Water is the Link for Soil, Plant, and Atmosphere Continuum

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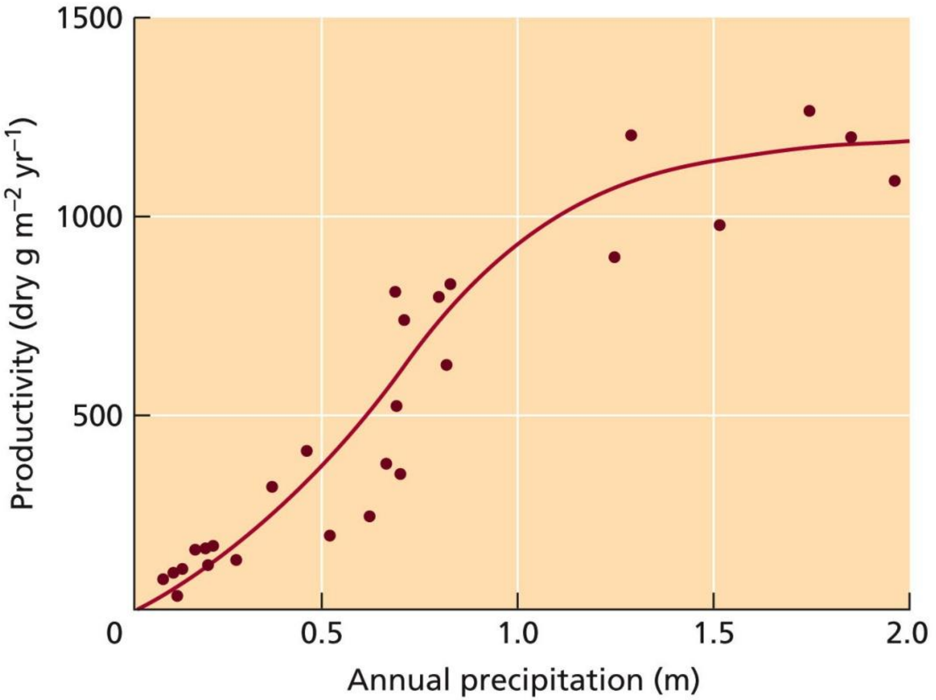
Overview

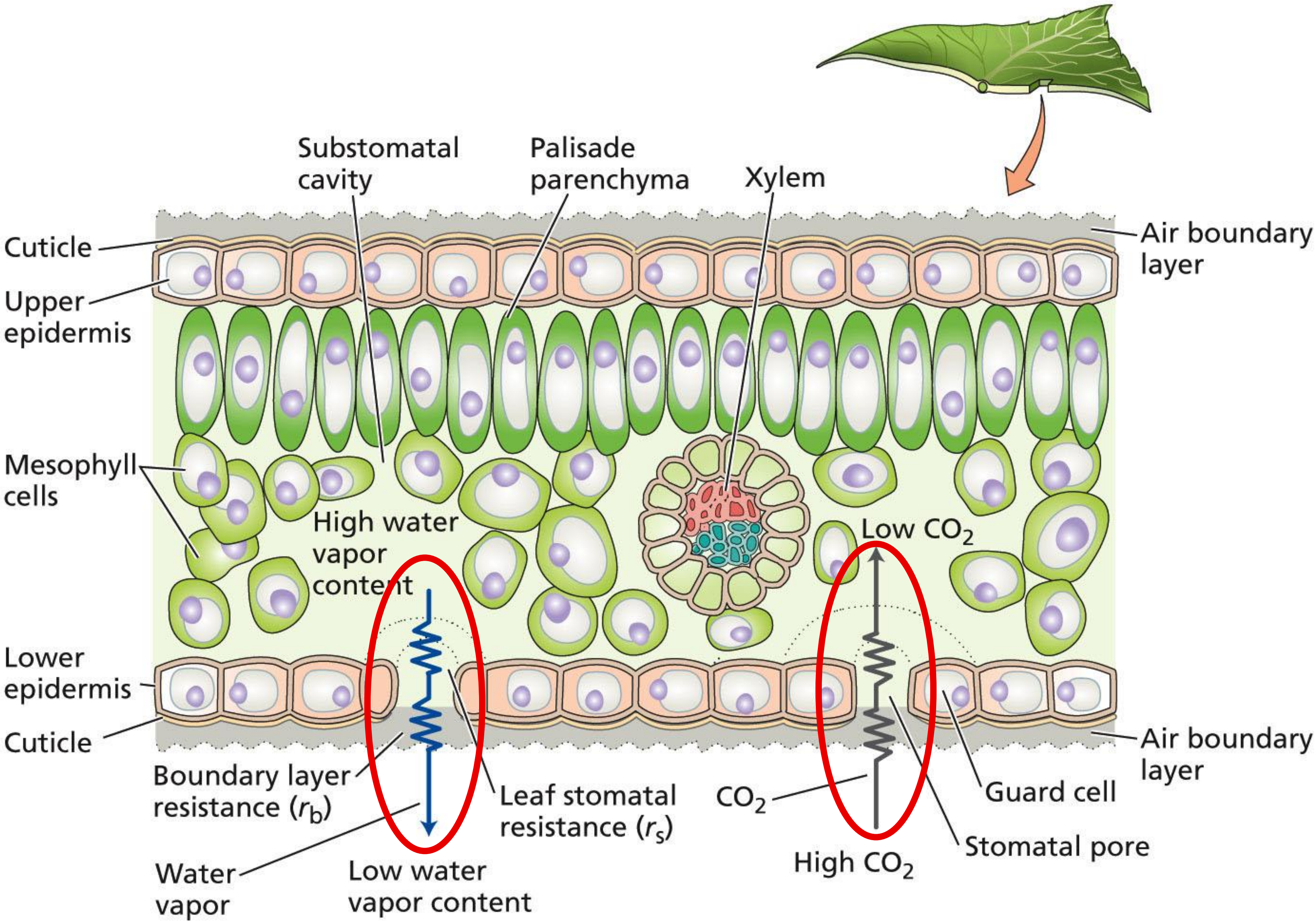
- Soil-Plant-Atmosphere Continuum
  - Function of water in plants
  - Plant response to water stress
  - Plant adaptation to water stress
- Redistribution of water by plants
- Methods to mitigate water stress
- Questions

Water and plants

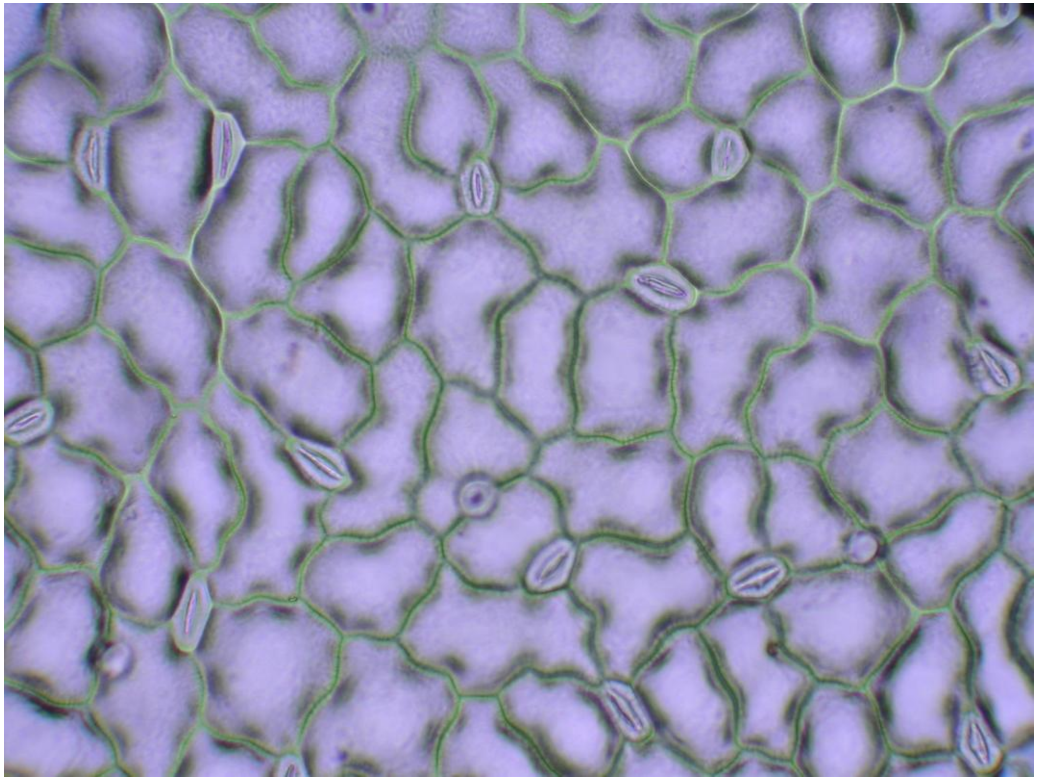
- Water availability limits the productivity in many ecosystems
- Functions within a plant
  - Most of plant fresh weight comes from water (up to 90%)
  - Provide structure and support
  - Source of oxygen release form photosynthesis
  - Medium for transporting nutrients, metabolites, and plant hormones
- Lost by **transpiration** through **stomata**
  - Inevitable consequence of photosynthesis

