir
- Effects of silvicultural treatments

Water Transport

- Water moves along gradients in water potential (Ψ)
- Transpiration reduces Ψ_{leaf}
- Water moves towards the stomata
- Cohesive forces create tension in the water column, reducing Ψ_{stem}
- This tension pulls the water column up the stem



A Tree's Water Balance = Supply vs Demand

Drivers of Water Supply

Inputs

- Precipitation
- Snowmelt
- Lateral movement/mass flow

Storage & Availability to Plants

- Soil texture
- Soil depth and rock fraction
- Compaction
- Physiography

Drivers of Evaporative Demand

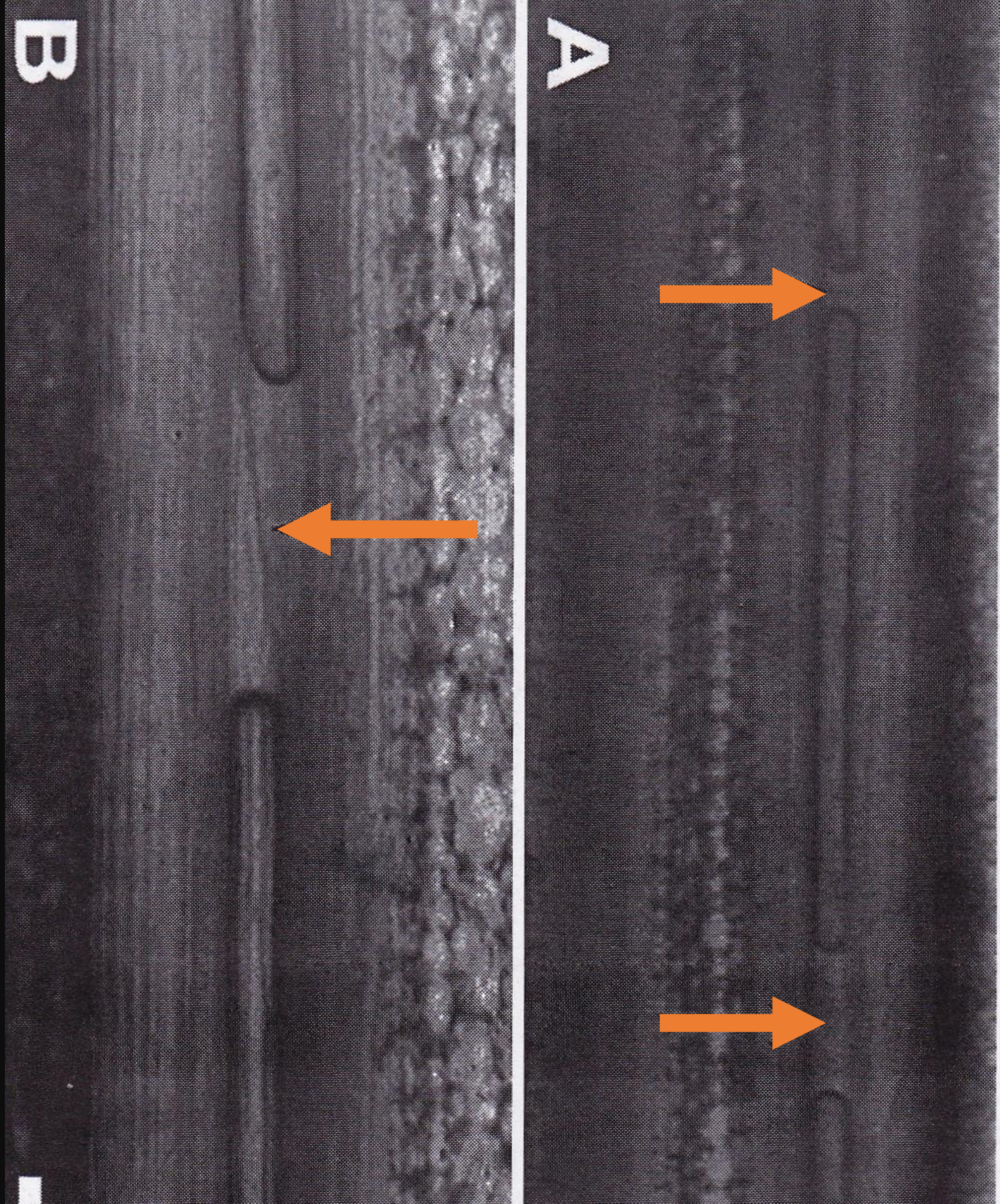
- Air temperatures
- Relative humidity
- Wind exposure & air mixing
- Leaf temperatures
  - Sun exposure
  - Air temperatures
  - Evaporative cooling
  - Leaf traits

Evaporative Demand Drives Water Loss from Leaves

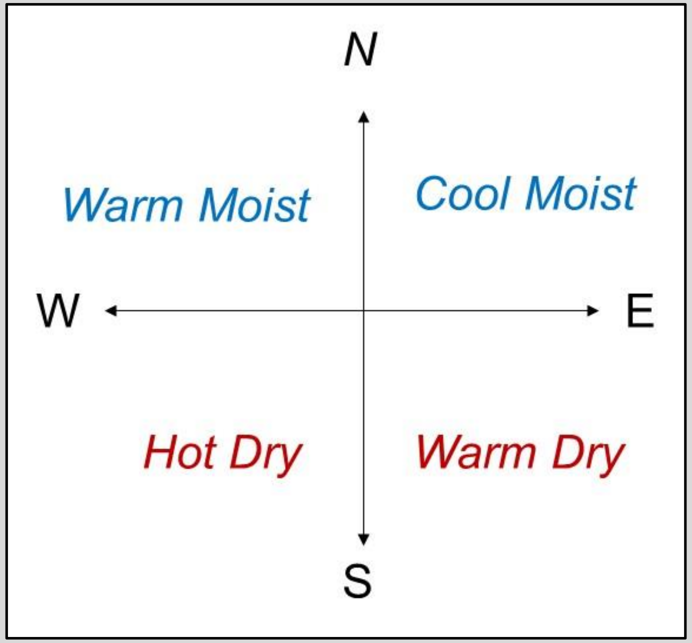
- High temps and low RH drive *high vapor pressure deficits* (VPD)
- Higher VPD drives higher rates of transpiration
- High transpiration adds tension to the water column.

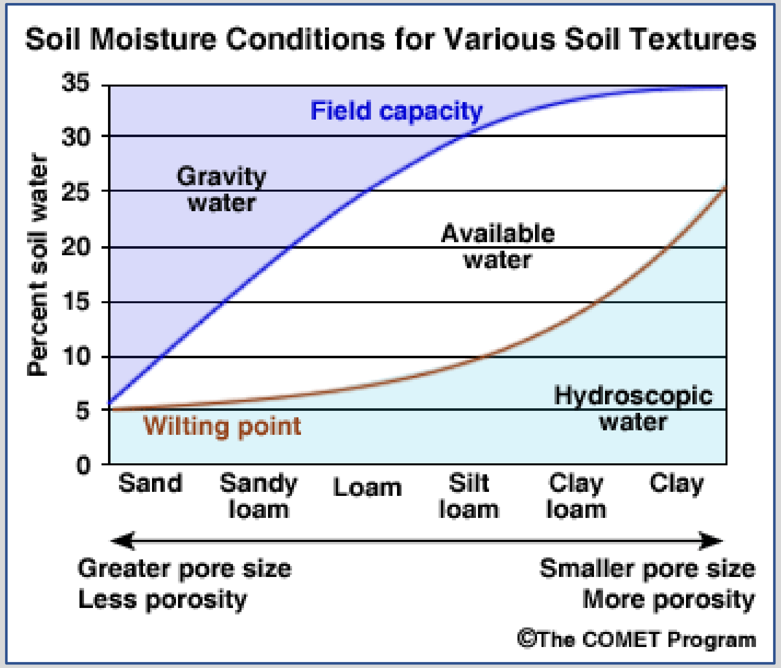
What happens when there's too much tension?

