# Soil Moisture Sequestration in Drylands:

Ecosystem Engineering in Pinyon Juniper Woodland via Soil Water Repellency

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Utah State University

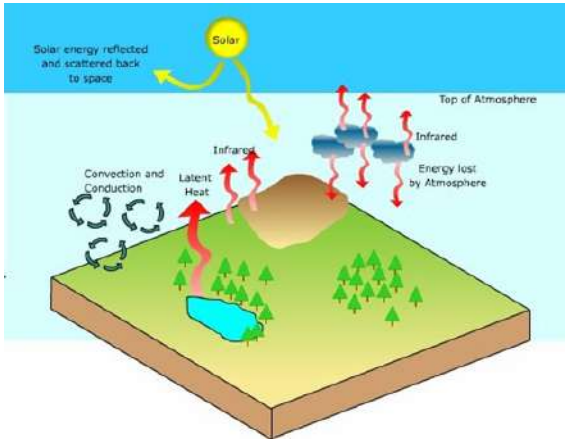
# Soil moisture in relation to processes at the land surface

**VEGETATION**

Provides transpirable pool of water controls the structure, function and diversity in water controlled ecosystems

**ENERGY BALANCE**

The land surface controls the partitioning of available energy at the surface between sensible and latent heat (soil moisture alters the albedo)




**HYDROLOGY**

Controls partitioning of water between infiltration and runoff

Soil moisture/transpiration, provides the water for convectional rainfall

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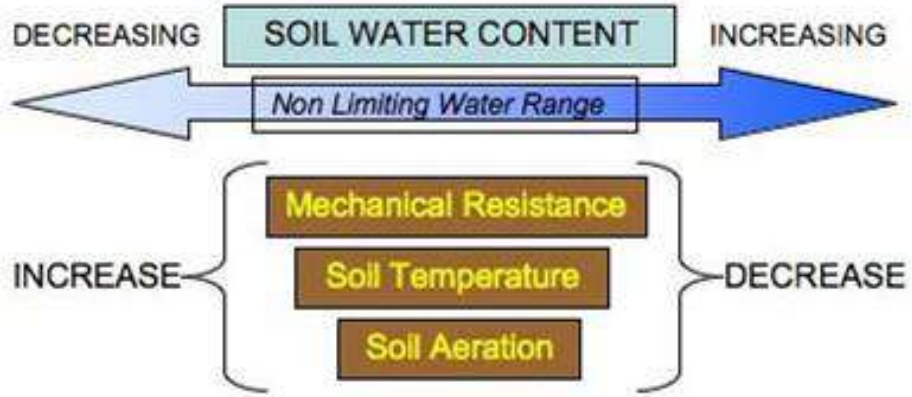
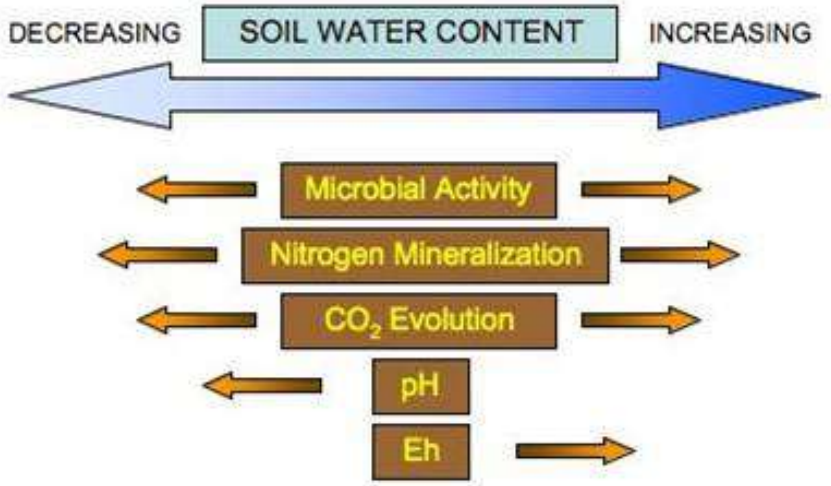
# Soil Moisture Control over Plant Growth and Soil Processes