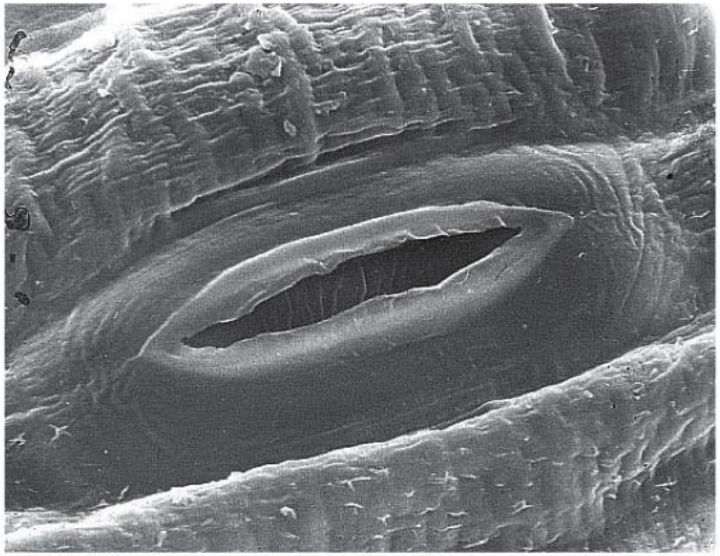


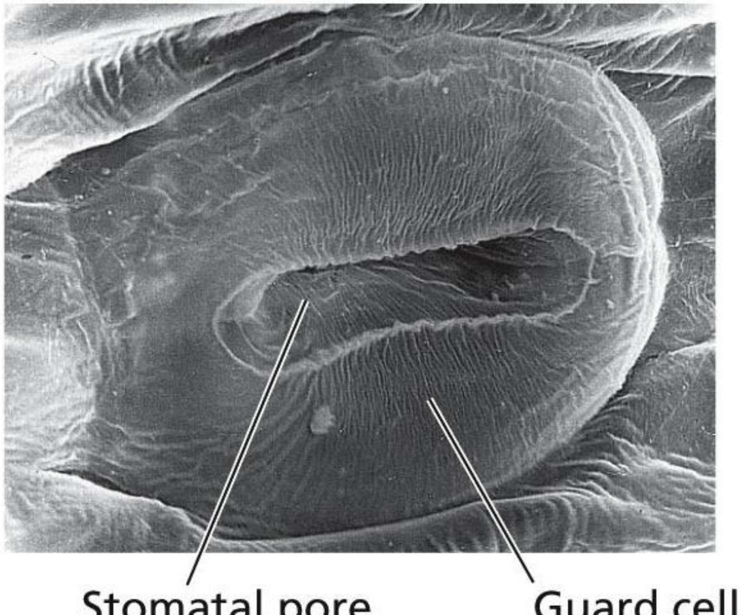
Leaf gas-exchange



Stomata







Opening and closing are dynamically regulated

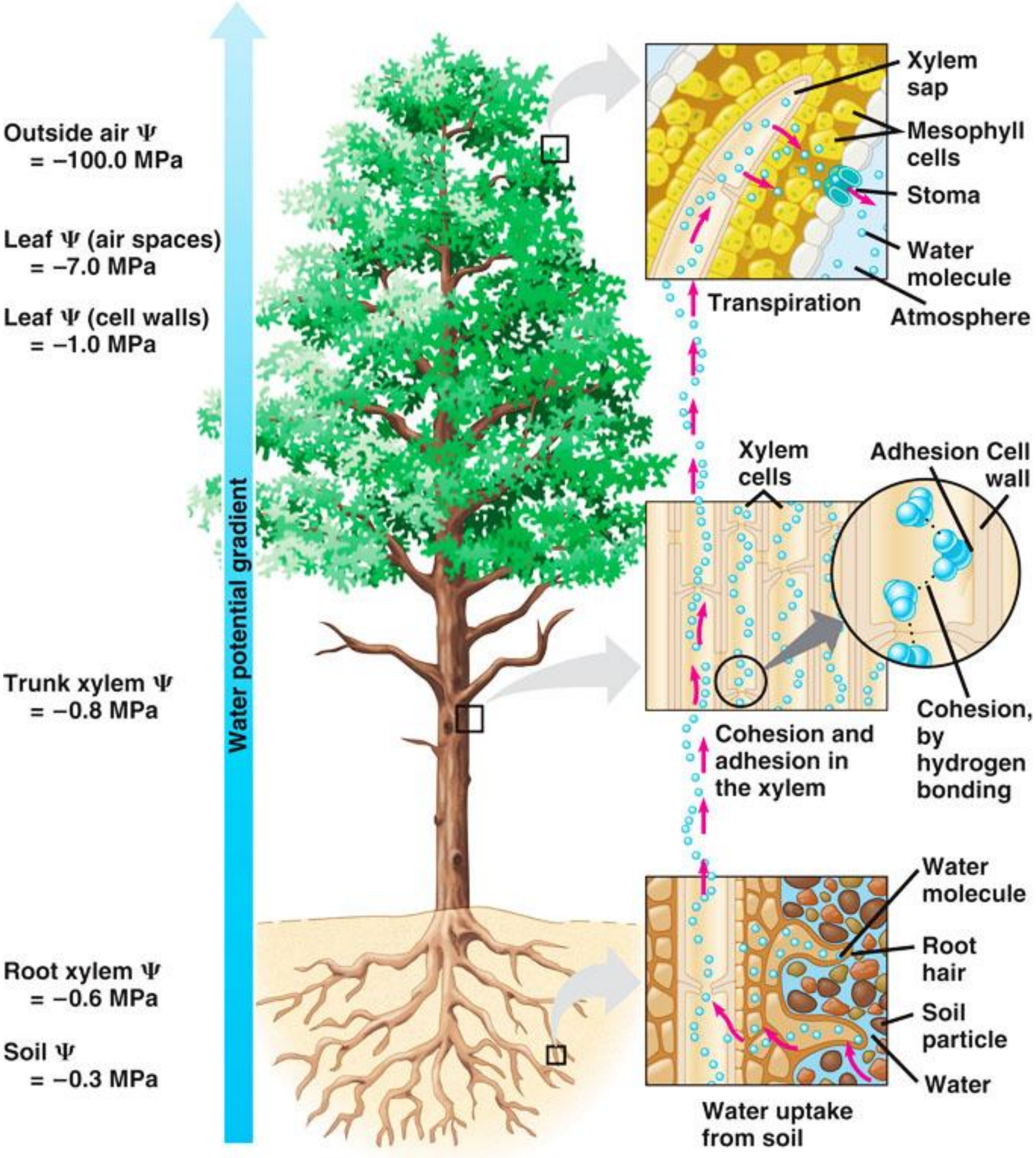
PLANT PHYSIOLOGY, Fourth Edition,

Ascent of Sap: How does water move to the tree top?

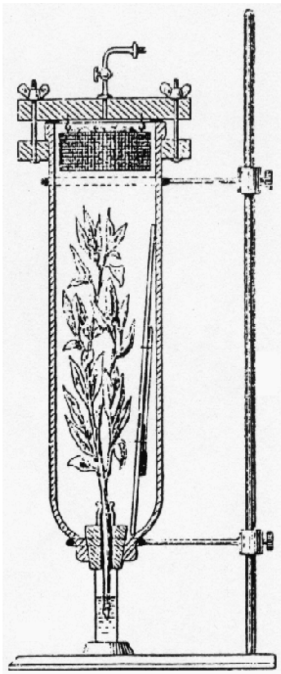
- "By suction"
- Where does the driving force for this suction come from?
- Water in the xylem is under tension
  - Water evaporating from the leaves (**transpiration**) creates this **tension** (i.e., suction)
  - **Cohesion** among water molecules provides a continuous water column
- Dixon and Joly (1894)
  - Cohesion-Tension theory

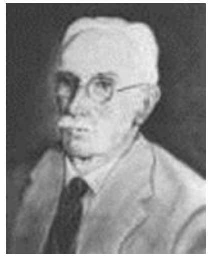
Koch et al. (2004) Nature 428: 851

Soil-Plant-Atmosphere Continuum (SPAC)

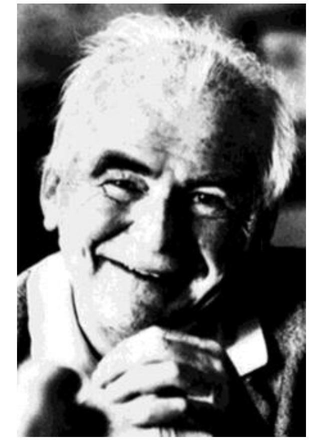


How can we test this theory?
Use a pressure chamber (aka, pressure bomb)