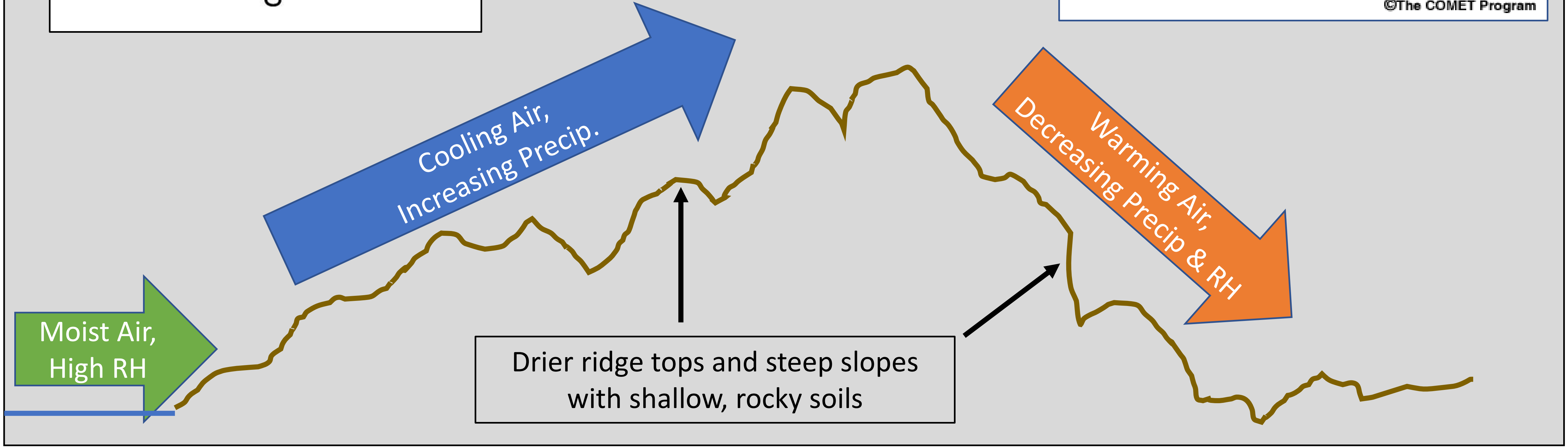
- *Cavitation* occurs
- Water transport stops
- Transpiration demands must be met elsewhere
- Potential for runaway cavitation



Site Drivers of Moisture Stress







How do trees avoid cavitation?

Three primary mechanisms:

- Stress avoidance: site selection, deep roots, etc
- Stress reduction: stomatal closure
- Stress tolerance: specialized xylem (junipers)

Stomatal Responses to Water Stress

Isohydric (most conifers)

- Rapid stomatal closure in response to declining internal Ψ
- Prevents cavitation
- Susceptible to C starvation

Anisohydric (junipers)

- Gradual stomatal closure
- Xylem resistant to cavitation
- Increases survival during extended droughts

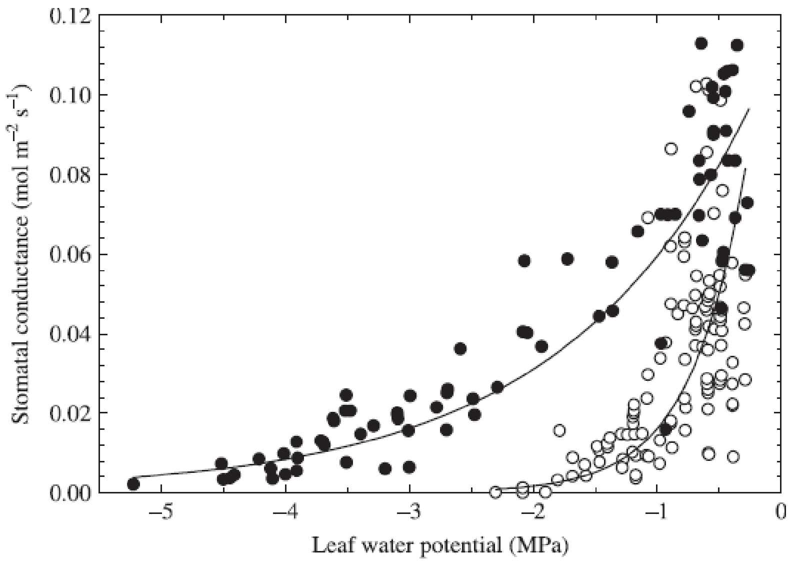
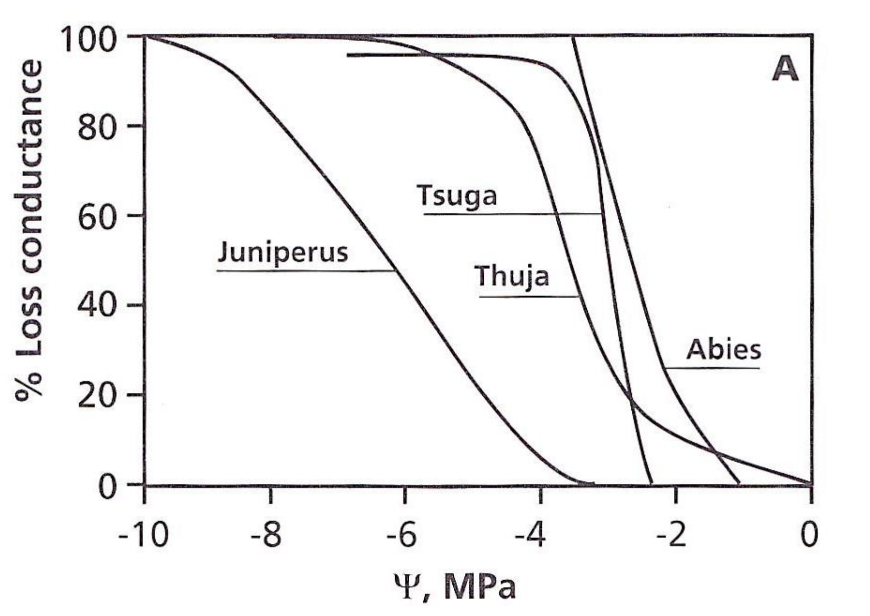