## Physical




## Biogeochemical

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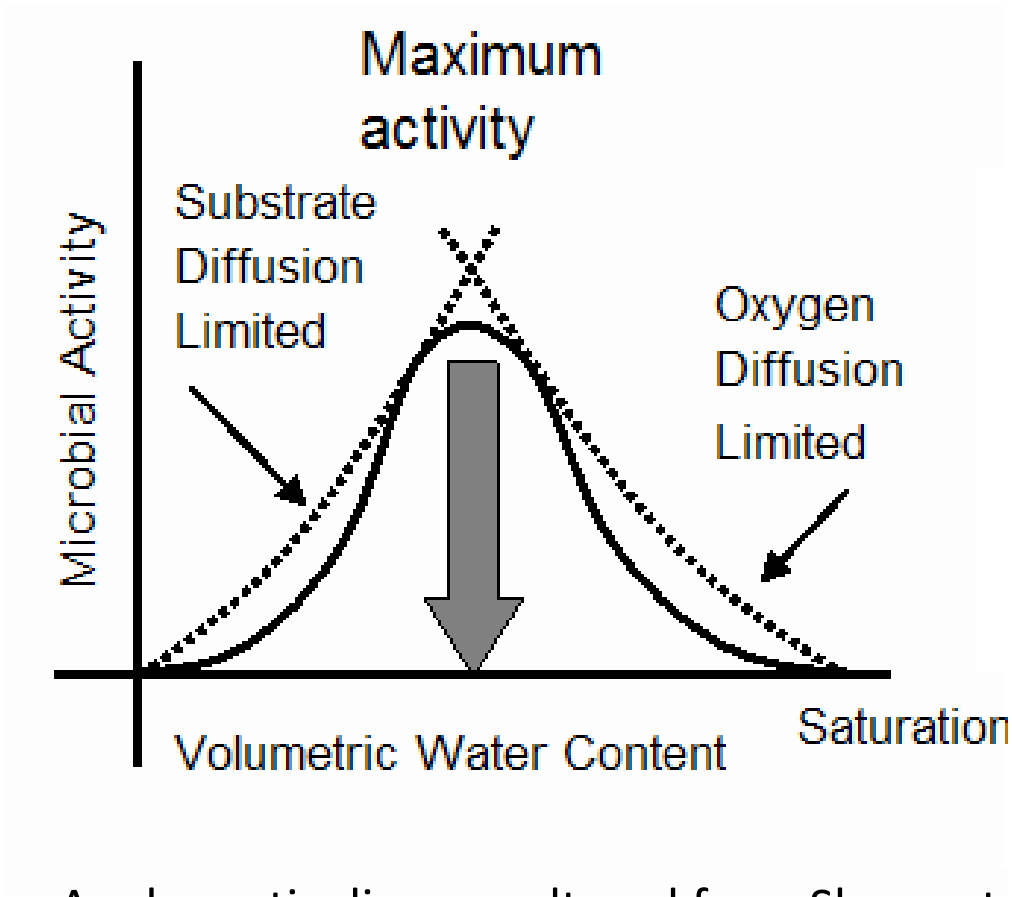
# Soil Moisture Control over Microbial Activity




A schematic diagram altered from Skoop et al. (1990) indicating conceptually how microbial activity is affected by soil water content.