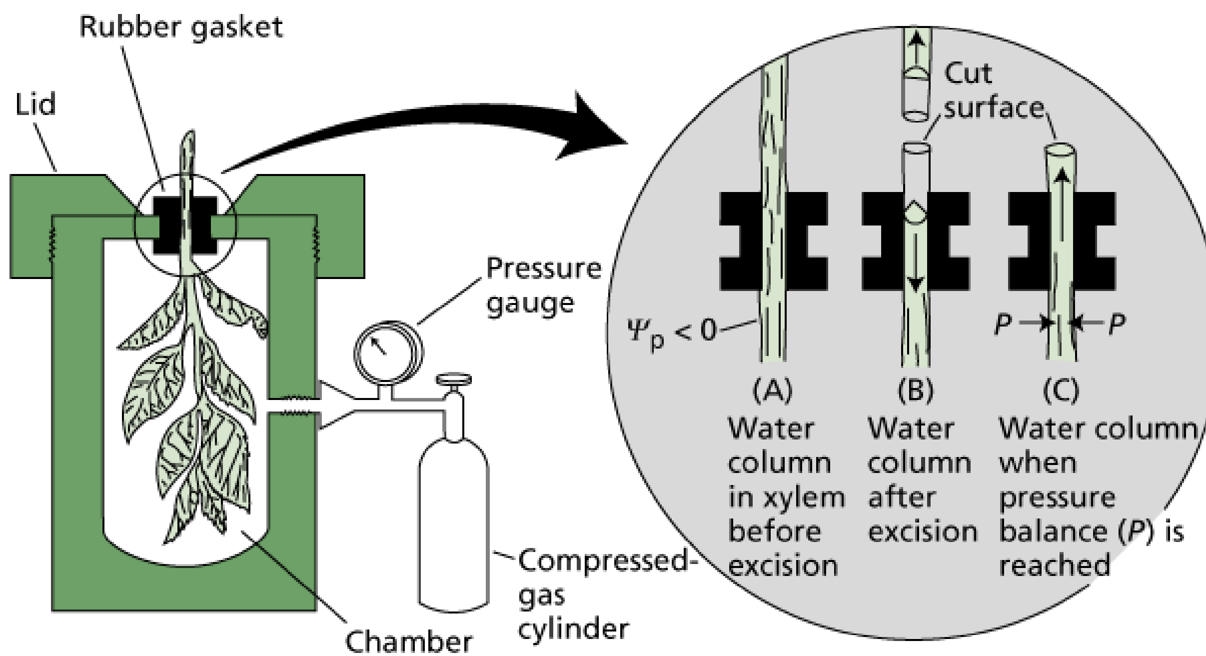




Henry Dixon

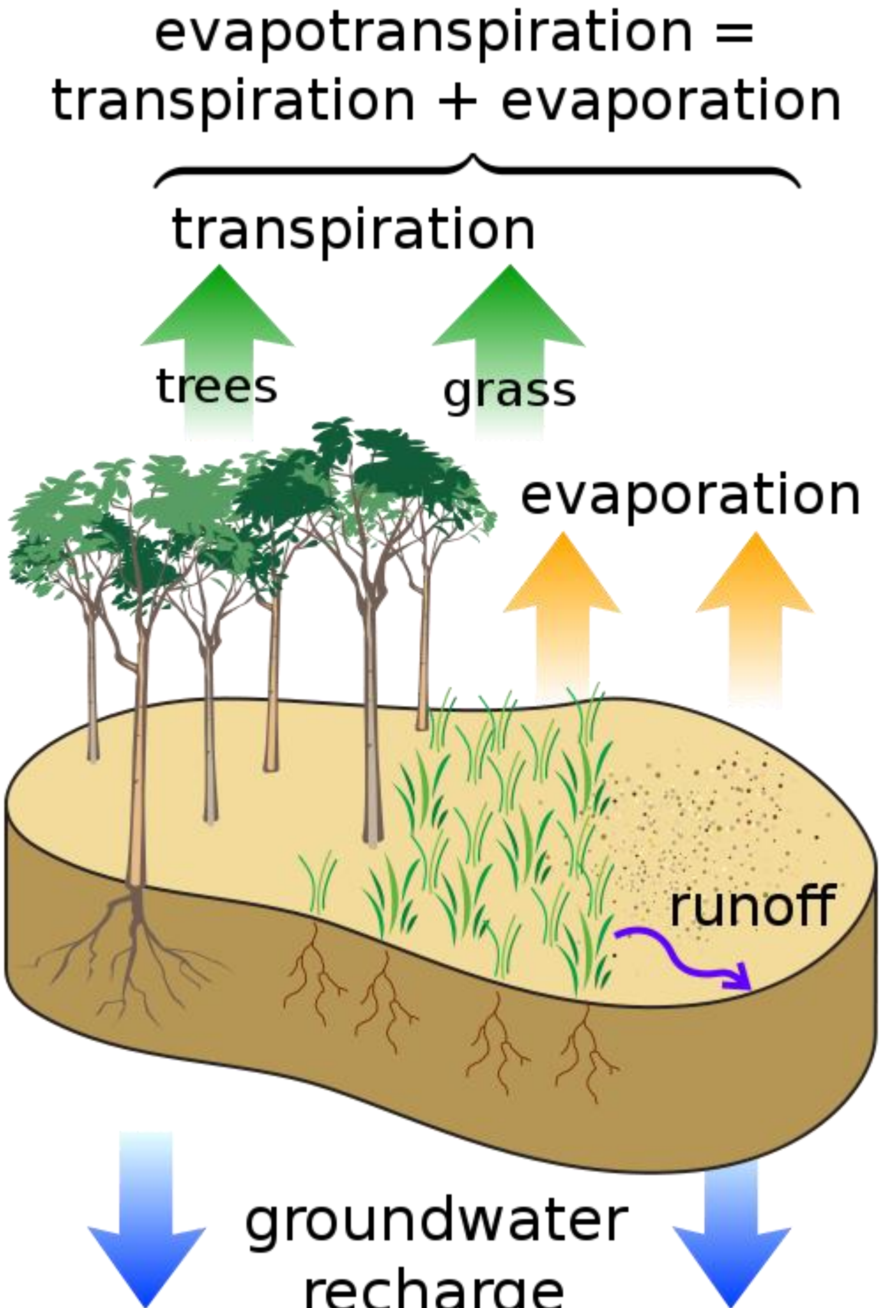


P. F. Scholander



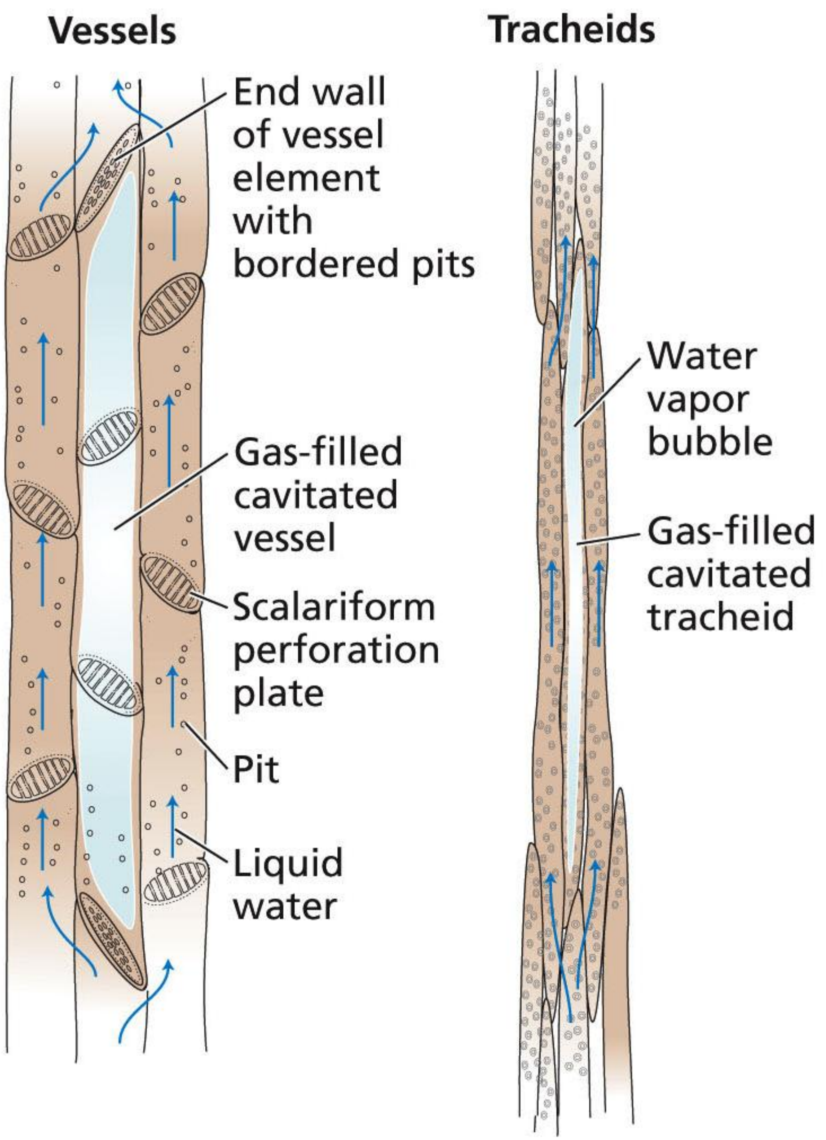
Soil water movement

- Evapotranspiration (ET)
  - Transpiration stream towards plants
    - Nutrients tag along
  - Surface evaporation
- Runoff
- Infiltration and seepage



Plant responses to water deficit

- Cell expansion slows down in the leaves
- Close the valves (stomata)
- Plants send more carbon to roots
- Shed leaves
- Accumulate solutes and hormones in the cells
  - Osmotic adjustments
- If dehydration continues?
  - The water column breaks (cavitation)



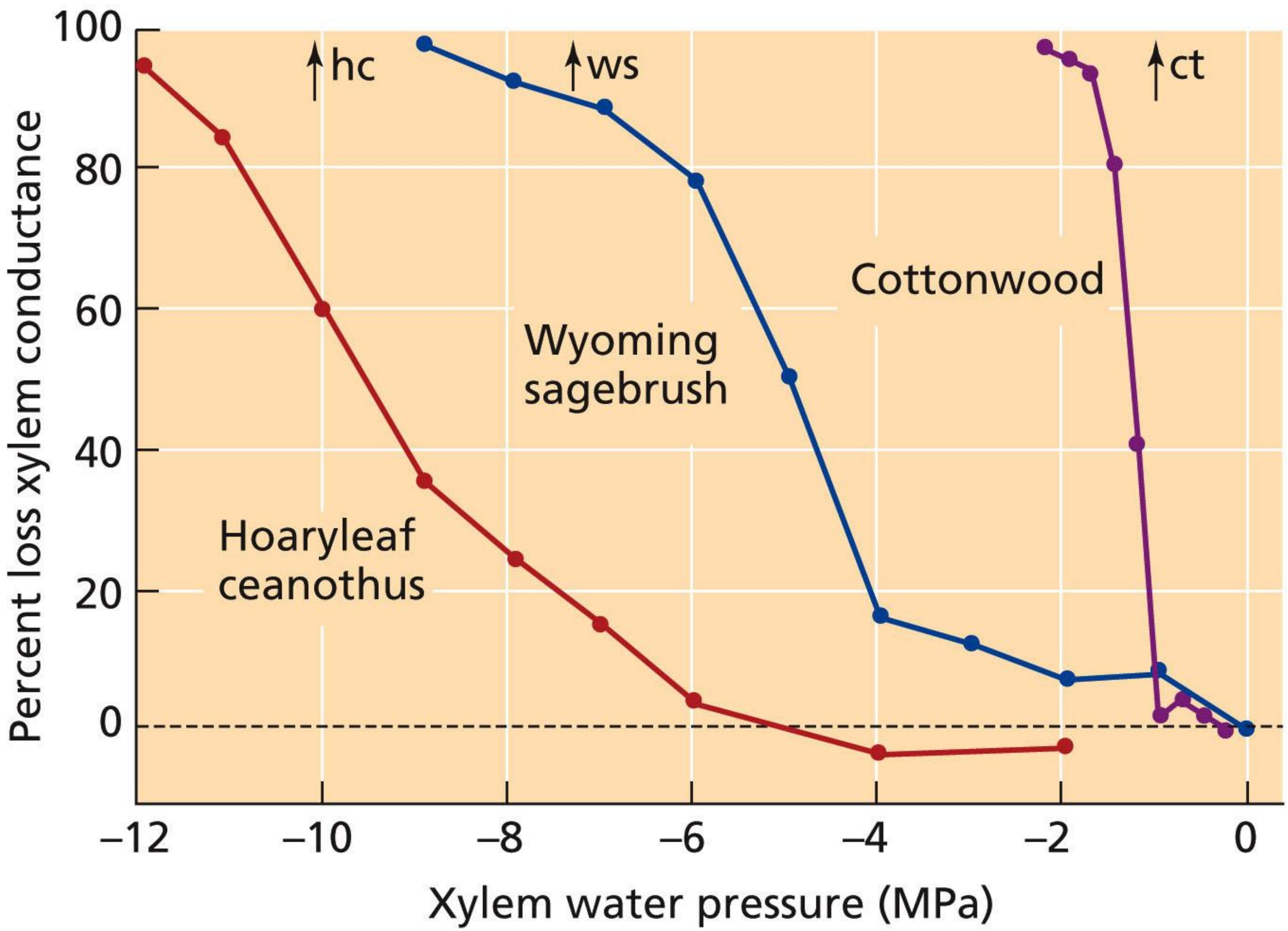
PLANT PHYSIOLOGY, Fourth Edition,

Plant adaptation to limited water

- Drought tolerators
  - Many evergreen perennials
  - Sclerophylous leaves, osmotic adjustment, conservative water use
- Drought avoider
  - Annuals, drought deciduous perennials
  - Timing of activities
- Drought escaper
  - Phreatophytes (deep rooted)
  - Reach water unavailable to other plants
  - Hydraulic lift, hydraulic redistribution