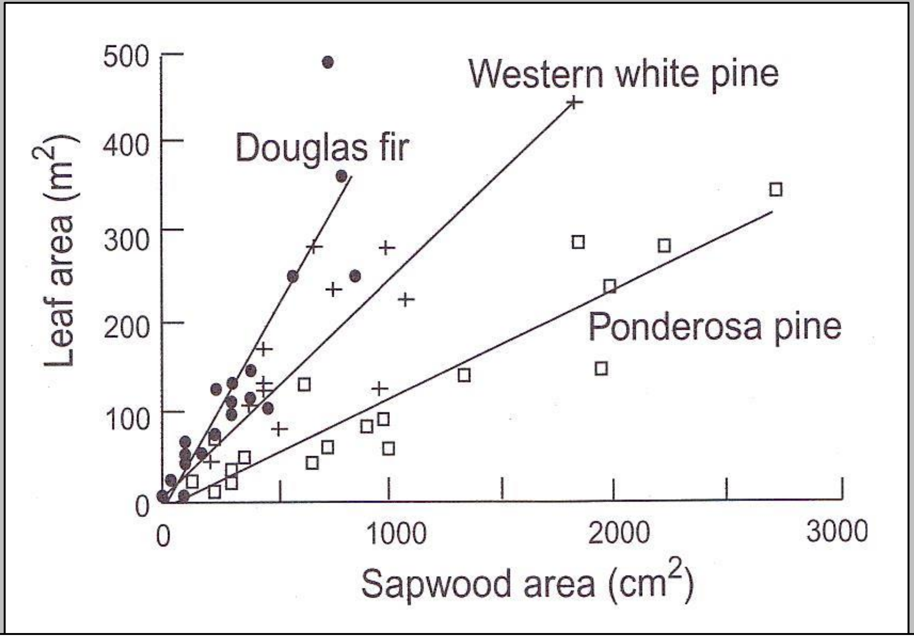
Fig. 8 Stomatal conductance vs leaf water potential for piñon (open circles) and juniper (closed circles) at Mesita del Buey, Los Alamos, New Mexico. Data from Barnes (1986).

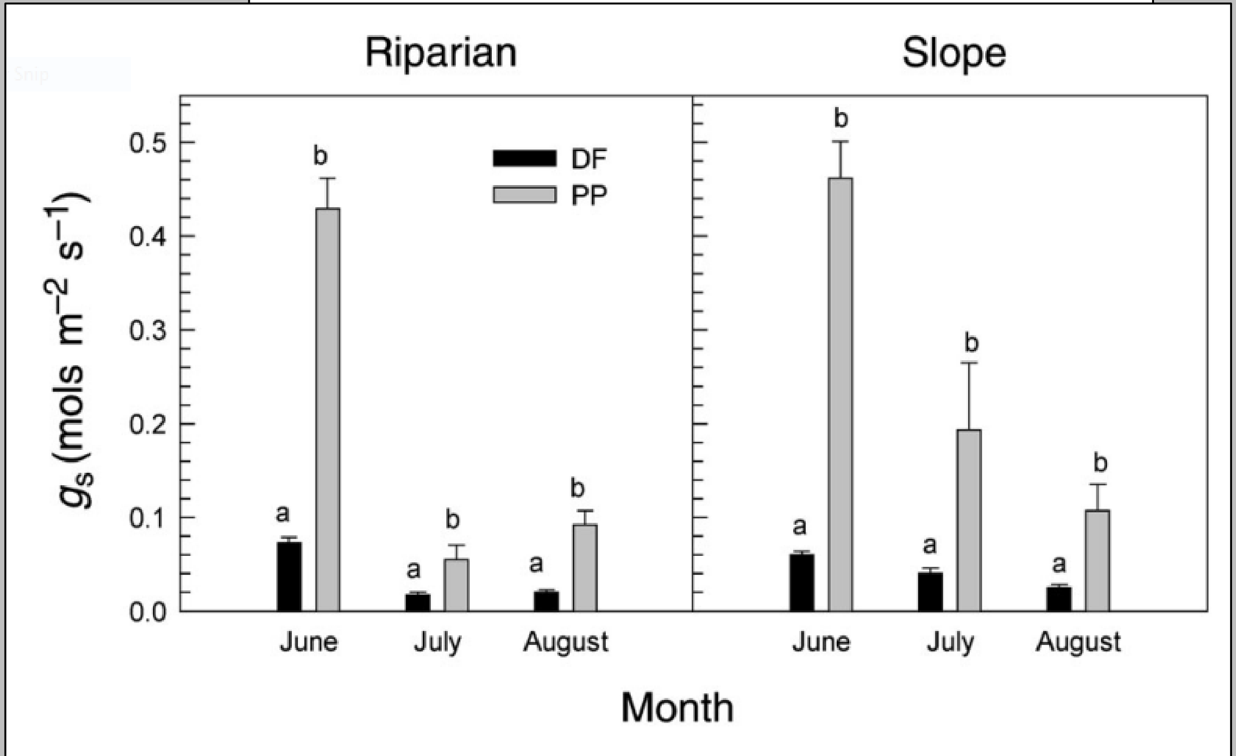


Ponderosa Pine vs. Doug-fir

Key differences:

- Xylem architecture
- SWA/LA & stem water storage
- Ability to maximize C uptake during “good” conditions
- Degree of stomatal response to changing Ψ and VPD
- Rooting depth?

