Water relations and water yield in aspen and conifer forests

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Question: Can vegetation manipulation affect water yield?

- Assessed this for aspen and conifer stands in context of conifer encroachment.

- Overview of talk:
  - Some perspectives and background
  - Our study
  - Conclusions and some final synthesis

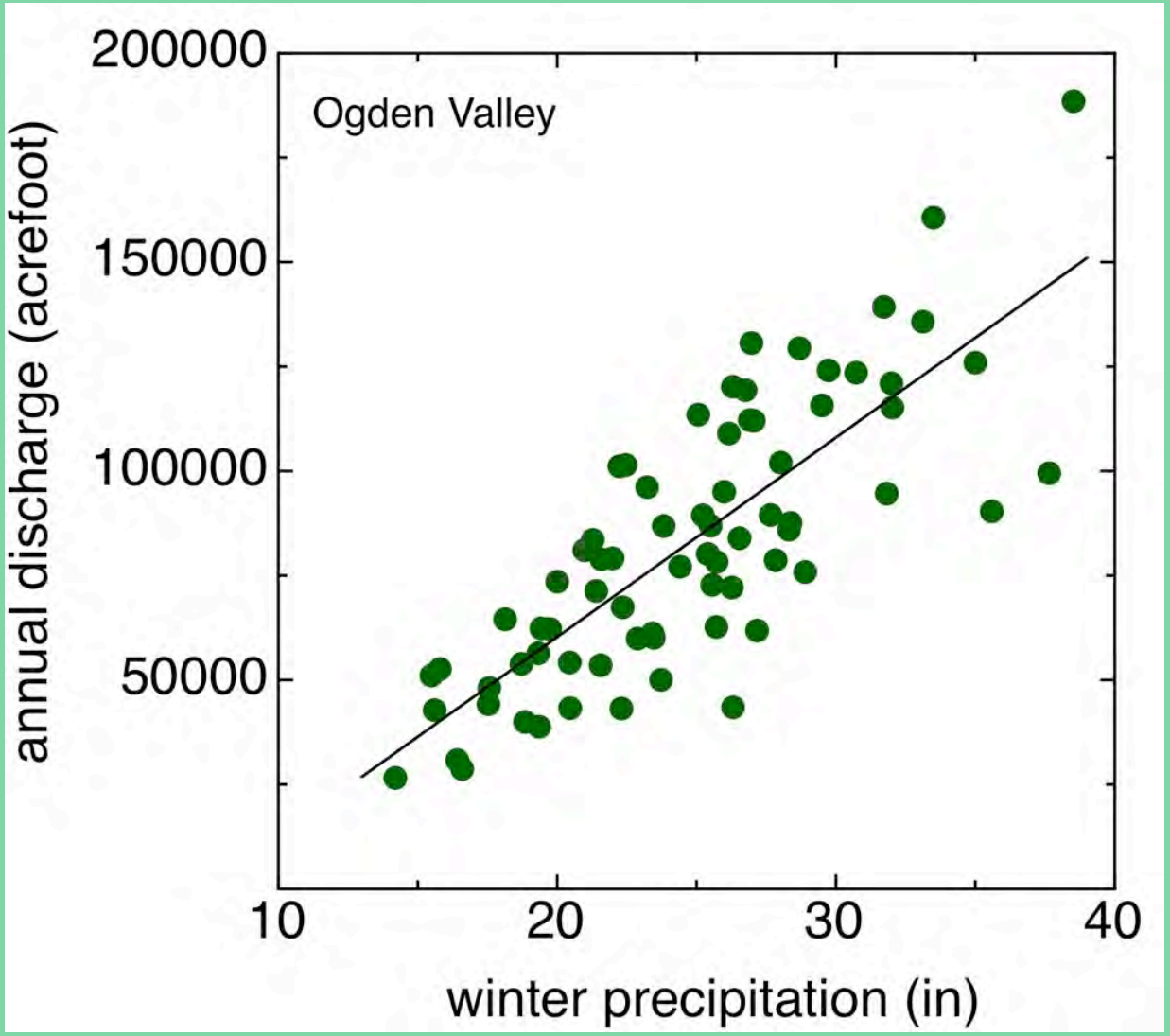
Some Perspectives

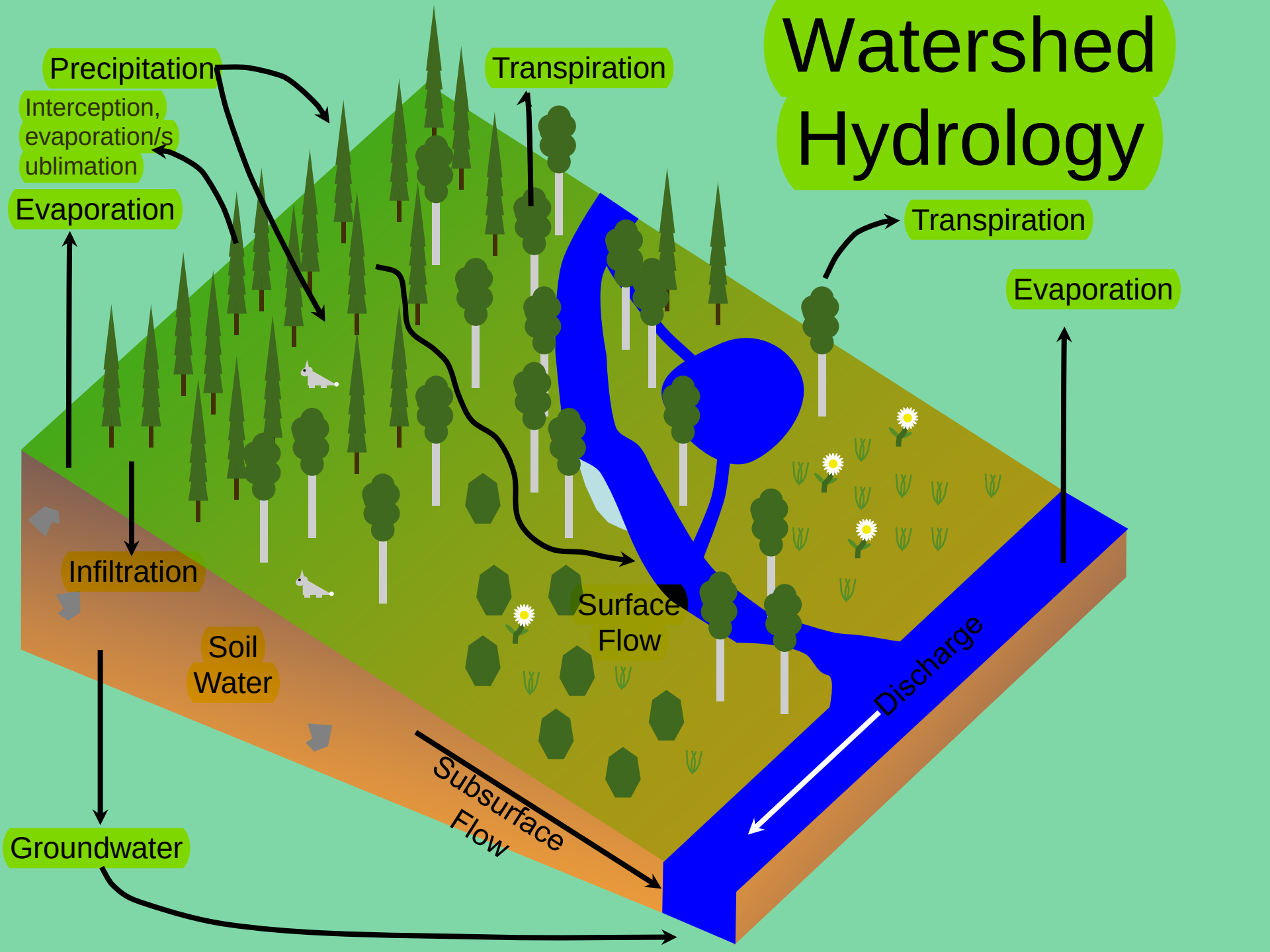
- Plant modify the environment
  - Modifications differ by species
- Quaking aspen occurs in both stable and seral stands
  - Stable are largely aspen monocultures
    - Persistent, relatively stable age structure
    - Exhibit gap dynamics
  - Seral stands are mixed aspen-conifer stands
    - Successional
    - Rely on periodic disturbance (usually fire)
    - I am focusing on this type