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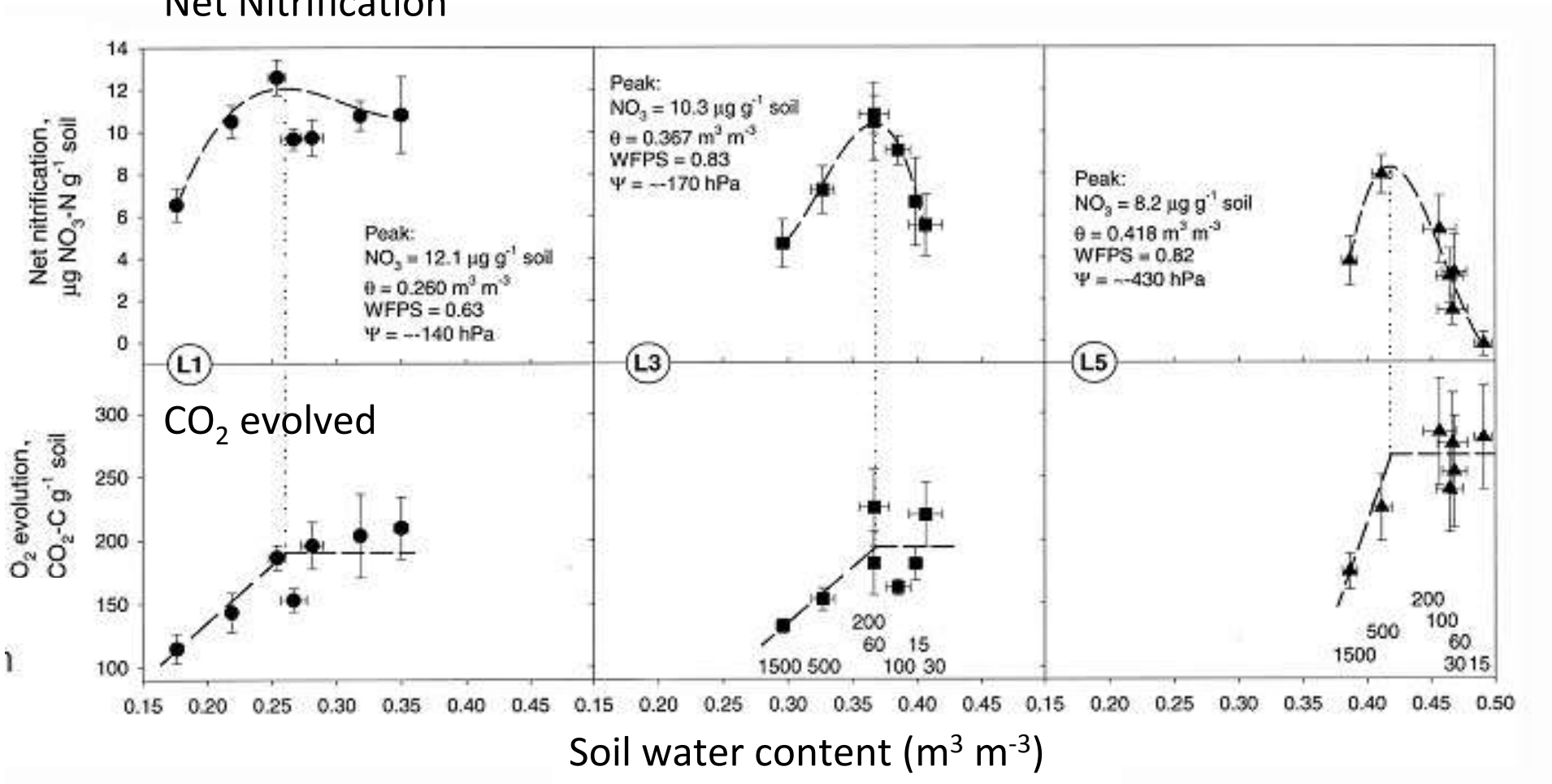
# Soil Moisture Control over Nitrification and $CO_2$ evolution

Net Nitrification




Sand (L1), Sandy loam (L2) Clay (L3)

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Schjonning et al., 2003, Soil Sci. Soc. Am. J. 67:156–165

# Two Overarching Research Themes

1. Soil moisture is a major control over the structure, function and diversity of dryland ecosystems.

2. In addition to the theories of competition and disturbance, plants must be viewed as ecosystem engineers, modifiers of the soil environment.