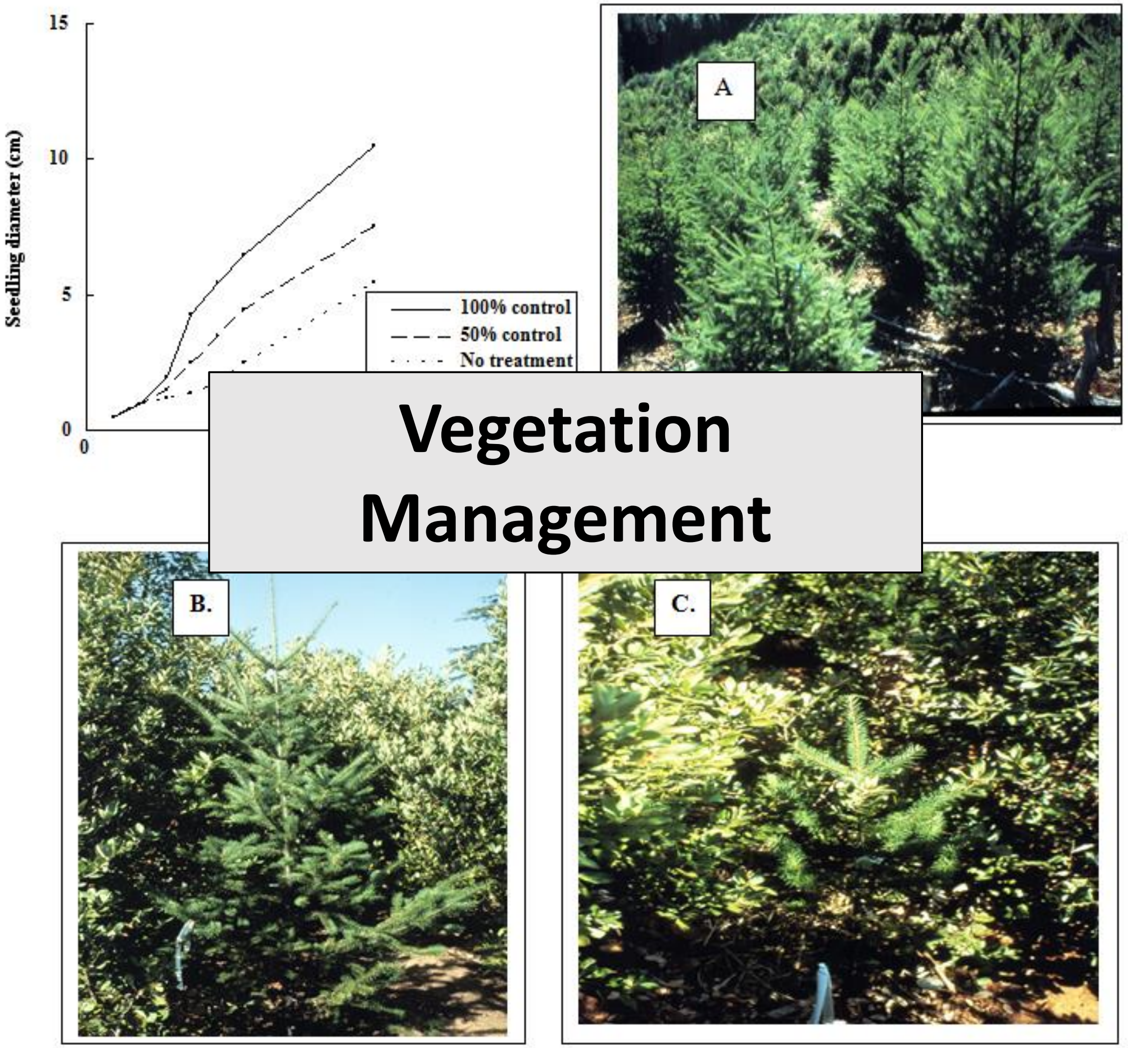




Ecophysiology Take Homes

- Too much demand or too little supply can cause cavitation.
- Some plants have specialized xylem to resist cavitation.
- Many trees reduce stomatal conductance to avoid cavitation, but this limits C uptake.
- Doug-fir has a middle-of-the-road strategy.
    - More susceptible to cavitation during hot periods & C starvation during prolonged droughts.
- Site conditions with limited water storage capacity or elevated evaporative demand increase risk.

Silvicultural Approaches to Mitigate Drought Stress

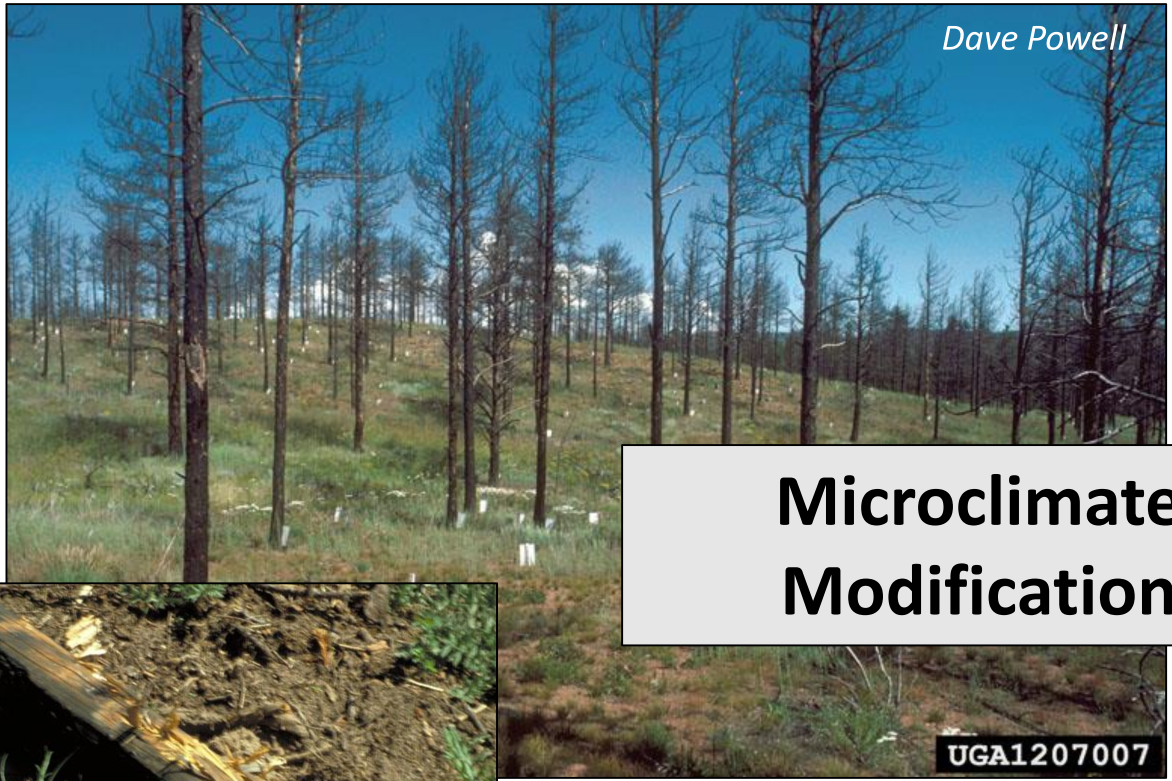


Vegetation Management

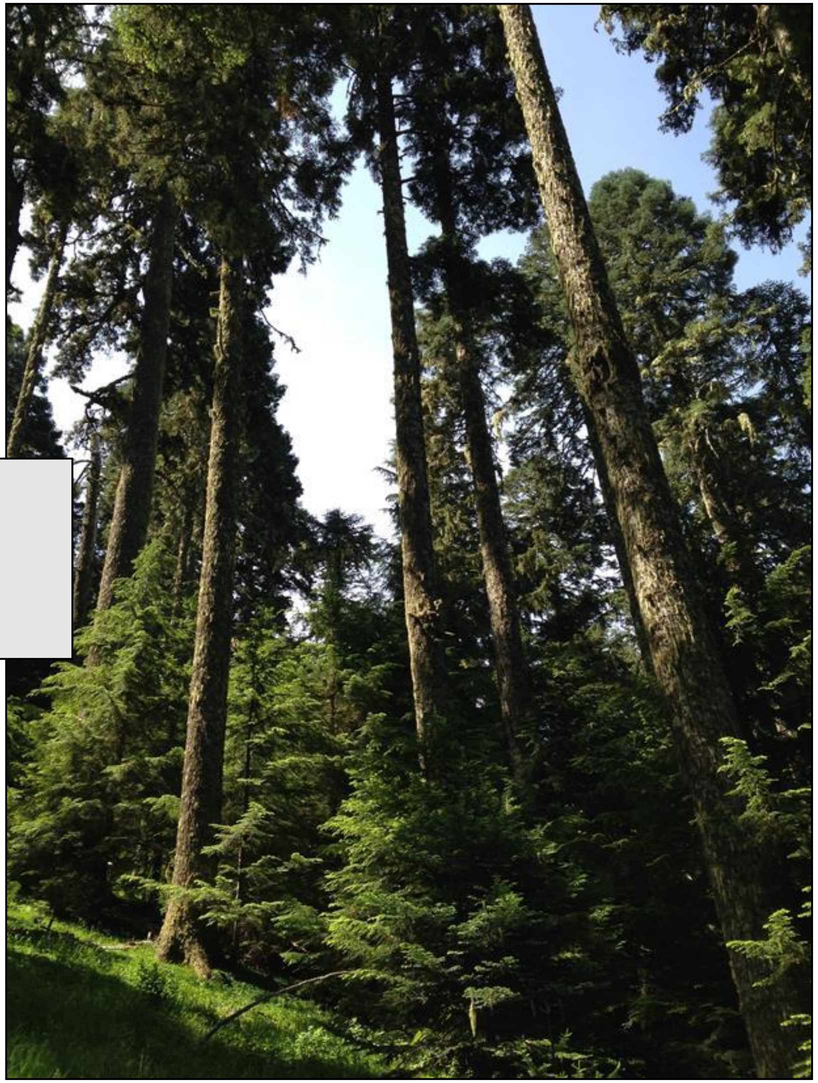
Tappeiner et al. 2015

Density Management (Thinning)