Decline in Western Aspen

- In the Intermountain West, there is strong evidence for reduced aspen forest coverage in many areas.
  - In Utah, estimates range from 50-60% reduction in aspen forest since European colonization. (Kay 1997; Bartos 2001)
  - Similar or greater reductions in several other western states. (Lachowski et al. 1996; Wirth et al. 1996; Brown 1995)
  - Colorado, however, appears to have had an increase in the coverage of aspen forests. (Manier and Laven 2002, 2001)
- In areas of decline, encroachment and replacement by various conifer species is prevalent. (Shepperd et al. 2006; Bartos 2001; Bartos and Campbell 1998)

Water Input ➜ Water Output




Watershed Hydrology
Precipitation
Interception, evaporation/sublimation
Evaporation
Transpiration
Transpiration
Evaporation
Infiltration
Soil Water
Surface Flow
Discharge
Subsurface Flow
Groundwater

Water Yield and Aspen

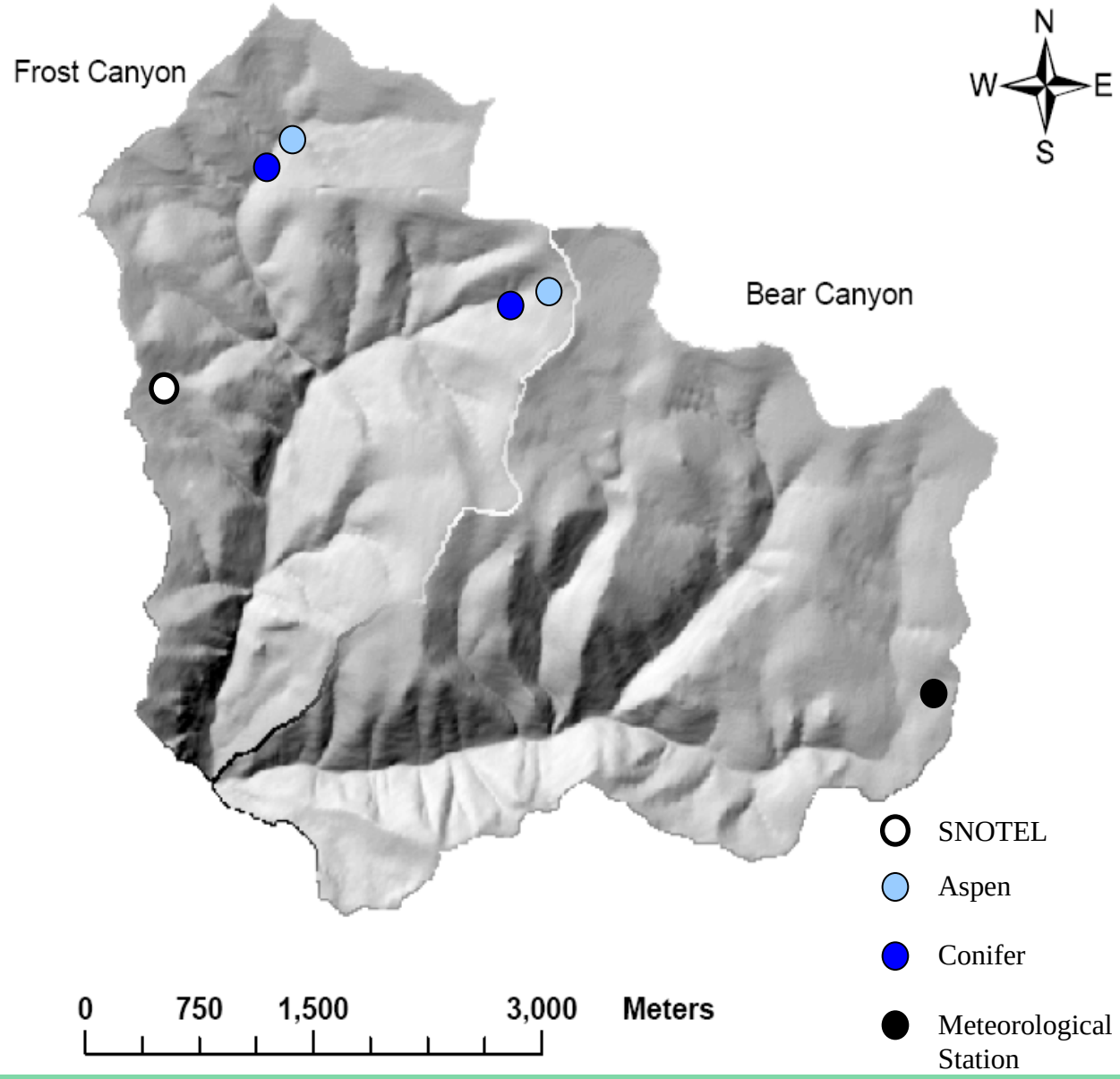
- **Goal of Research:** to assess effects of conifer encroachment into aspen on watershed water yield.
- **Objective:** Identify mechanisms causing differences in water relations between aspen and conifer stands that could result in differences in watershed water yield.
- **Central Hypothesis:** Aspen dominated watersheds yield more water than those dominated by conifer stands.