Plant adaptation to limited water

- Xylem vessel diameter

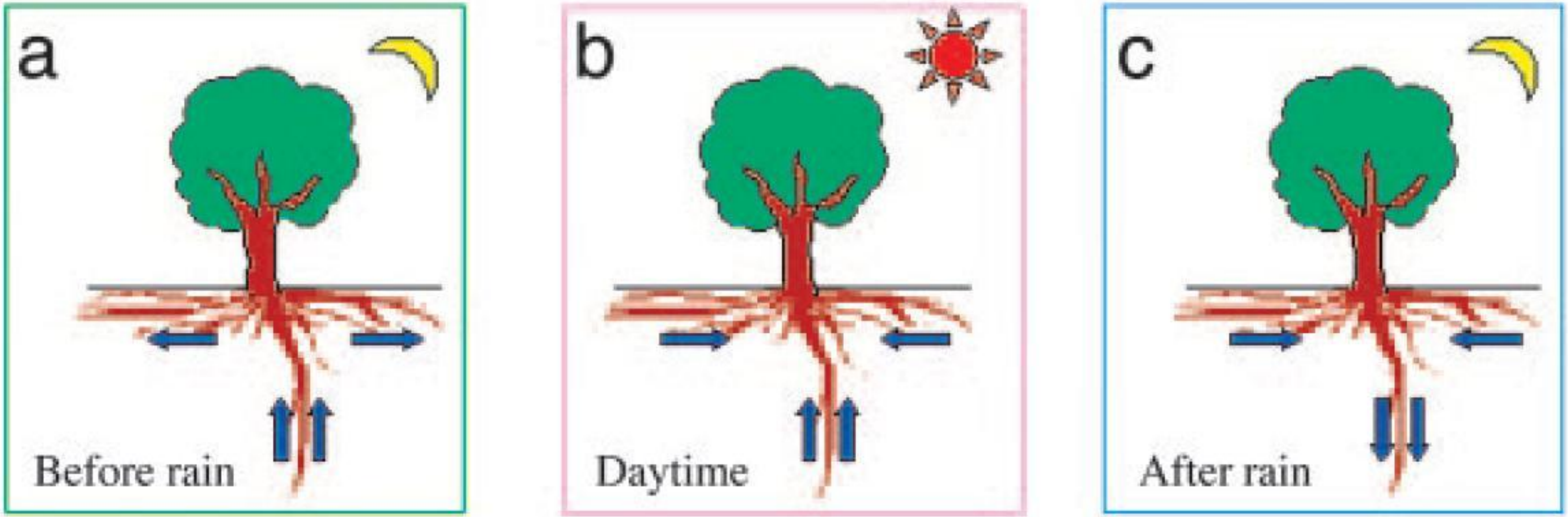


PLANT PHYSIOLOGY, Fourth Edition, Figure 4.10

Plant adaptation to limited water

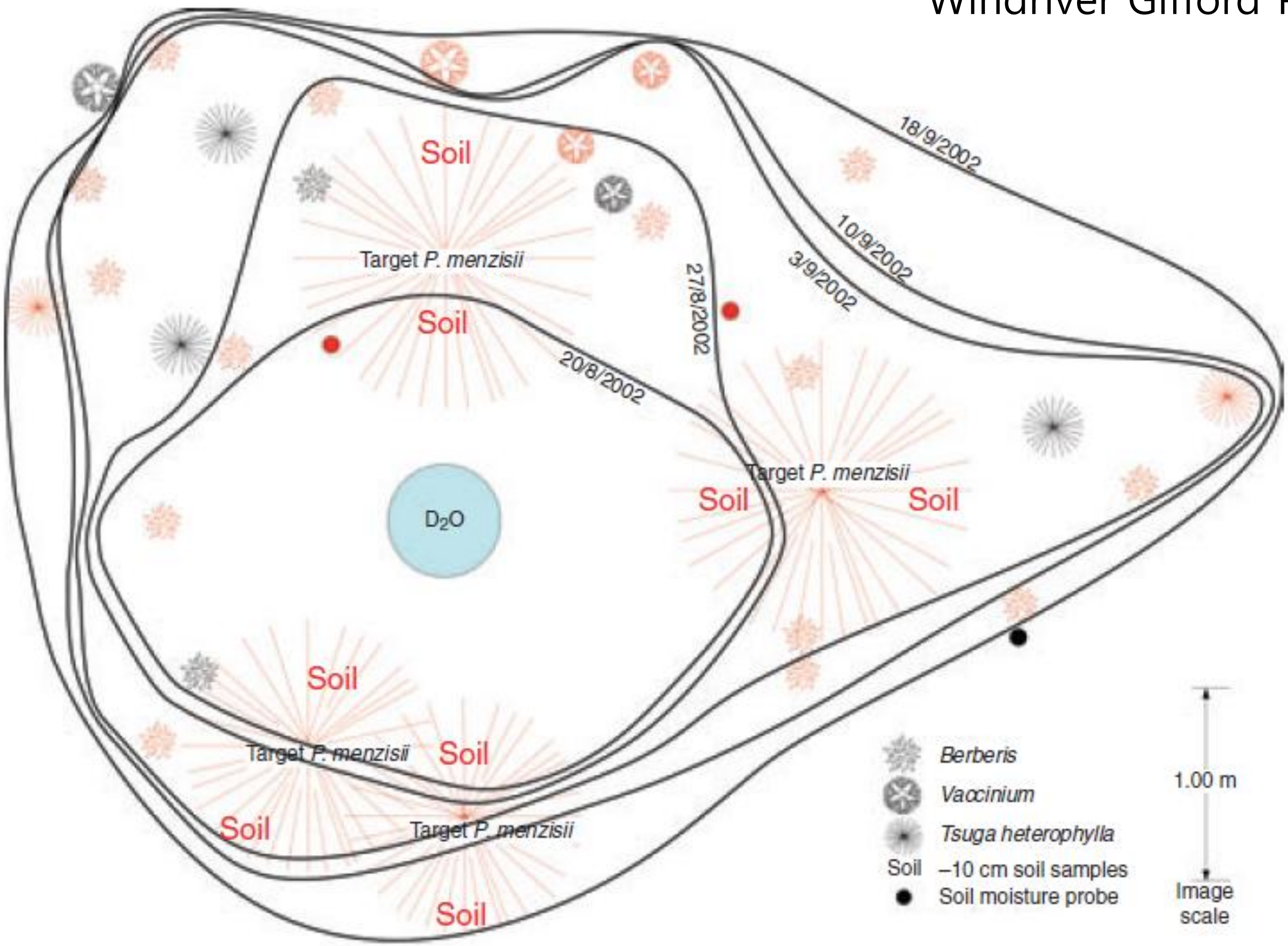
- Drought escapers and hydraulic redistribution of water

Artemisia tridentata (sagebrush)



Water redistribution to neighboring plants

Windriver Gifford Pinchot Forest



Brooks et al., 2006

Really redistributed by plants?