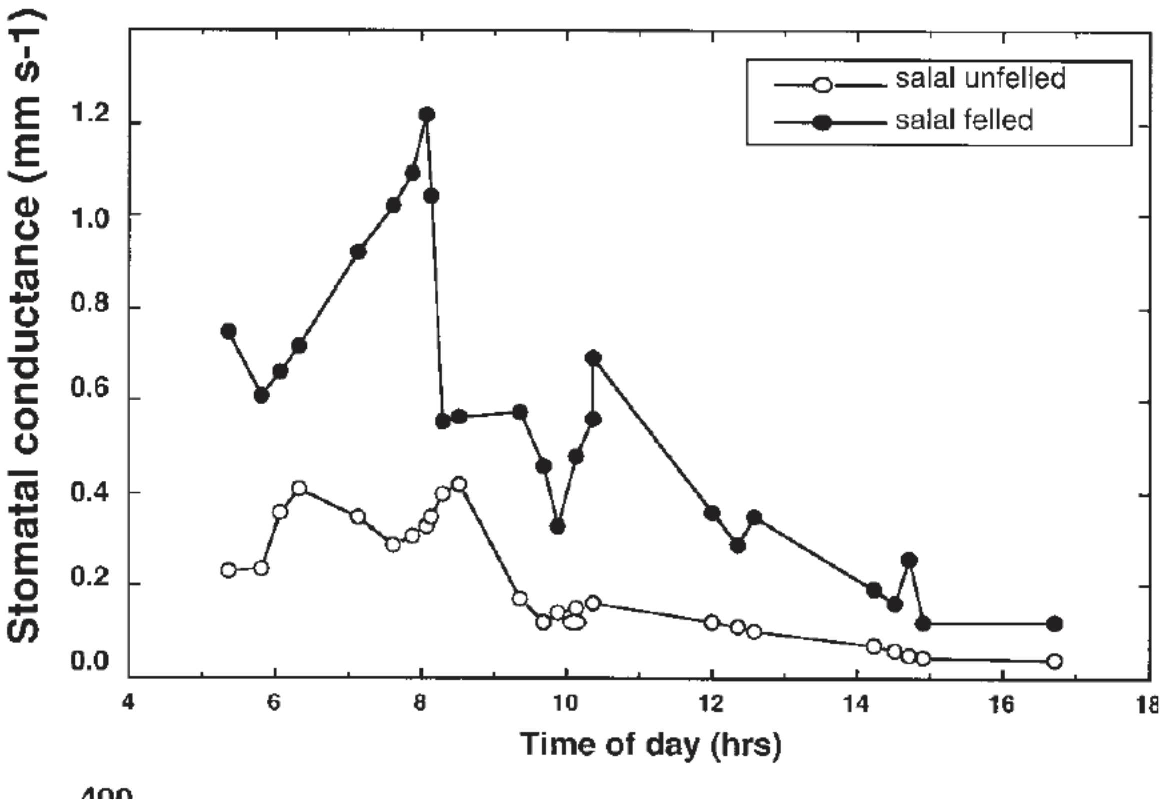
Silvicultural Approaches to Mitigate Drought Stress