Approach:

- Use “end-point” mature stands of aspen and conifer to assess differences in water relations.
- Stands are adjacent pairs on similar soils, slope, aspect, and elevation

Hypothesized Mechanisms causing Differences in Water Yield between Aspen and Conifer Stands

- H1: Different water accumulation in snow pack
- H2: Different sublimation/evaporation patterns
- H3: Different melting rates and patterns
- H4: Different precipitation related soil recharge
- H5: Different water use by tree species
  - Different transpiration rates
  - Different timing of water use
  - Difference sources of water

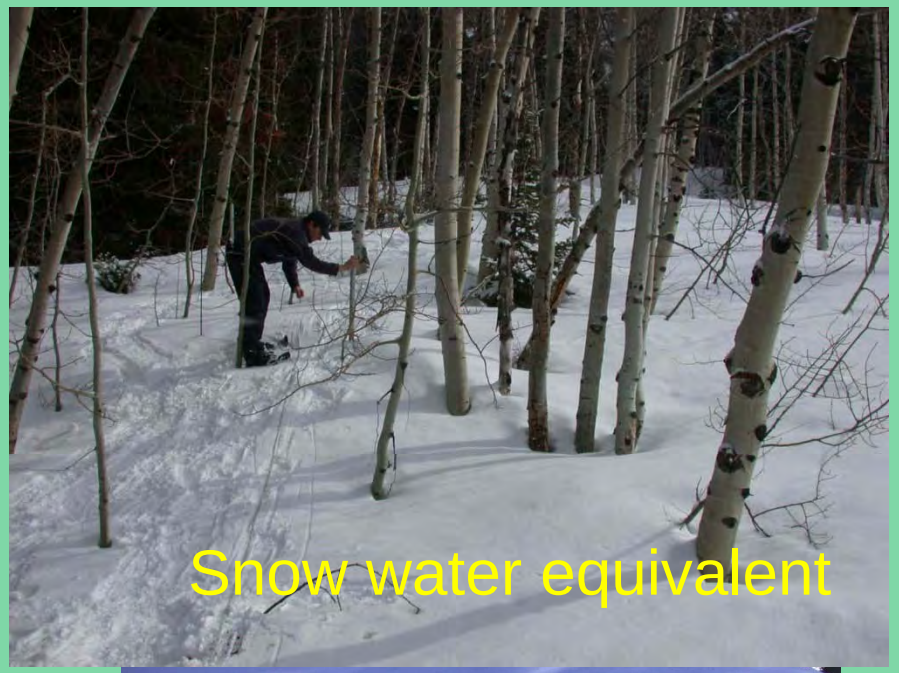


Bear and Frost Canyons

Deseret Land and Livestock

Methods


Tree Sap Flow


Snow water equivalent

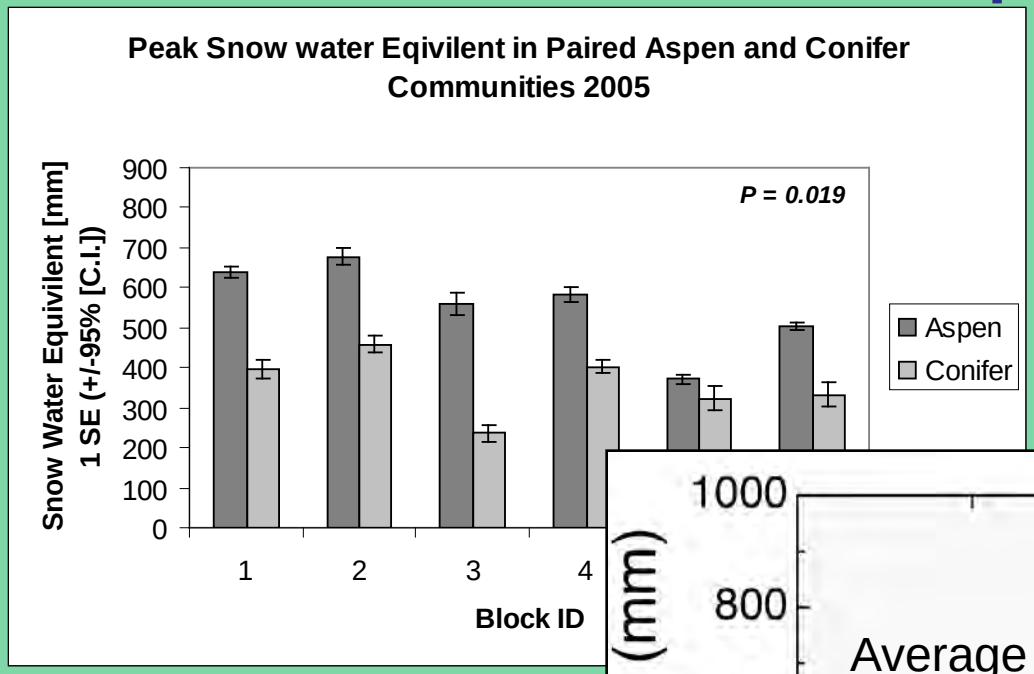

Soil moisture sensors

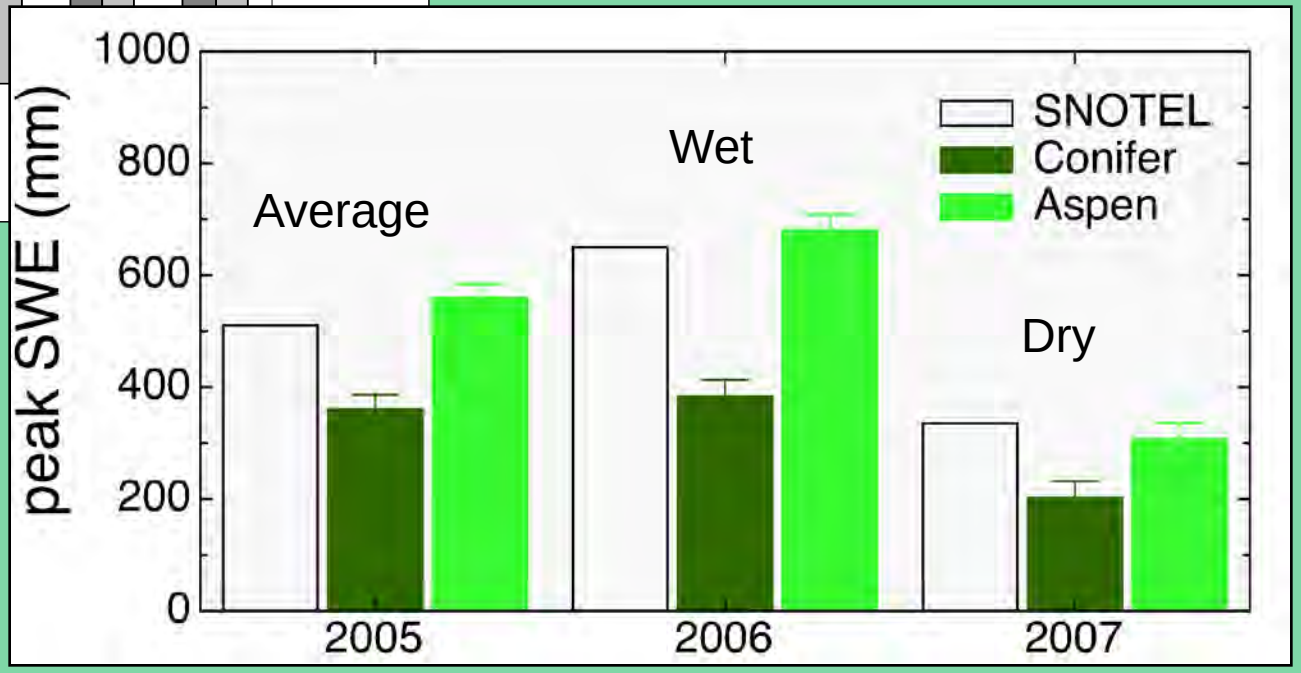

Evaporation pan

Elk protection…

Results …

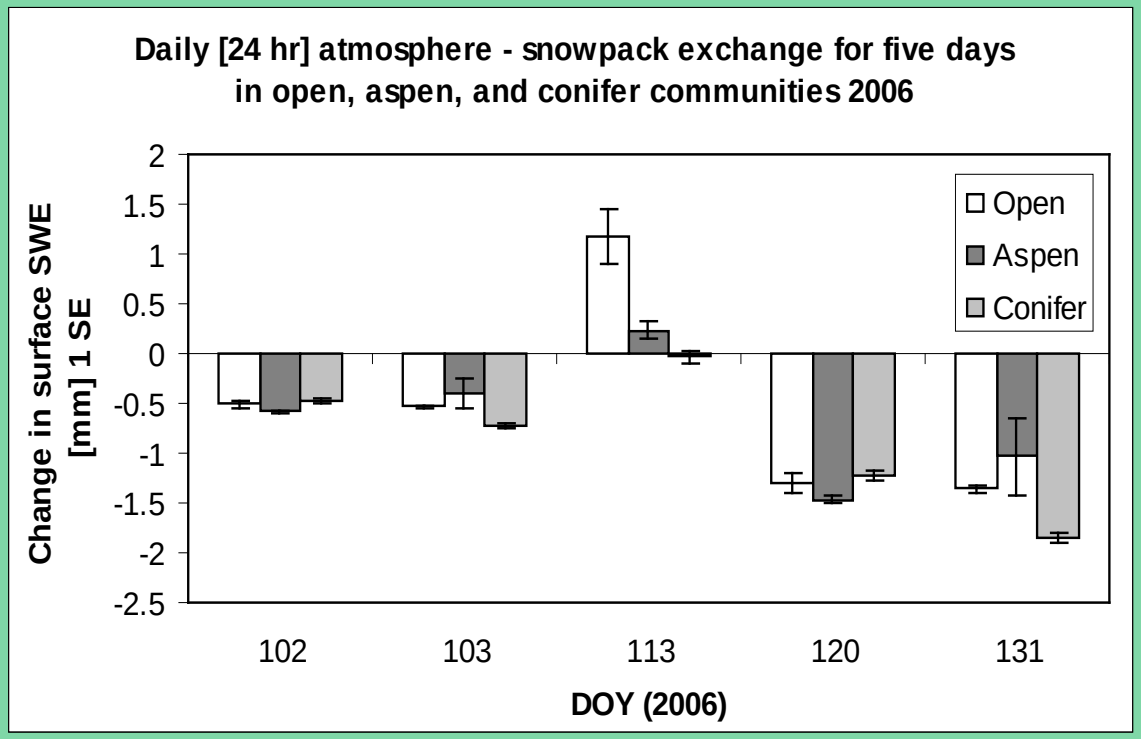
H1: Different water accumulation in snow pack

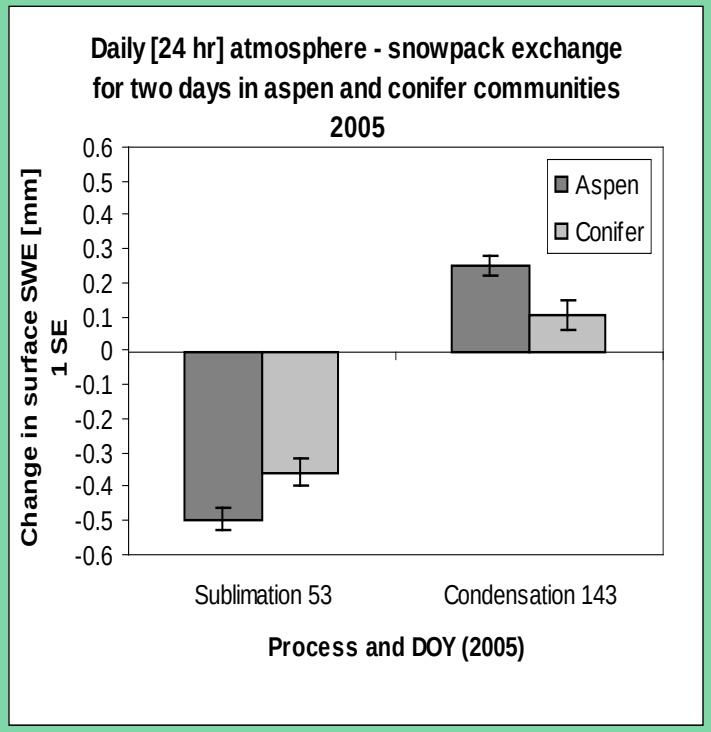




Result: conifer stands 33-44% less water in snow than aspen

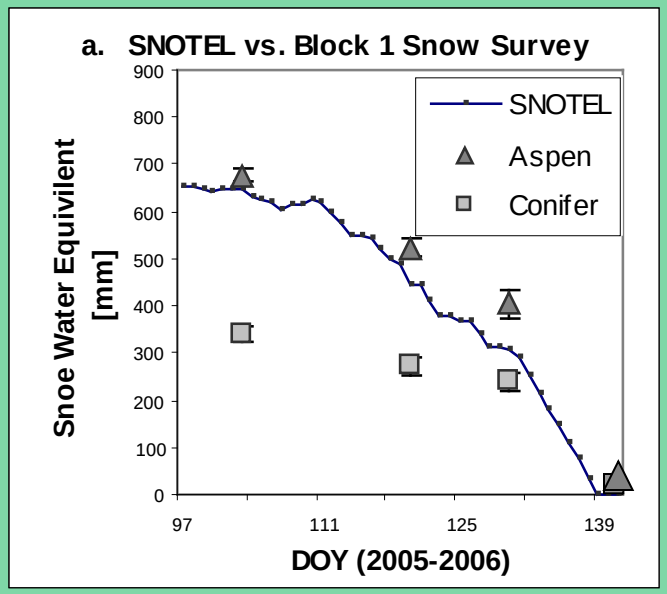
H2: Different sublimation / evaporation patterns