# What do you see?

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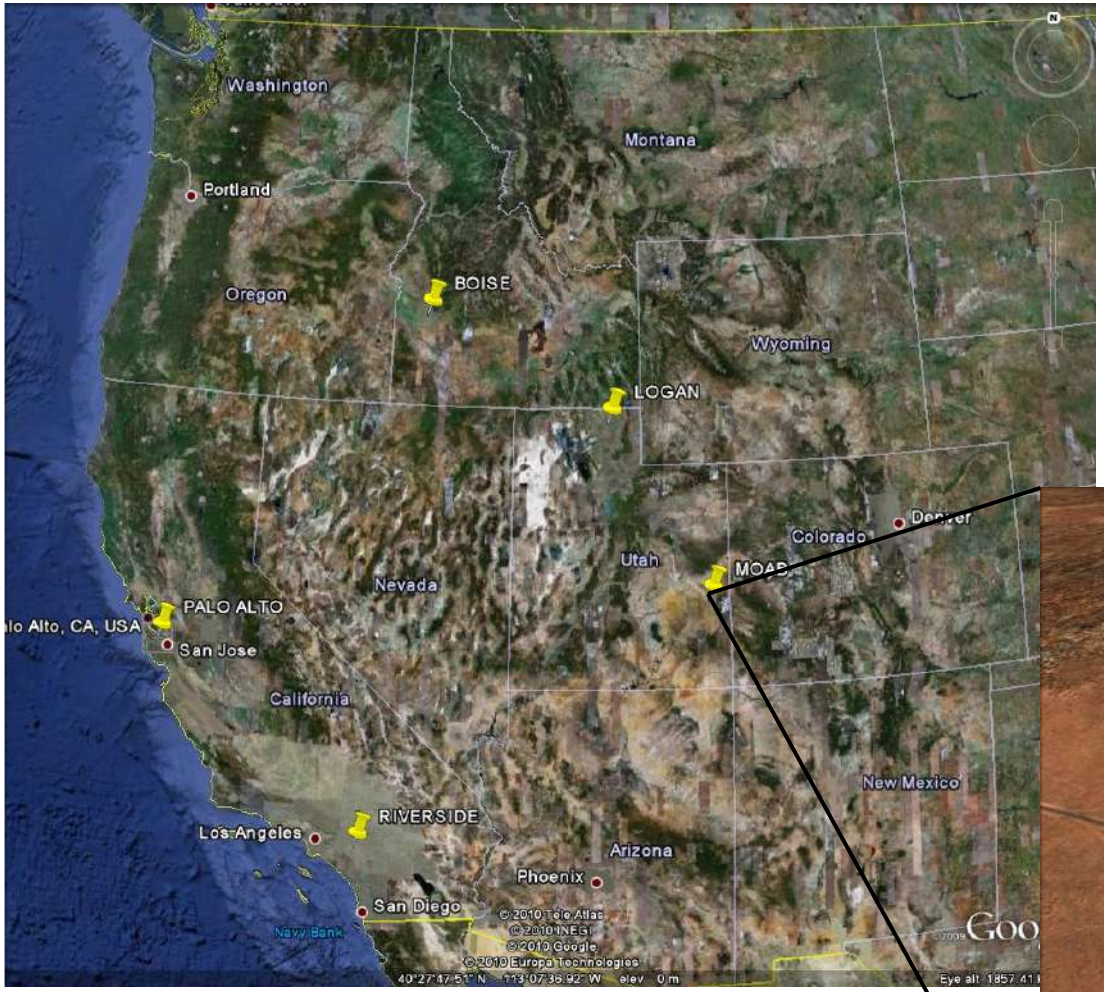
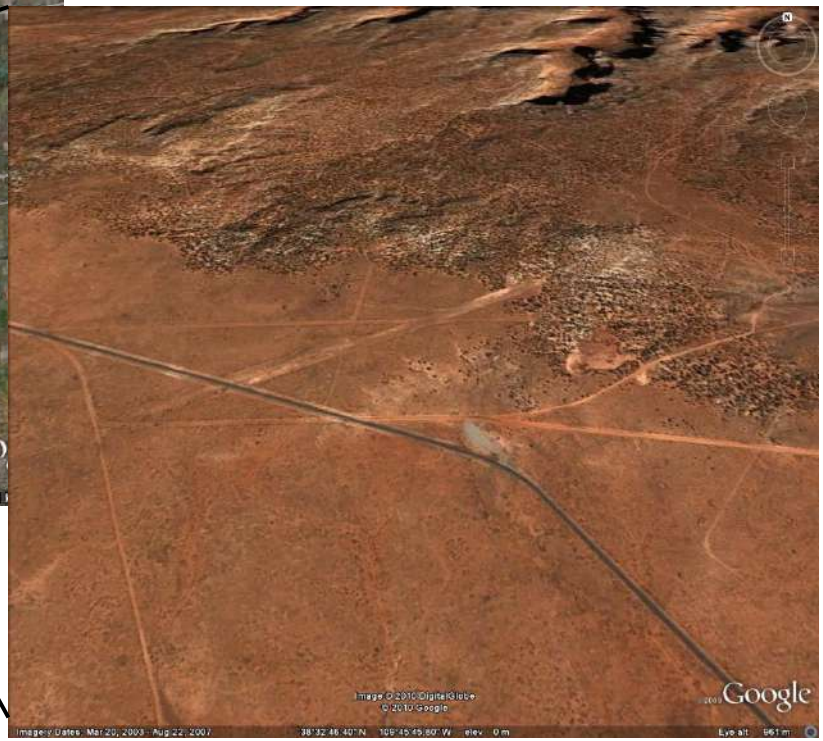
# THE WESTERN USA