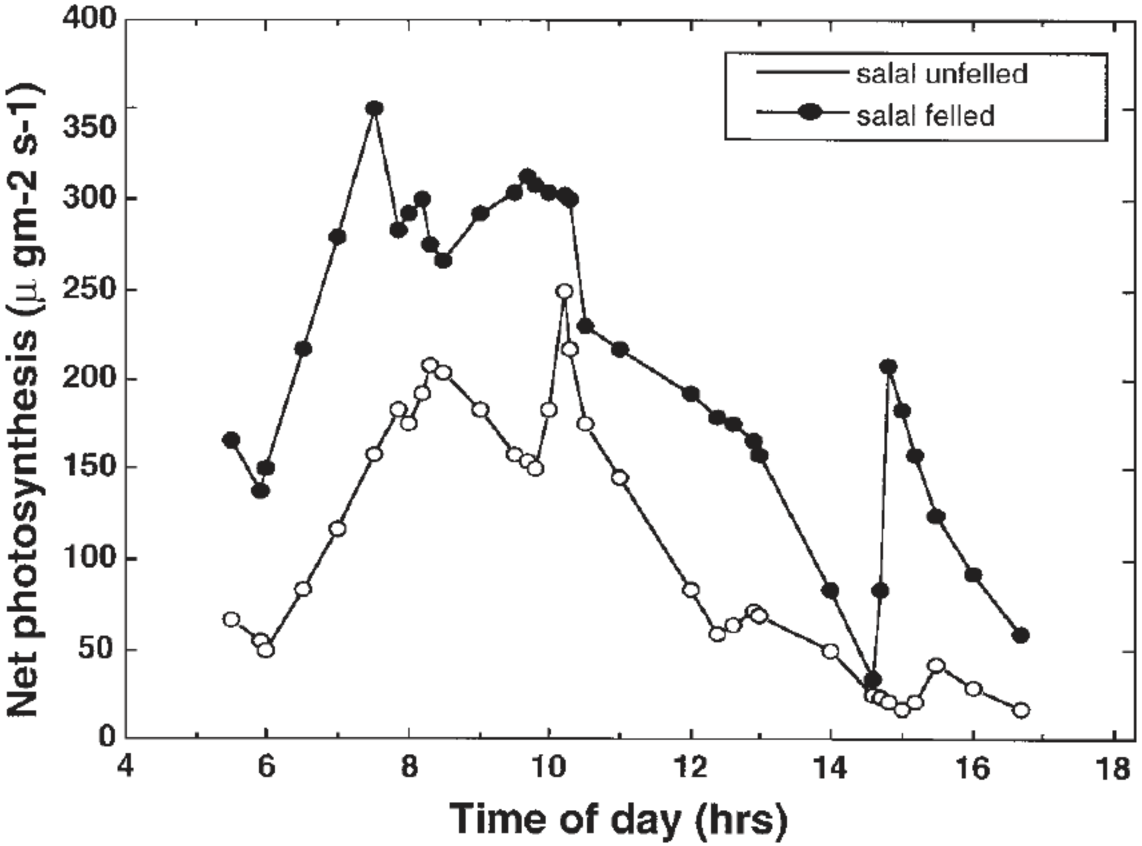


Microclimate Modification



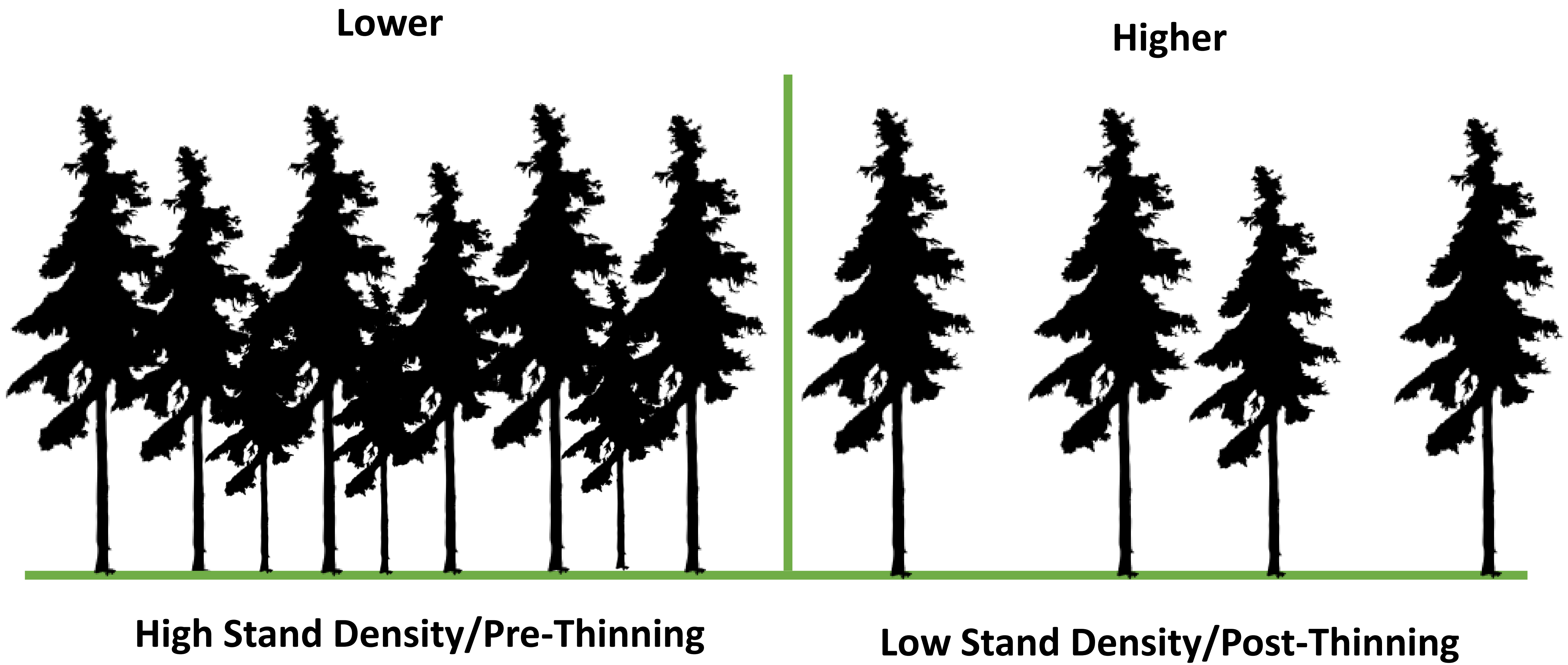
Effects of Veg Management on Doug-fir Gas Exchange





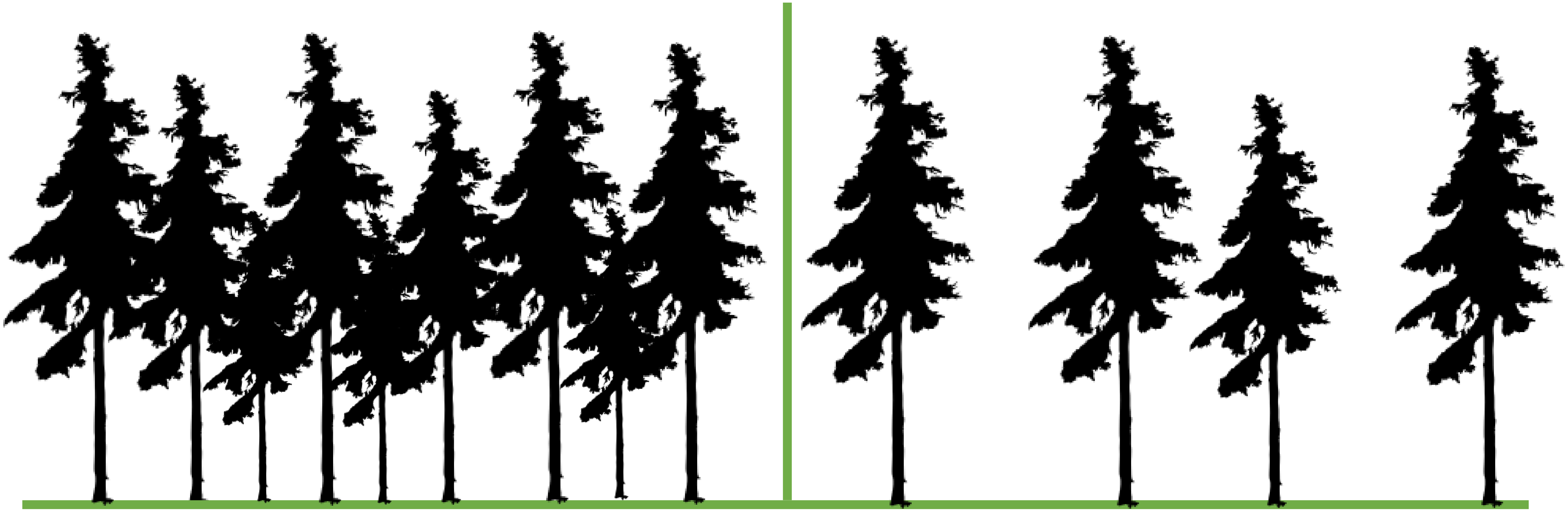
Price 1986

Soil Water Availability



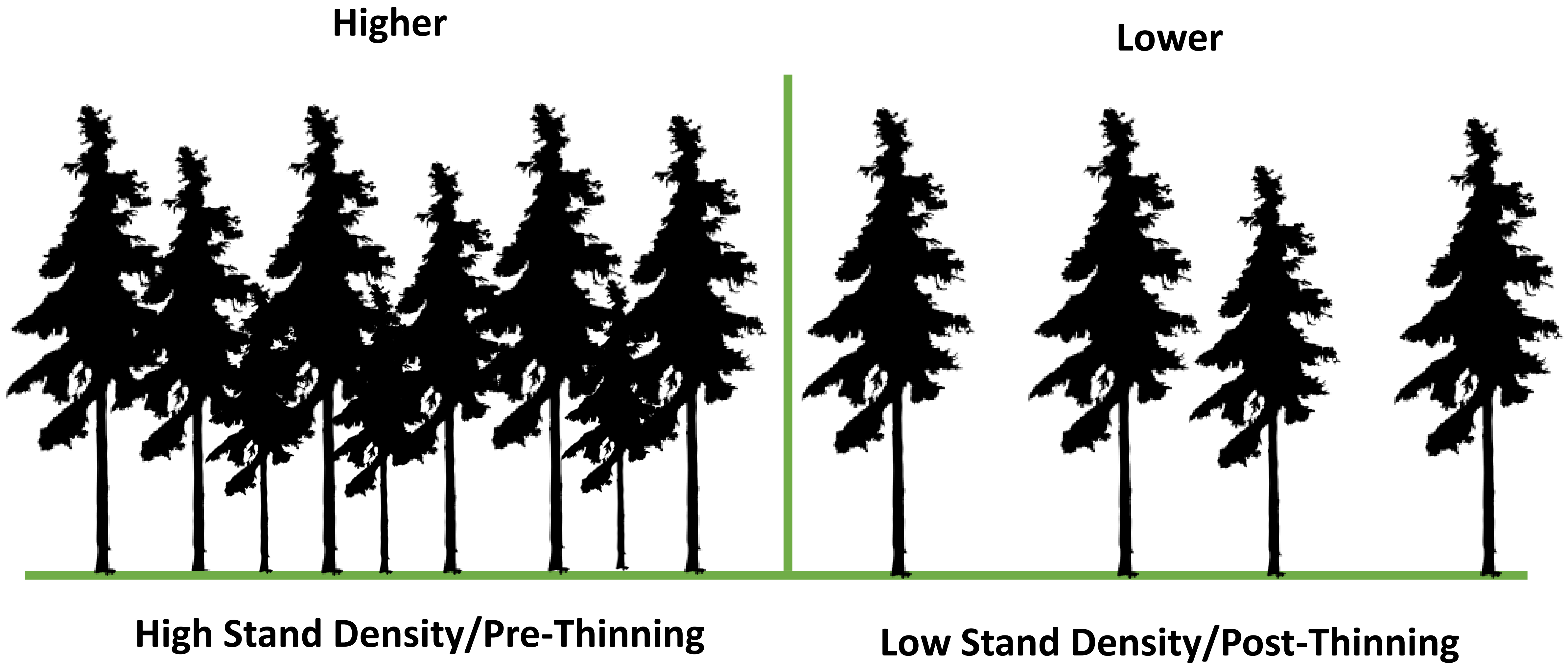
Stand-Scale Transpiration (*E* per unit ground area)