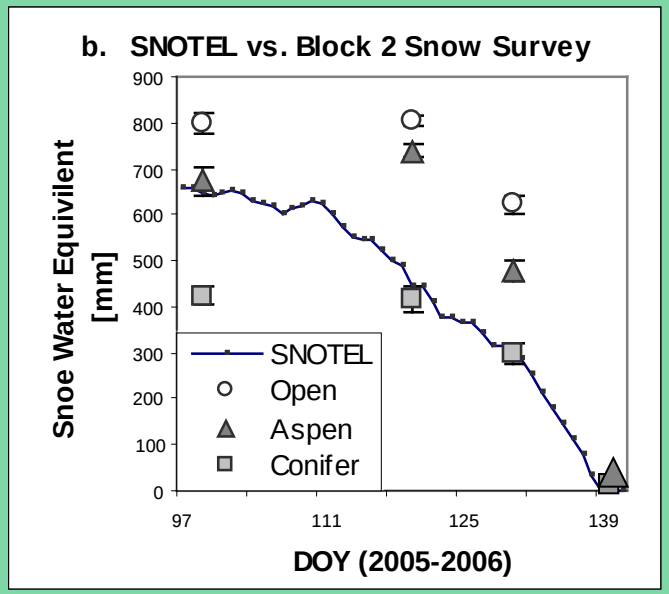


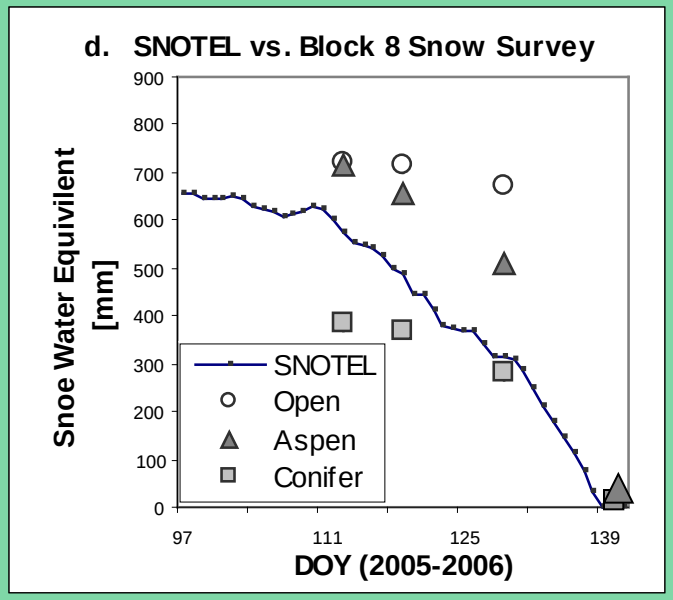


Result: similar sublimation /evaporation rates, small in quantity.

H3: Different melting rates and patterns

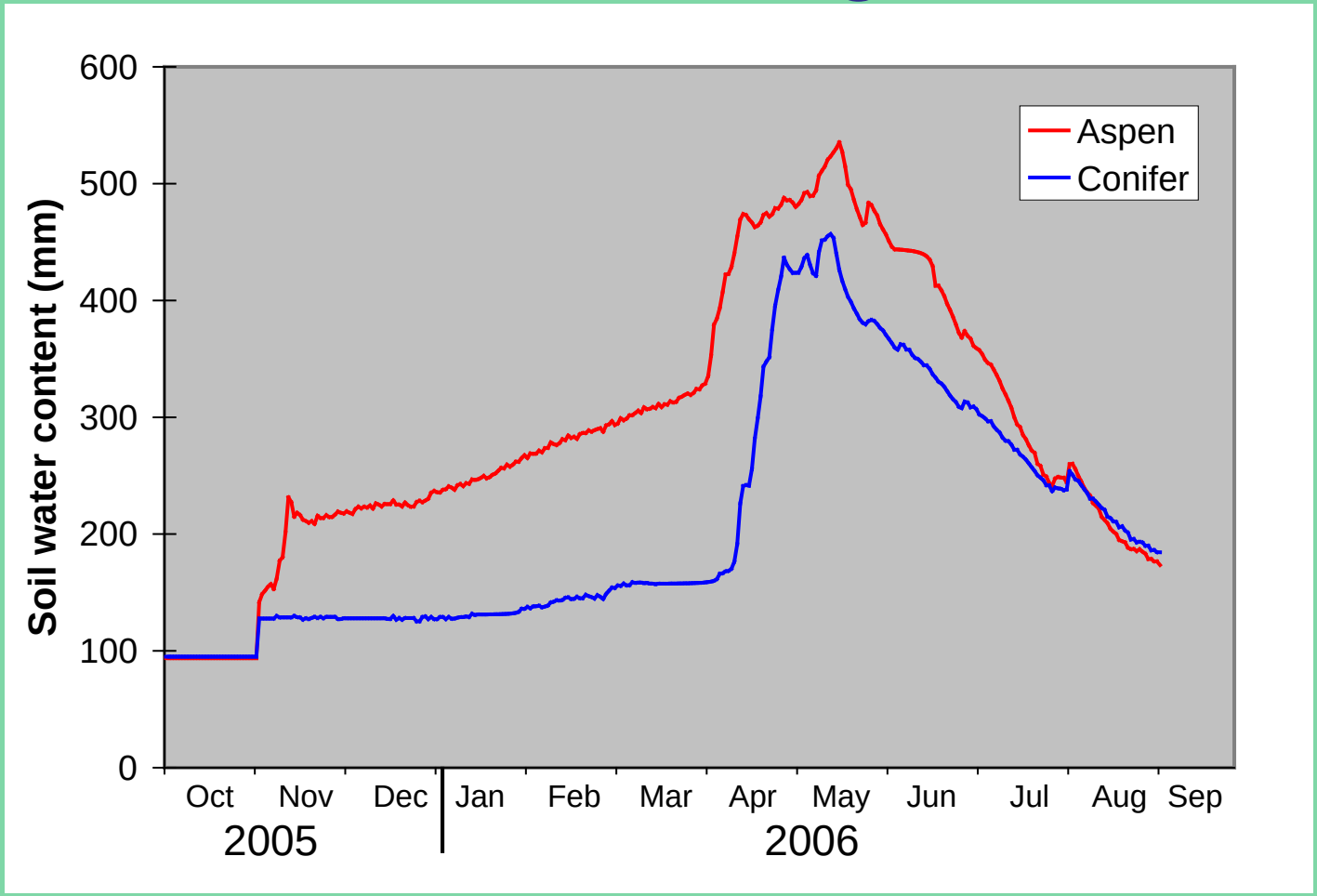






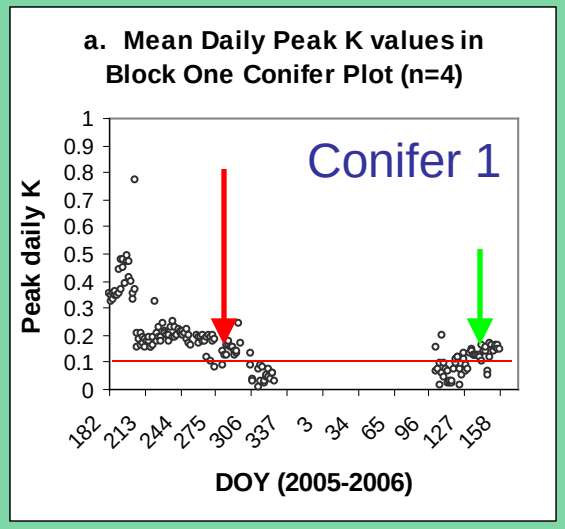
Result: similar melt period despite differences in total snow water.