March of the Pinyon Juniper Woodland

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# ARCHES

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# RANGELAND INVASION BY PINYON JUNIPER WOODLAND

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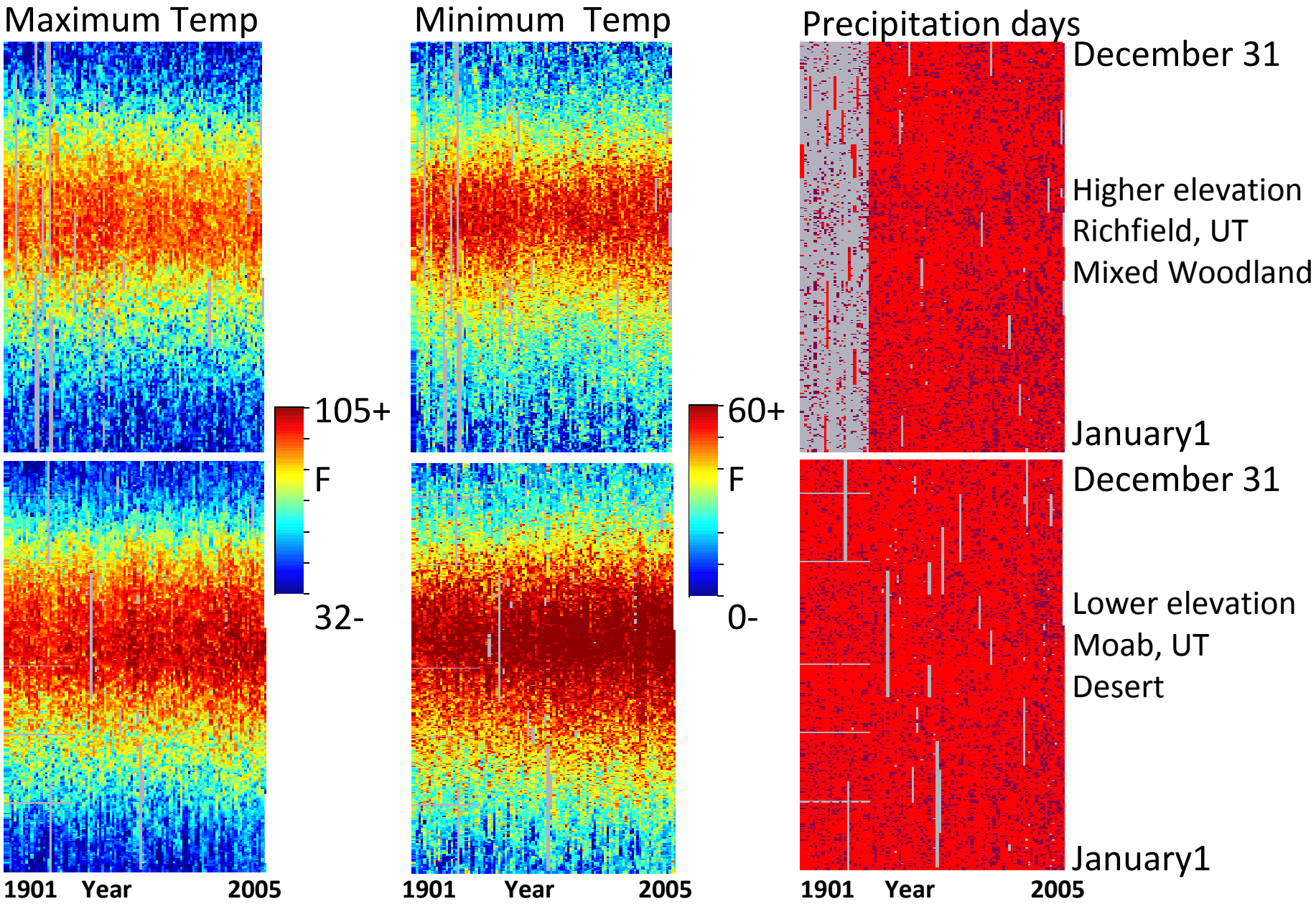
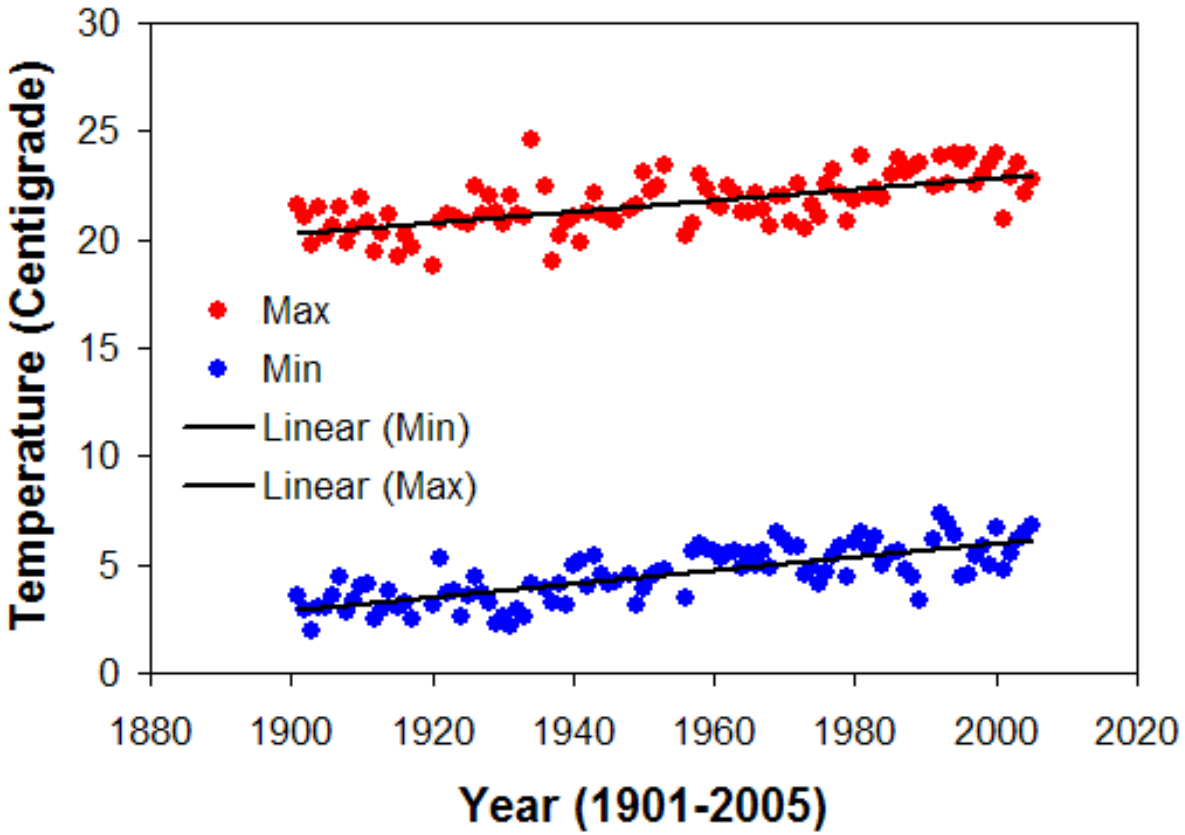
# THE WEST IS CHANGING!