Higher **Lower**

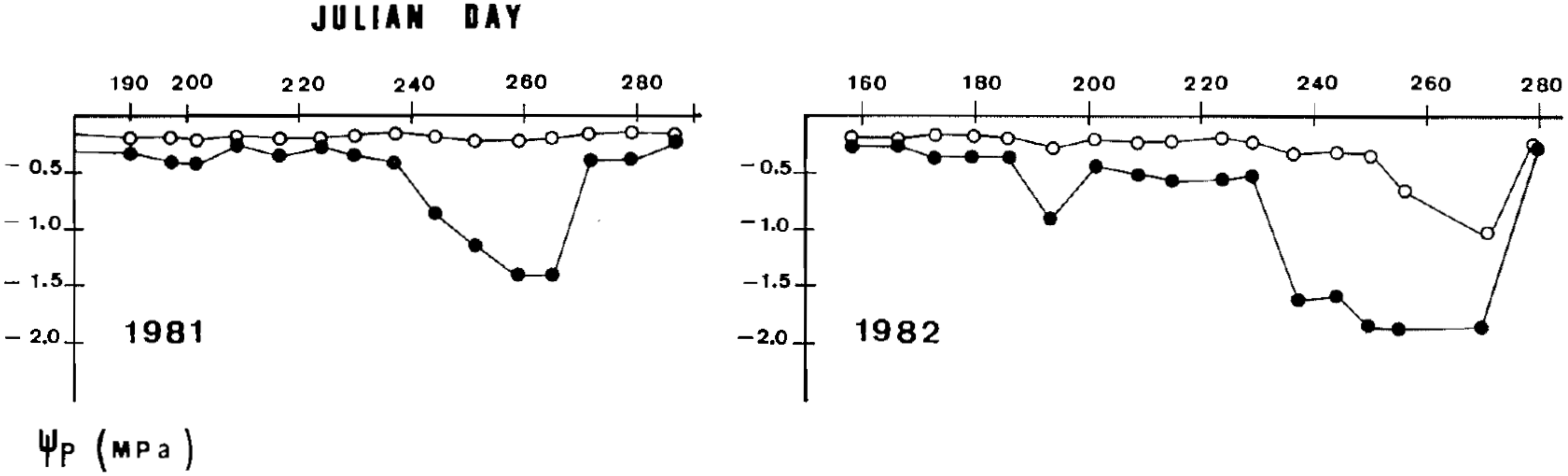


High Stand Density/Pre-Thinning **Low Stand Density/Post-Thinning**

Canopy Interception



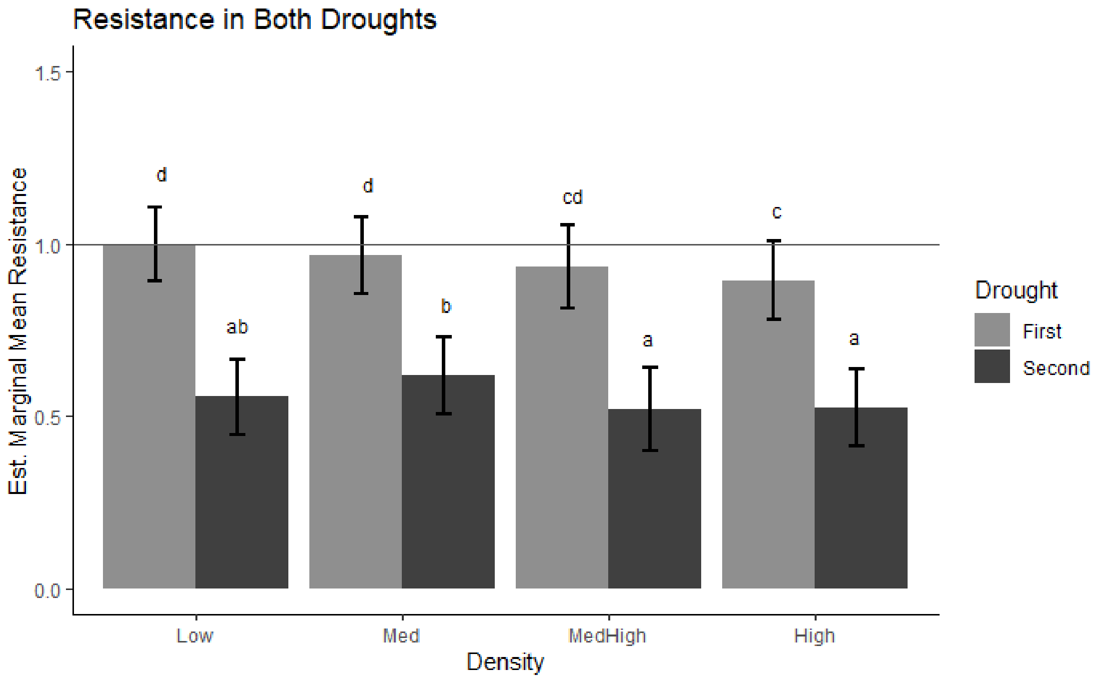
Effects of Thinning on Water Stress in Doug-fir