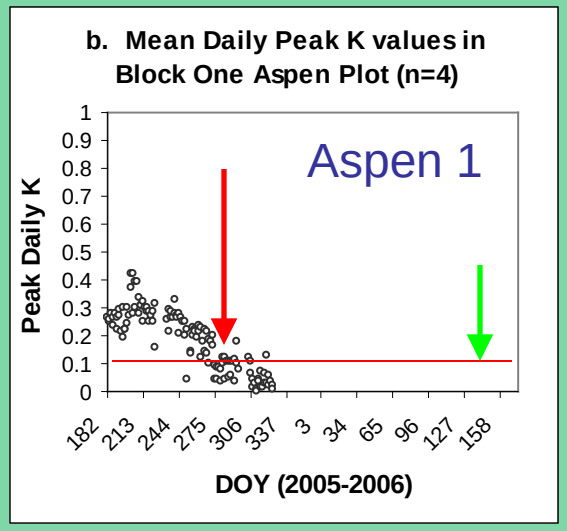
H4: Different precipitation-related soil recharge



Result: aspen recharged soil moisture earlier, and had higher total soil moisture. Same moisture at start of WY.

H5: Different water use by tree species

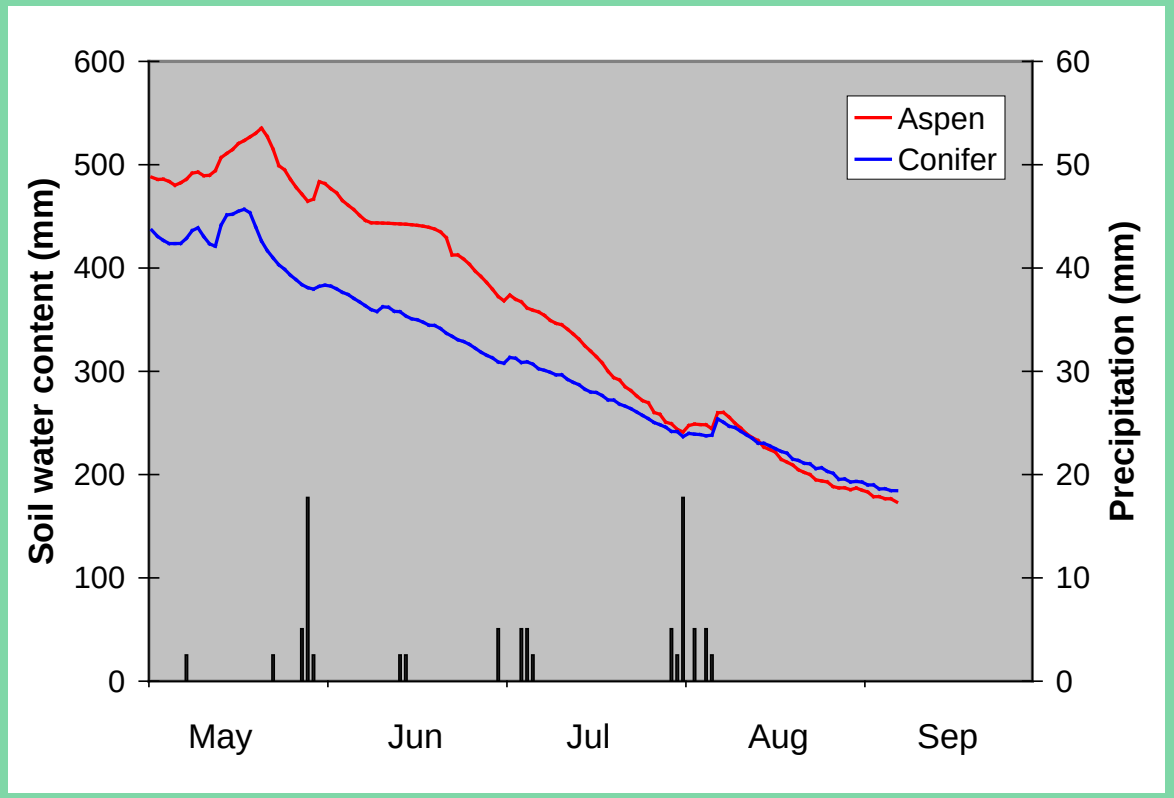




Transpiration rates:

Aspen = 3.5 mm d^{-1}

Conifer = 3.0 mm d^{-1}

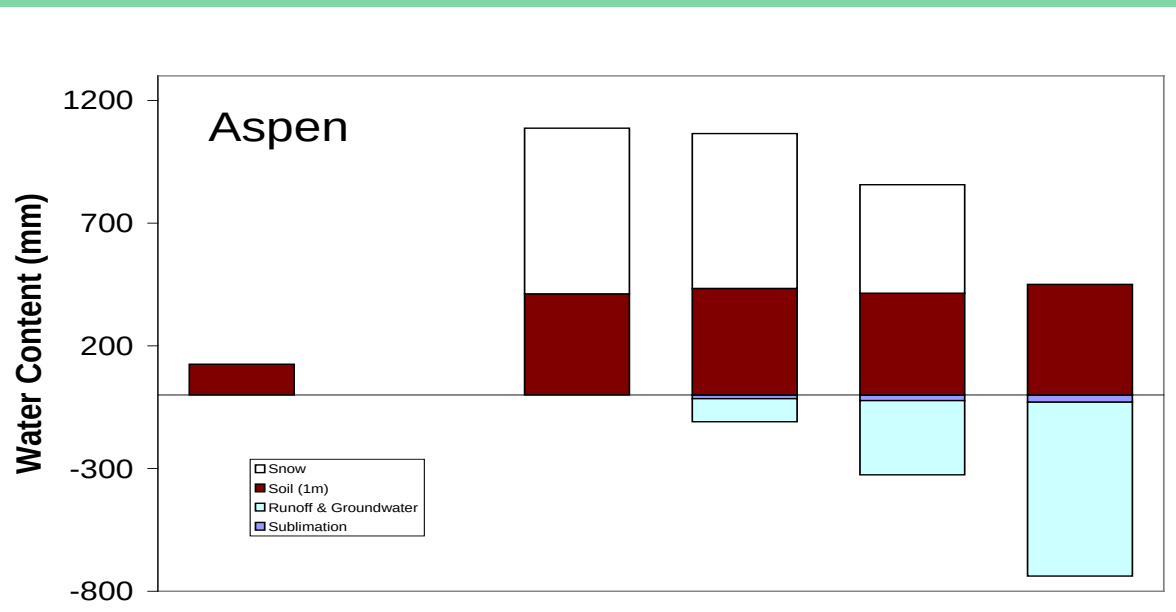


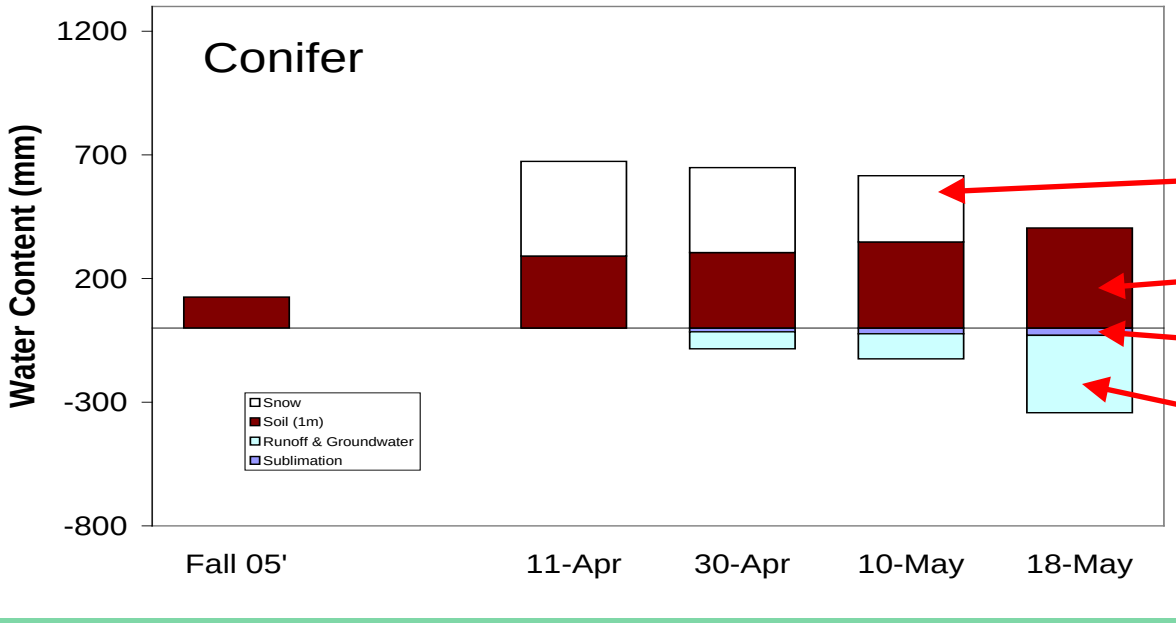
Result: transpiration in conifer longer, but at very low rates (< 1 mm d^{-1}).

Summary of Results

- Primary differences appear to be:
  - Snow water accumulation
  - Soil moisture accumulation dynamics
- Aspen higher on both counts
- Does this result in greater runoff potential?

Potential for Runoff, Groundwater Recharge





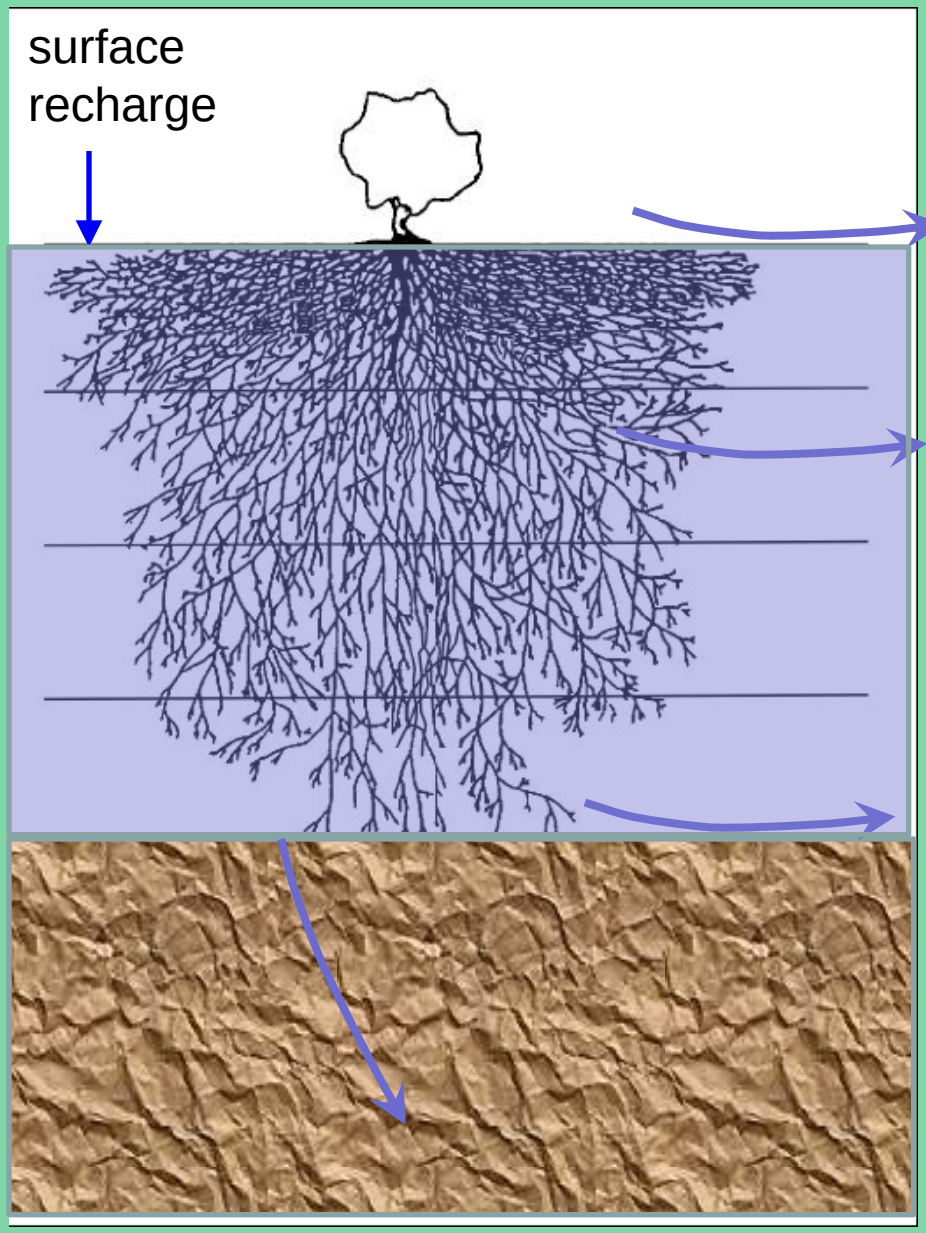
Result: aspen has higher potential for runoff and recharge

- Snow water
- Soil water
- Sublimation loss
- Runoff, GW
- Transpiration (too small to show)

Conclusion – Higher water yield with aspen ?