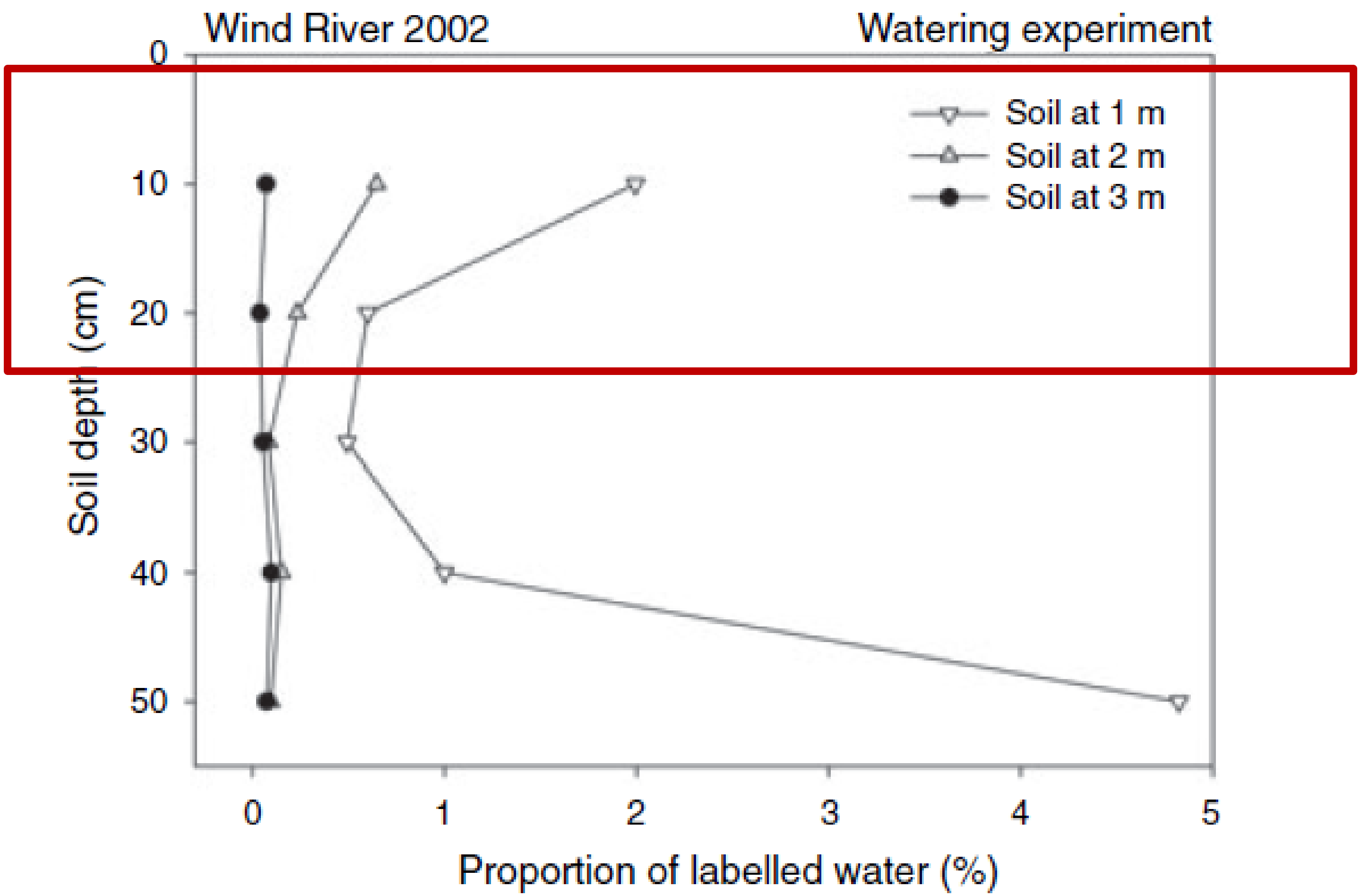


Figure 7. Profiles of deuterated water in soil samples collected at three distances from the watering site 36 d after the application of deuterated water began.

Brooks et al., 2006

Interesting findings but implications?

- Potential pathways
  - Liquid and vapor transport through soils
  - Through plant roots
  - Through mycorrhizal network
- Potential ideas for plant selection in water-wise landscapes
  - Mix in hydraulic redistributors in the landscape
  - Drip irrigate those plants for redistribution
  - Disclaimer: *This idea has not been tested!*

Methods to Reduce Water Stress of Conifer Seedlings in Seattle Forests

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EXPERIMENTAL TREATMENTS

Wood Chip Mulch

DRIP IRRIGATION

Irrigation Gel

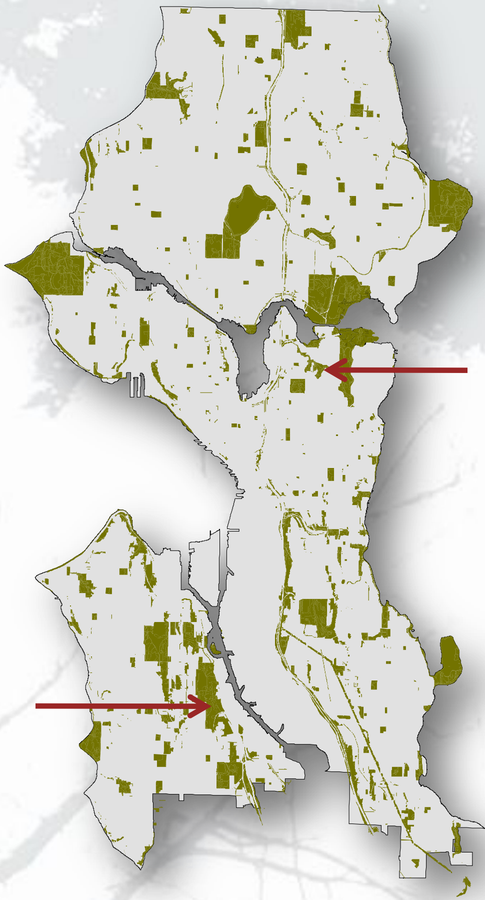
2 x 3 Factorial:

- **control**
- **irrigation gel**
- **drip irrigation**
- **mulch**
- **mulch + irrigation gel**
- **mulch + drip irrigation**

SPECIES

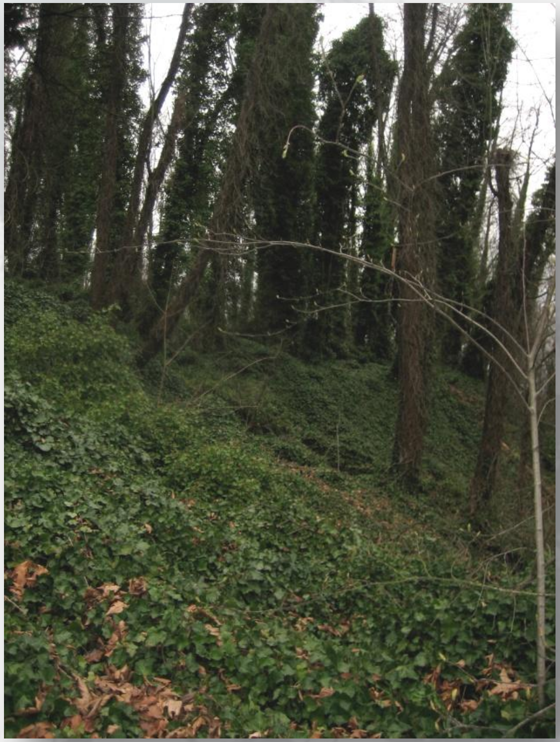
GRAND FIR > WESTERN RED CEDAR > WESTERN HEMLOCK

LOCATION



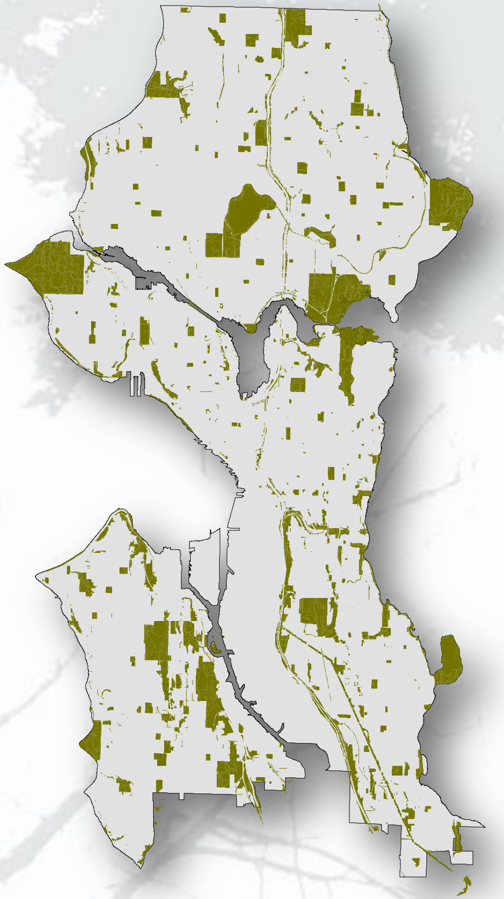
SEATTLE PARKS

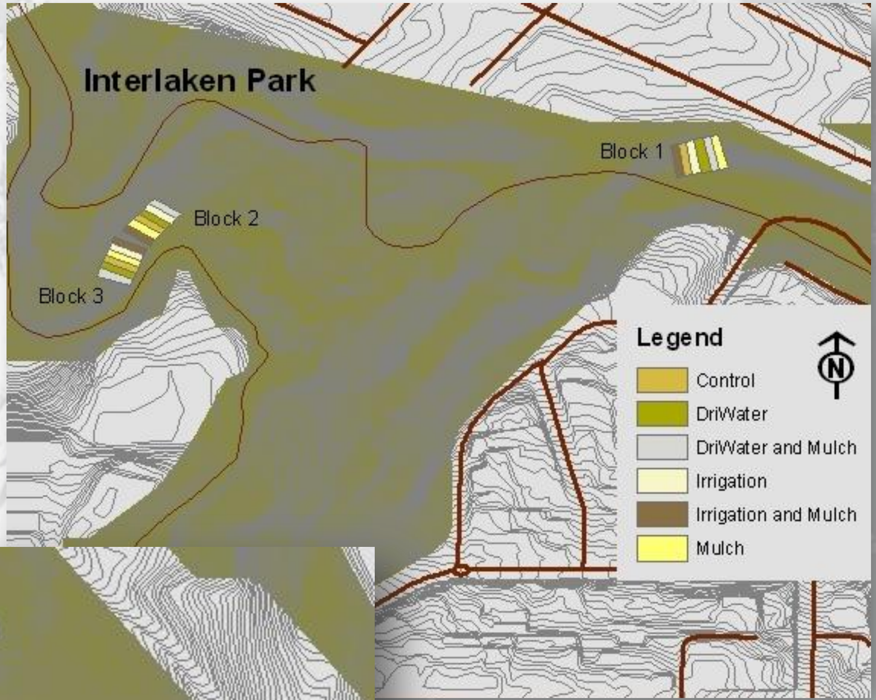
WEST DUWAMISH GREENBELT

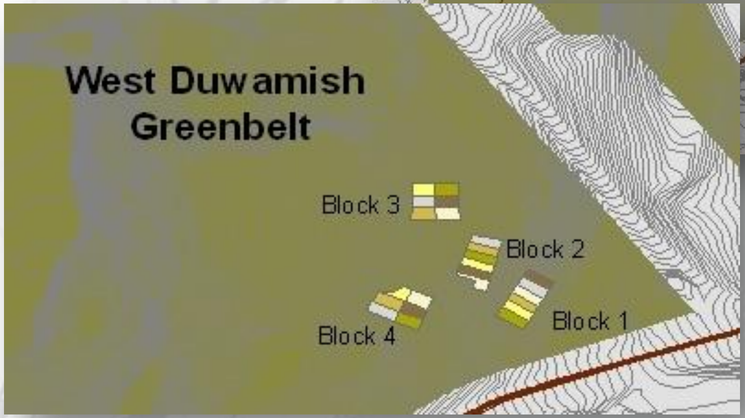


INTERLAKEN PARK

DESIGN




Interlaken Park
Block 1
Block 2
Block 3
Legend
Control
DriWater
DriWater and Mulch
Irrigation
Irrigation and Mulch
Mulch
N