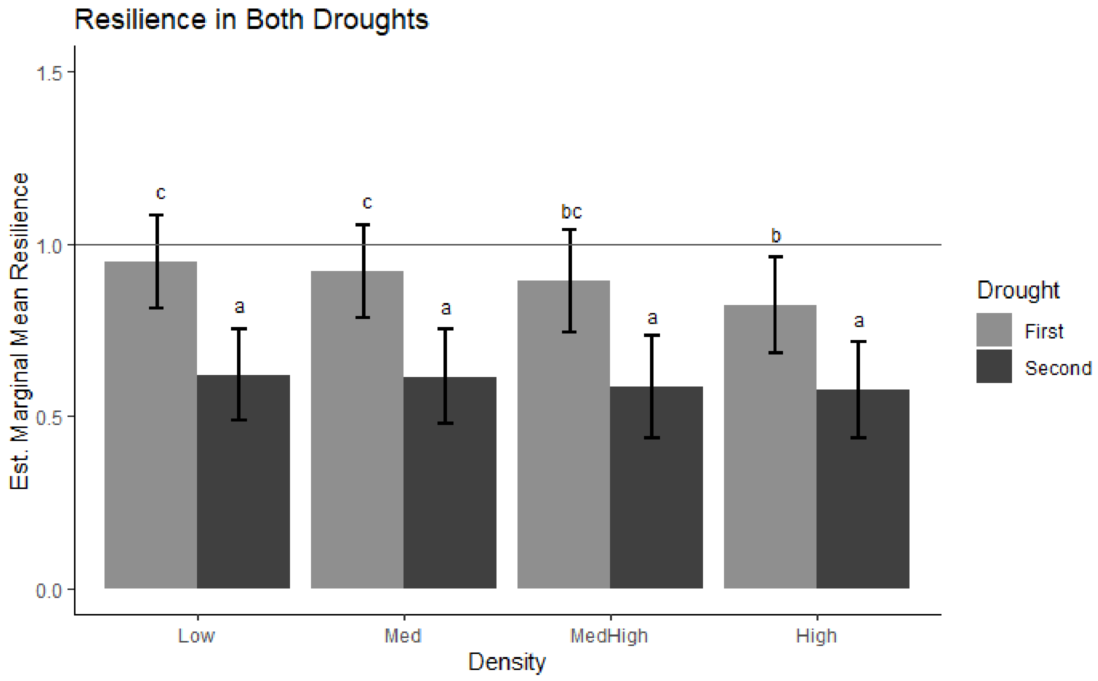


Open Circles = Thinned **Closed Circles = Unthinned**

Aussenac & Granier 1988

Effects of Thinning on Drought Resistance and Resilience in Doug-fir

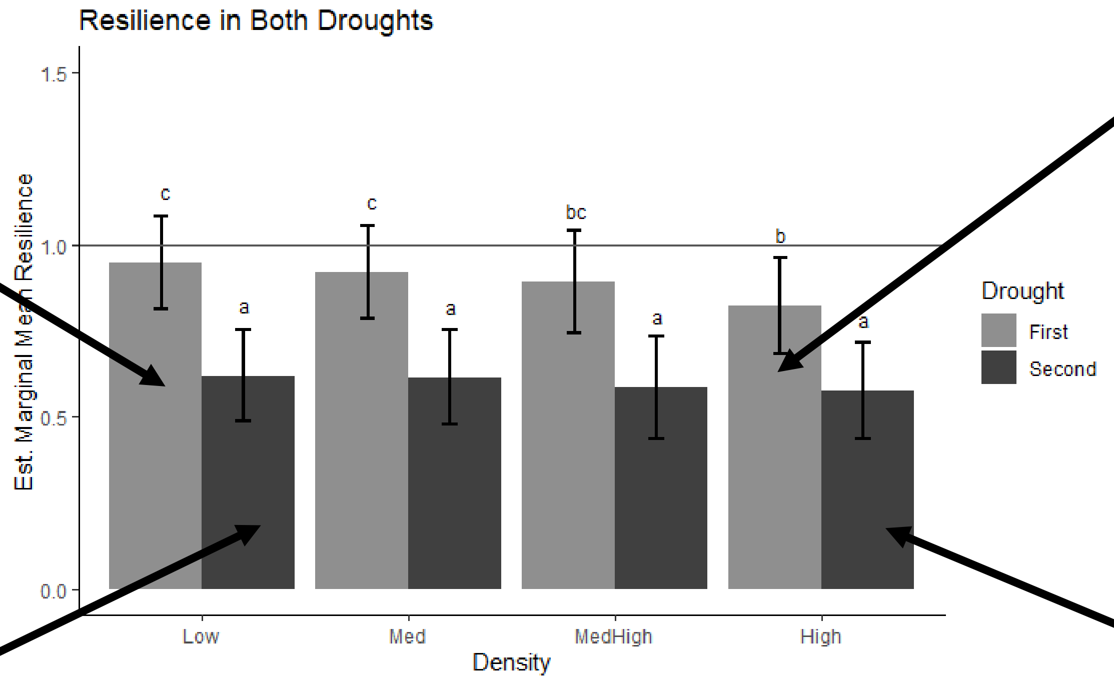




Why do the benefits of thinning decline over time?

Thinned to CRD = 17-18, seven years prior to 1st drought

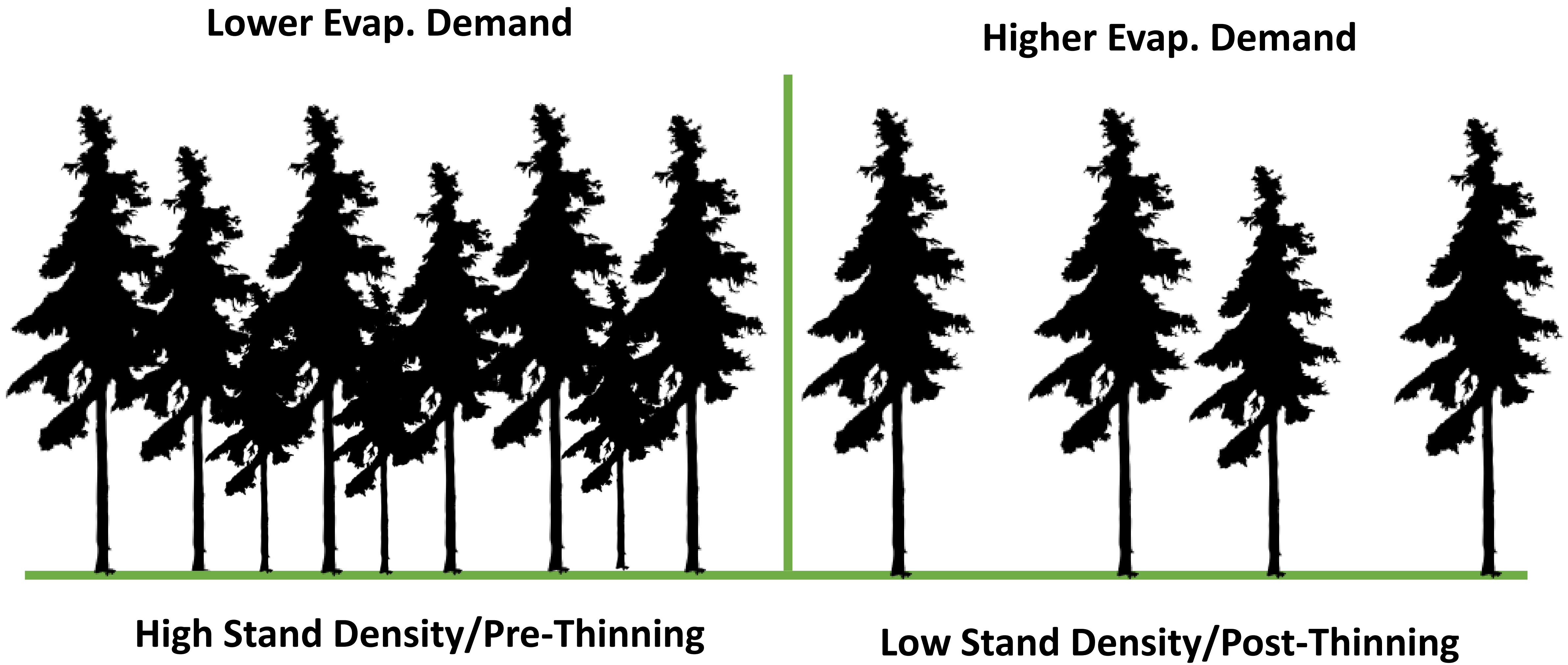
Thinned to CRD = 32-33 seven years prior to 1st drought.



CRD = 48-49 when measured after 2nd drought

CRD = 53-55 when measured after 2nd drought

Caveats: Thinning Effects on Evaporative Demand



Silviculture Take Homes

- Vegetation management can increase water availability to young trees, which is critical on dry sites.
- Partial shade can reduce VPD and tissue temperatures, which also benefits very young trees.
- Thinning is an effective tool for reducing drought stress in Doug-fir, but must be repeated regularly to maintain benefits.
- Maximizing drought adaptation requires residual densities lower than traditional stocking guides.
- Thinning may result in dieback if the timing of thinning coincides with a hot, prolonged drought.

Questions?