- Yes, but water can go to surface water, groundwater or move downslope in soils.
  - Accessibility to user depends on fate

Fate of snow melt



Surface runoff

Lateral flow

Groundwater recharge

Conclusion – Higher water yield with aspen ?

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  - Accessibility to user depends on fate

- Where does snow go in conifers?
  - Sublimation of intercepted snow, enhanced by “black body” of dark conifer trees.
  - Wind transports snow intercepted by branches to other areas.
  - Evidence exists for both mechanisms.

The Bigger Picture: Water Yield across Systems

- Two mechanisms for increased water yield with vegetation manipulation.

1. Interception of precipitation (often snow)
2. Lateral flow of soil water

The Bigger Picture: Water Yield across Systems

1. Dense woody vegetation intercepts snow
   - Result is less snow reaching ground
   - Conifers yields less than aspen or meadow
   - Thinned conifer systems yield more than dense stands (20% or more cover removed)

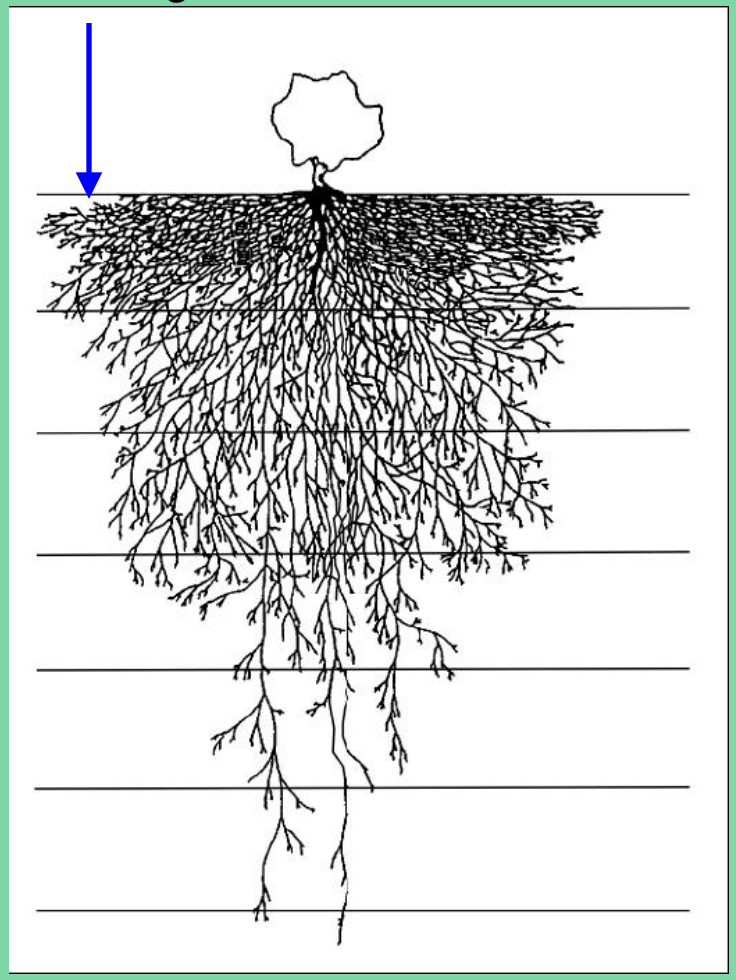
     (Stednick 1996)
   - Other types less successful: sagebrush, juniper. Excess water only recharges soil
   - Requires full soil recharge each year

The Bigger Picture: Water Yield across Systems

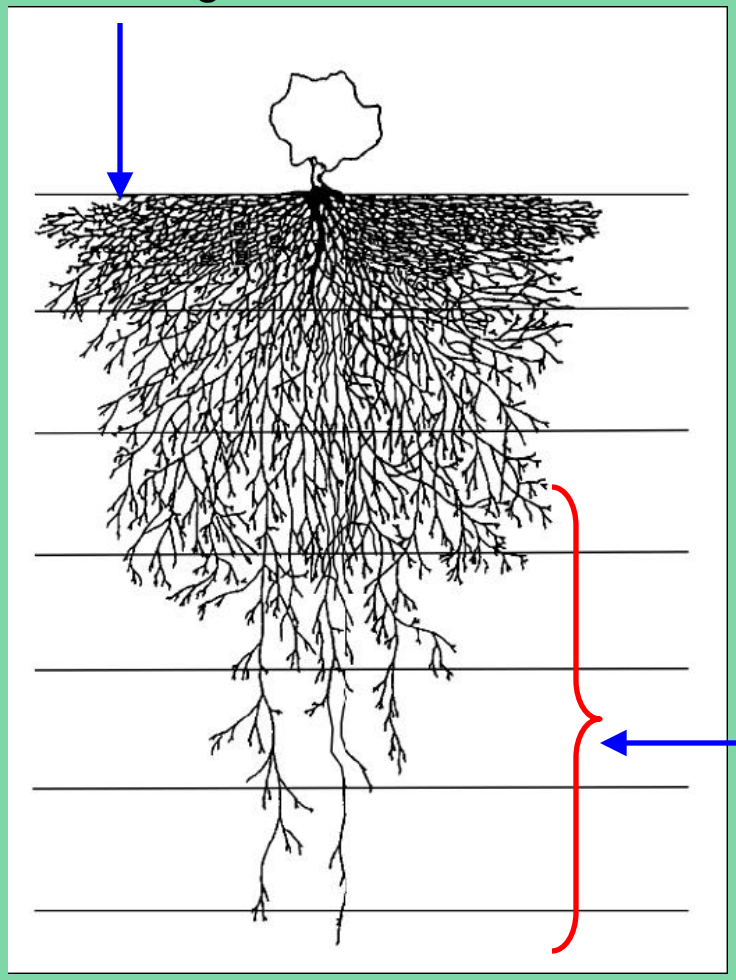
2. Laterally moving water is intercepted

Surface recharge vs. Lateral flow

surface
recharge



surface
recharge



sub-
surface
recharge

The Bigger Picture: Water Yield across Systems

2. Laterally moving water is intercepted
   - Deep water comes from off site
     - Shallow water comes from rain/snow on site
     - Deeper water comes from lateral flow
   - Typical of riparian systems (cottonwoods, willows, saltcedar)
   - Can occur with juniper (perhaps more important than interception)

Concluding remarks

- Vegetation types will affect watershed water yield
- Mechanisms relate to precipitation interception and lateral flow of water in soil
- An ecohydrological assessment is needed to assess if vegetation manipulation will affect watershed water yield, and where such gains may occur (surface, groundwater)

Acknowledgements

http://www.western-aspen-alliance.org/

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