# ANNUAL AVERAGE MAX AND MIN TEMPERATURE FOR MOAB UT




| Lin Max Temp C | |
|---|---|
| 1901 | 20.3 |
| 2001 | 22.9 |
| Difference | 2.6 |

| Lin Min Temp C | |
|---|---|
| 1901 | 2.9 |
| 2001 | 6.0 |
| Difference | 3.1 |

Data from Utah Climate Center

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# PINYON - JUNIPER WOODLANDS

## ARE WE SETTING US RANGELAND ECOSYSTEMS UP FOR FAILURE?

*These photos show the massive die-off of pinyon pines that occurred during the recent drought. Pinyons, normally evergreen, have reddish-brown foliage in October 2002 (left). By May 2004, the dead pinyons have lost all their needles, exposing gray trunks. The photos were taken from the same vantage point in the Jemez Mountains near Los Alamos, N.M. (Photo credit: Craig D. Allen, U.S. Geological Survey)*

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Driving questions:

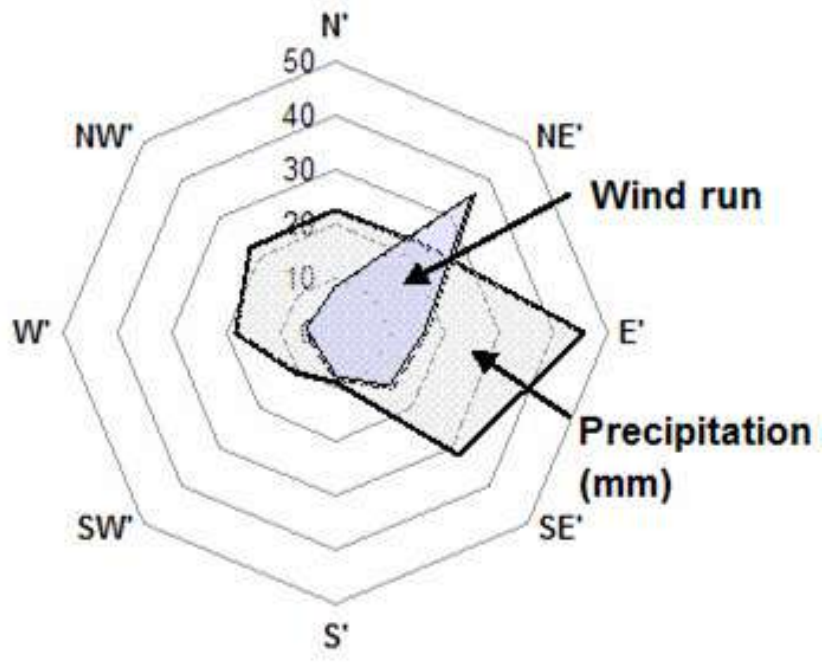
How are vegetation shifts likely to affect the western landscape?