West Duwamish Greenbelt
Block 3
Block 2
Block 1
Block 4

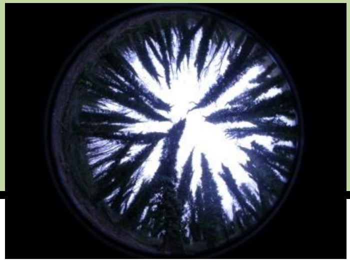
Measurements

- Site Conditions
  Soil chemical analysis
  Soil texture
  Canopy cover
  Microclimate

- **Soil Moisture**
  Watermark sensors

- **Tree Health and Growth**
  Height and diameter
  Root and shoot biomass
  Survivorship

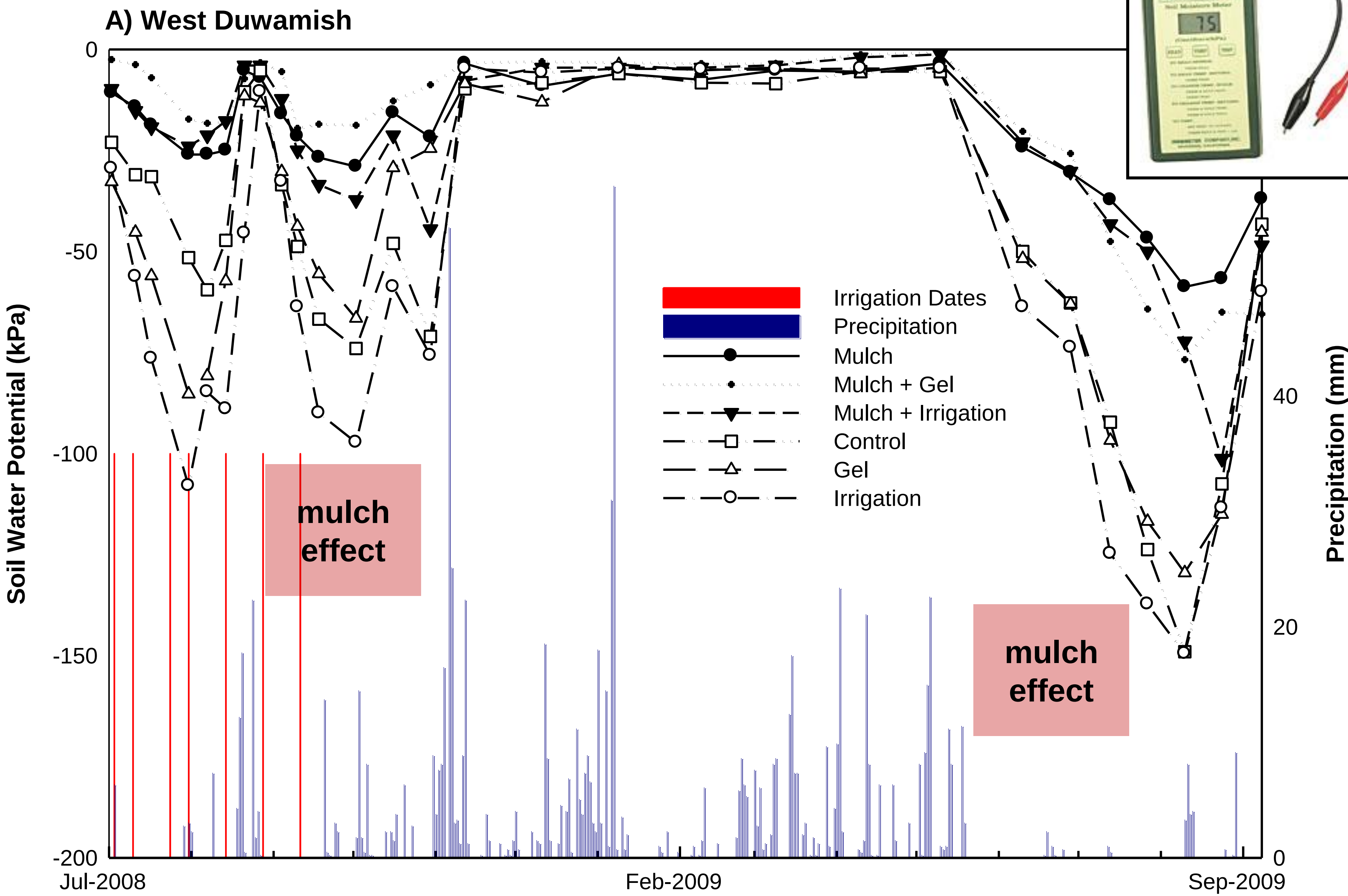
- **Stem Water Potential**
  Pre-dawn plant water status



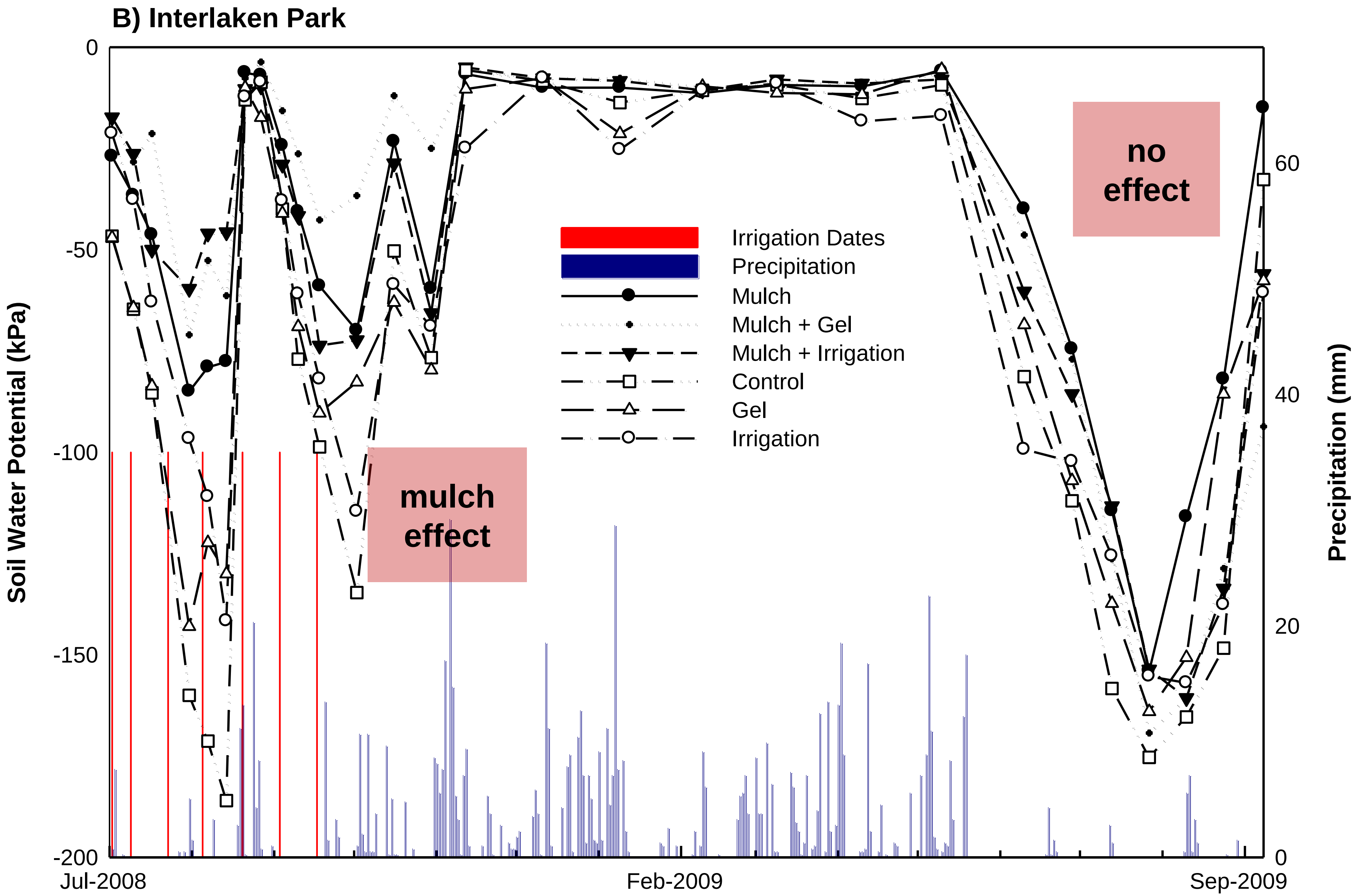
Western Hemlock
March 2008

Western Hemlock
August 2008

Soil Moisture : West Duwamish



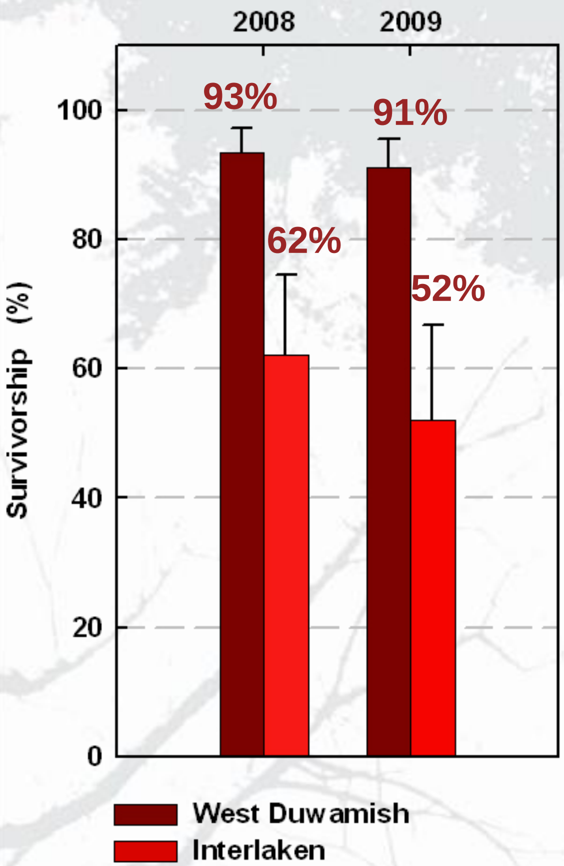
Soil Moisture : Interlaken



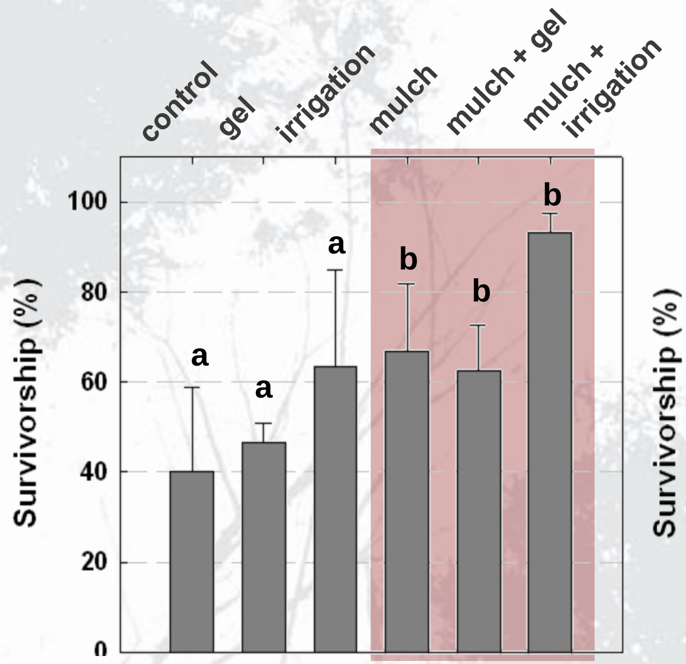
SURVIVORSHIP

WESTERN RED CEDAR

Site differences

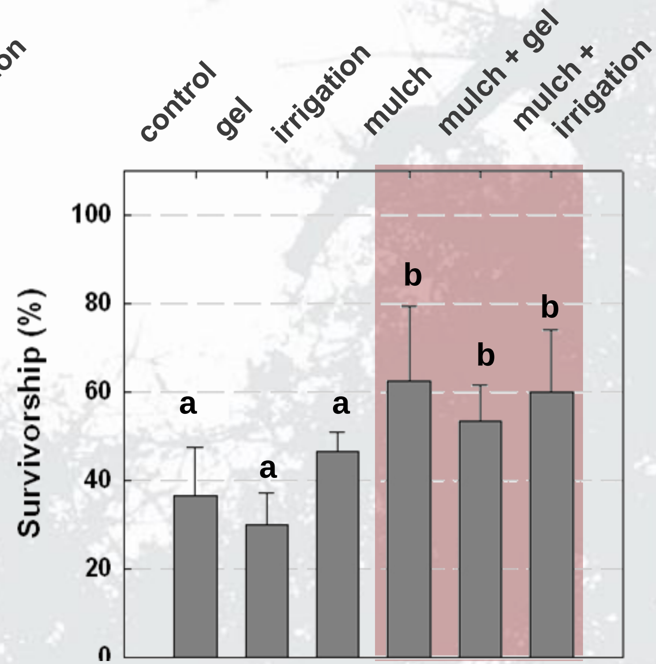


2008



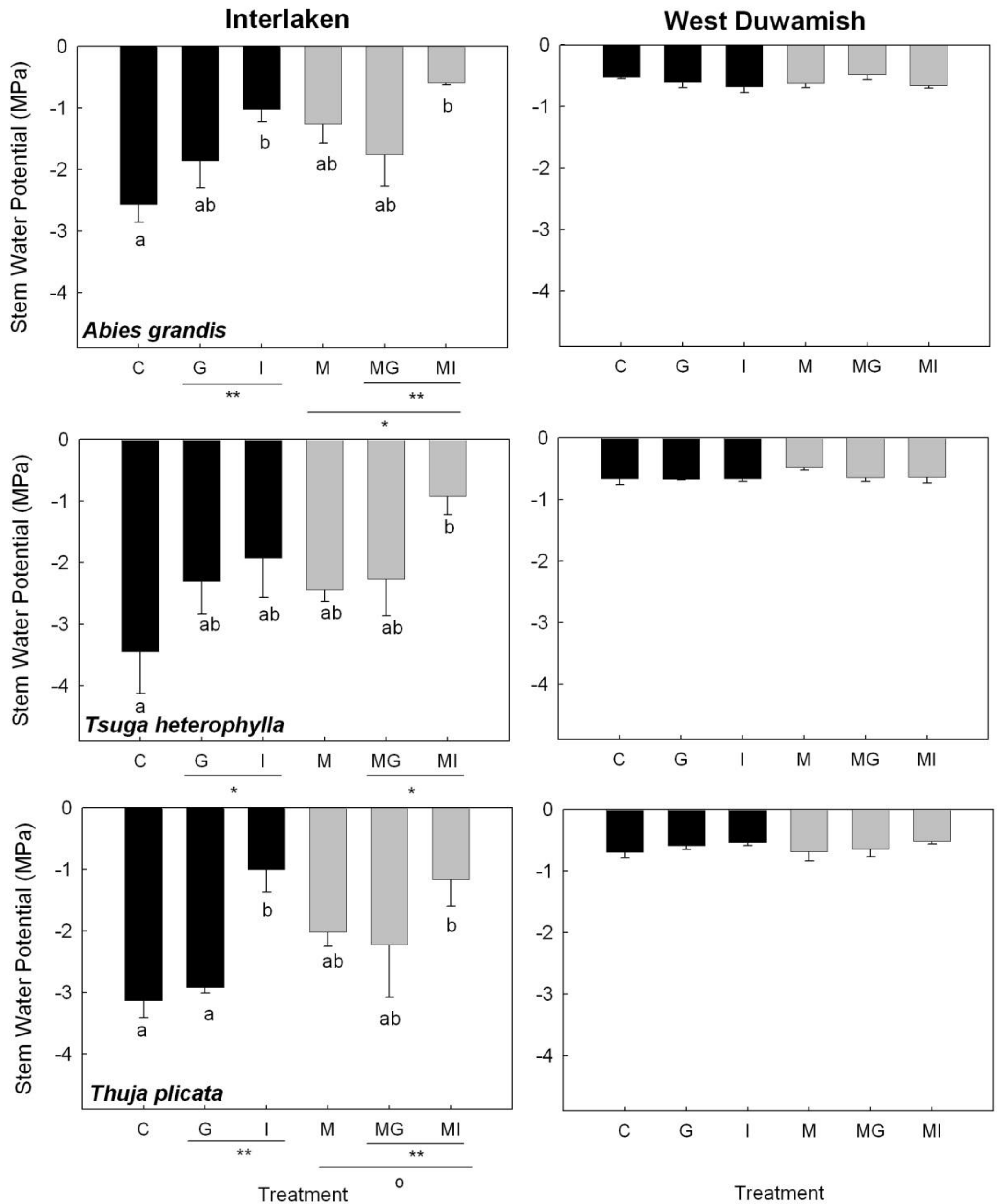
All mulch increased survival (p = 0.020)

2009



All mulch increased survival (p = 0.062)

Stem Water Potential in Summer of Year 1



SUMMARY

- **To test the influence of:**
  - **Coarse wood chip mulch**
  - **Drip irrigation**
  - **Irrigation gel**
- **To understand each treatments influence on water stress**
- **To characterize environmental conditions at two parks**

- **Significant park differences**
- **No treatment influence at West Duwamish**
- **Mulch treatments had the most influence on at Interlaken**
- **Soil texture influenced soil moisture**

Overview

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Thank you

Contact:
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Methods for estimating landscape water use

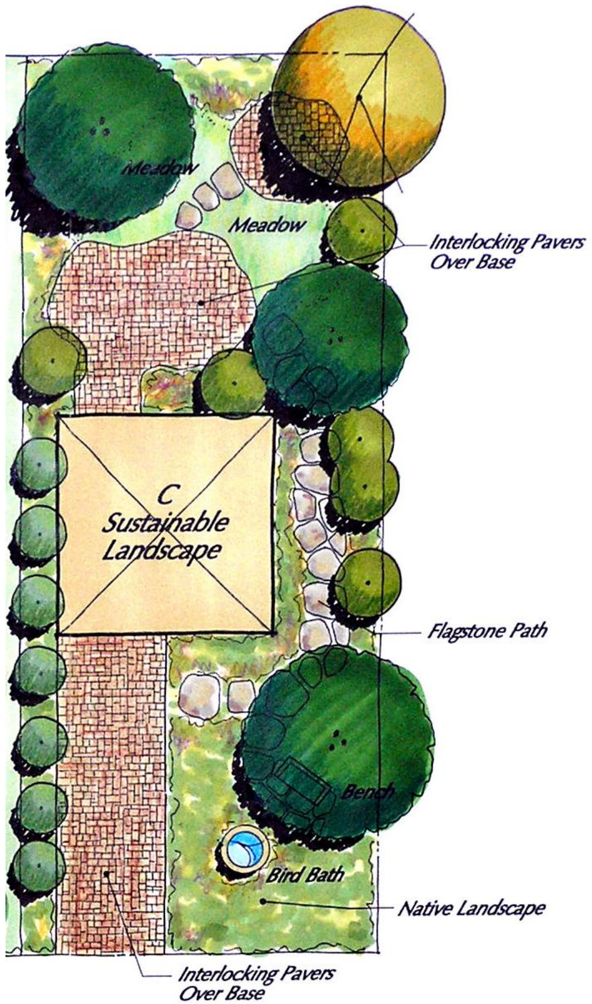
WUCOLS 2000: Water use classification of landscape species
www.water.ca.gov/wateruseefficiency/docs/wucols00.pdf

Weather (ET) based irrigation management

- Concept derived from crop irrigation
- Weather-based irrigation systems determine water requirement based on:
  - ET (Evapotranspiration): Soil evaporation + plant transpiration
    - $ET = ET_0 * K_c$
      - ET_0: reference (or potential) ET
  - ET_0: Value available from weather station data
    - Determined by pan evaporation, cool-season turf, or model
  - K_c : Crop coefficient

Adjustments for landscape plants

- Adjust it to meet landscape ET (ET_L)
  - ET_L is determined in reference to ET_0
- Adjust it by:
  - K_c – crop [species] coefficient
  - K_h – hydrozone [microclimate] coefficient
  - K_d – density [canopy area] coefficient
- Landscape coefficient (K_L)
  - $K_L = K_c * K_h * K_d$
- ET for a landscape planting (ET_L)
  - $ET_L = ET_0 * K_L$
- Amount of water to apply (W)
  - $W = ET_L / AE$
  - AE = application efficiency



Graphics: Clark & Green

Worksheet for Estimating Landscape Water Needs

Step 1: Calculate the Landscape Coefficient (K_L)

K_L formula: $K_L = k_s \times k_d \times k_{mc}$ .... k_s = species factor
k_d = density factor
k_{mc} = microclimate factor

k_s = _______ (range = 0.1-0.9) (see WUCOLS list for values)

k_d = _______ (range = 0.5-1.3) (see Chapter 2)

k_{mc} = ______ (range = 0.5-1.4) (see Chapter 2)

$K_L = \underset{(k_s)}{\_\_\_\_\_\_} \times \underset{(k_d)}{\_\_\_\_\_\_} \times \underset{(k_{mc})}{\_\_\_\_\_\_} = \_\_\_\_\_\_$.

Step 2. Calculate Landscape Evapotranspiration (ET_L)

ET_L formula: $ET_L = K_L \times ET_o$ .... K_L = landscape coefficient
ET_o = reference evapotranspiration

K_L = _______ (calculated in Step 1)

ET_o = ______ inches (listed in Appendix A for month and location)

$ET_L = \underset{(K_L)}{\_\_\_\_\_\_} \times \underset{(ET_o)}{\_\_\_\_\_\_} = \_\_\_\_\_\_$ inches.

Step 3. Calculate the Total Water to Apply (TWA)

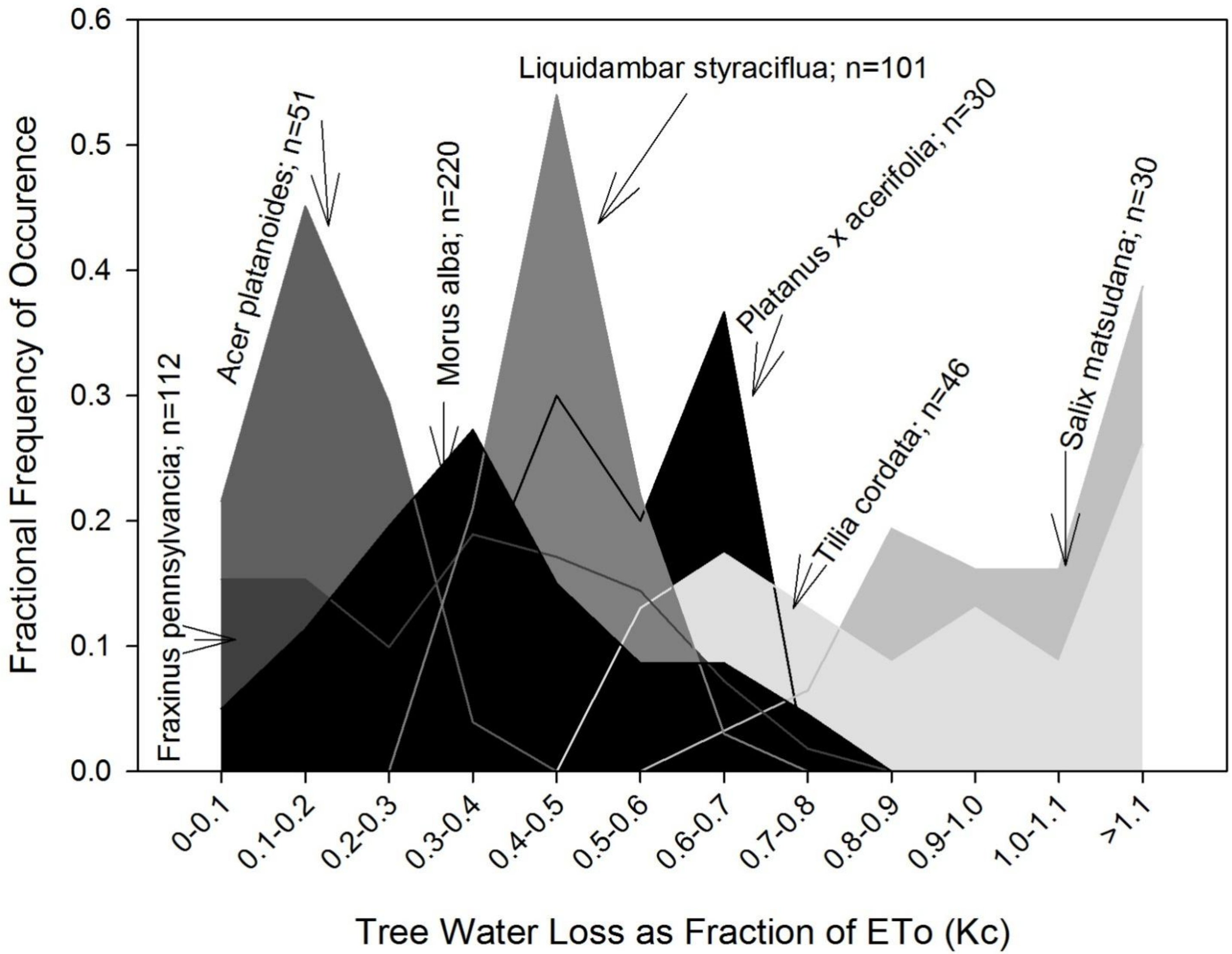
TWA formula: $TWA = \frac{ET_L}{IE}$ .... ET_L = landscape evapotranspiration
.... IE = irrigation efficiency

ET_L = _______ (calculated in Step 2)

IE = ________ (measured, estimated, or set) (see Chapter 5)

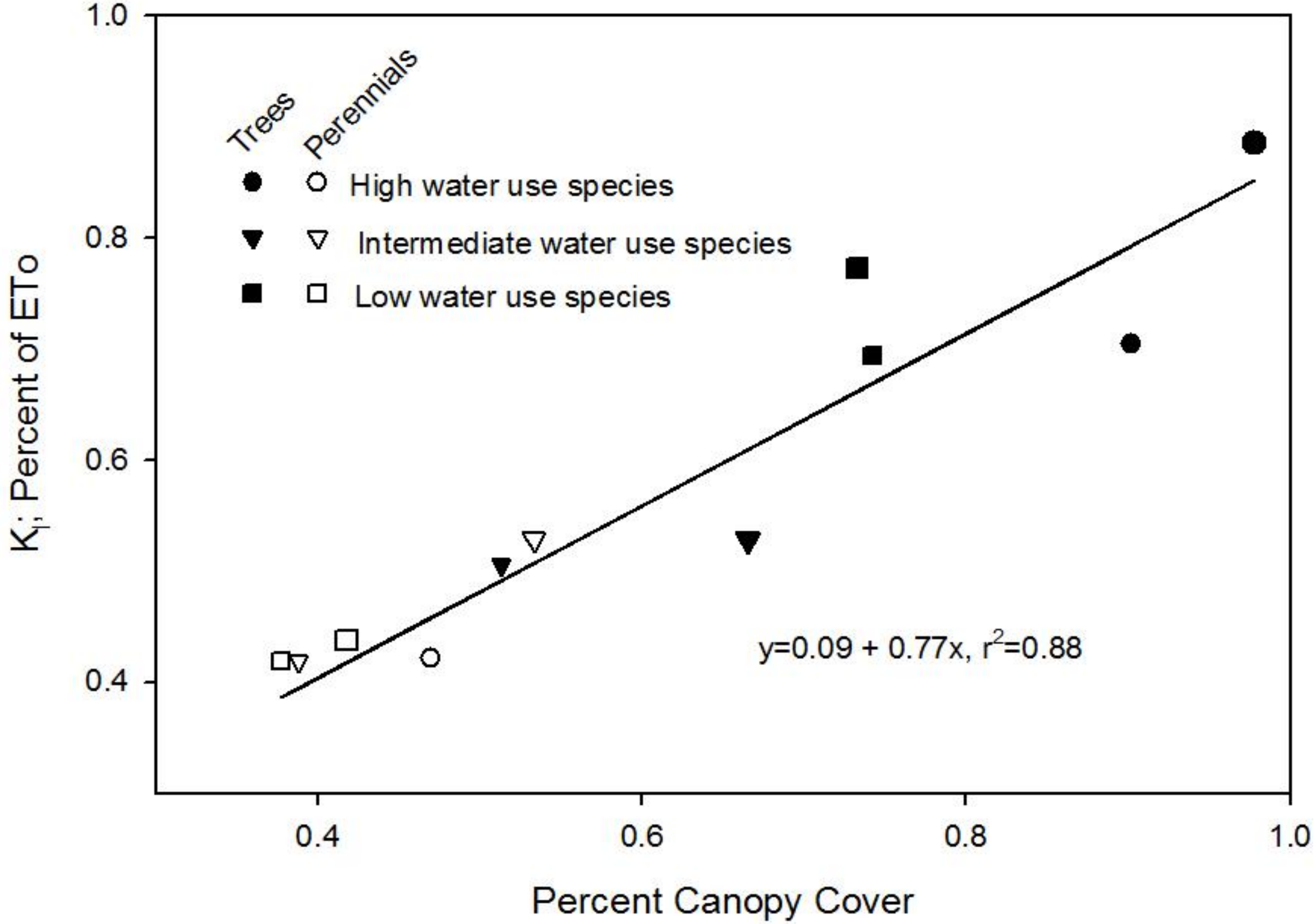
$TWA = \frac{ET_L}{IE} = \_\_\_\_\_\_\_$ inches

K_L values vary with species and environment



Data source: Dr. Roger Kjelgren

K_L values are closely correlated with density factor



Data source: Dr. Roger Kjelgren, Utah State Univ.