How do these species compete for resources, especially soil moisture, how does this impact runoff and recharge?

Do plants modify / engineer their environment to give themselves a competitive advantage?

mortality for 2000-2003 >12,000 $km^2$

# DIRECTIONAL RAINFALL




Storms come from the west, moving to the east.

Majority of the precipitation occurs when the wind is blowing to the east

Precipitation:

85% of events are less than 5.0mm
50% of events are less than 1.7mm

Monsoonal summer rain and winter snow, resulting in spring moisture pulses are important precipitation events, contributing as much as 20-40mm

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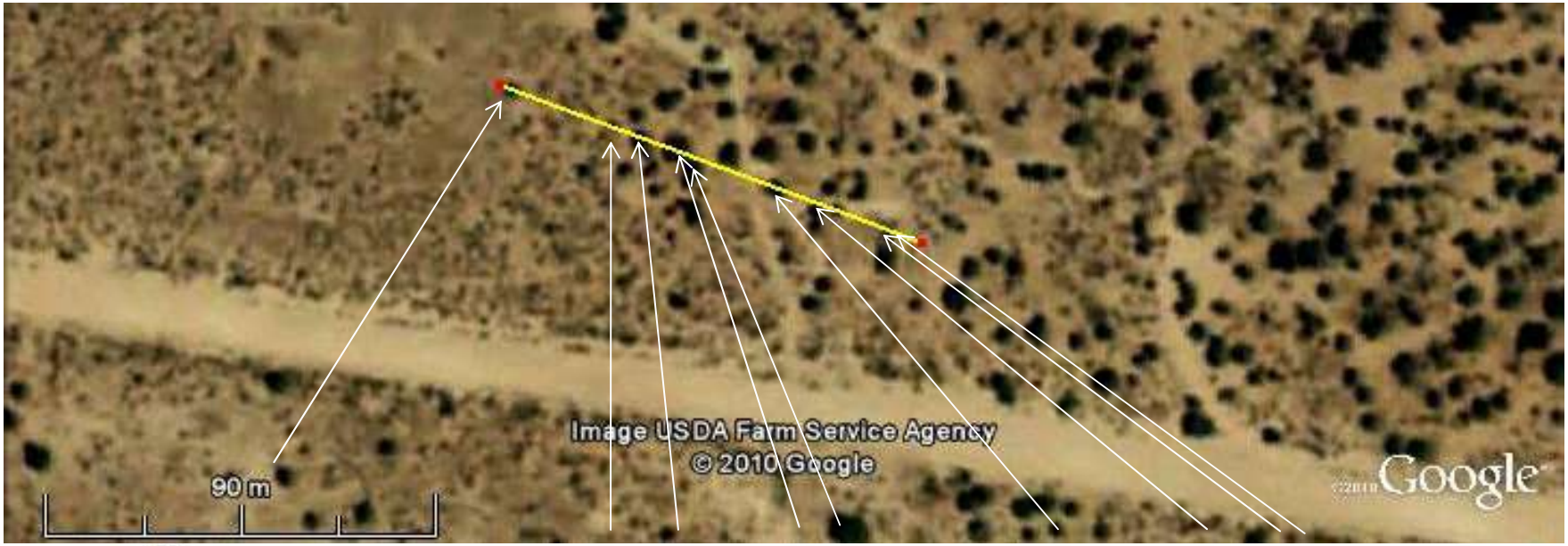
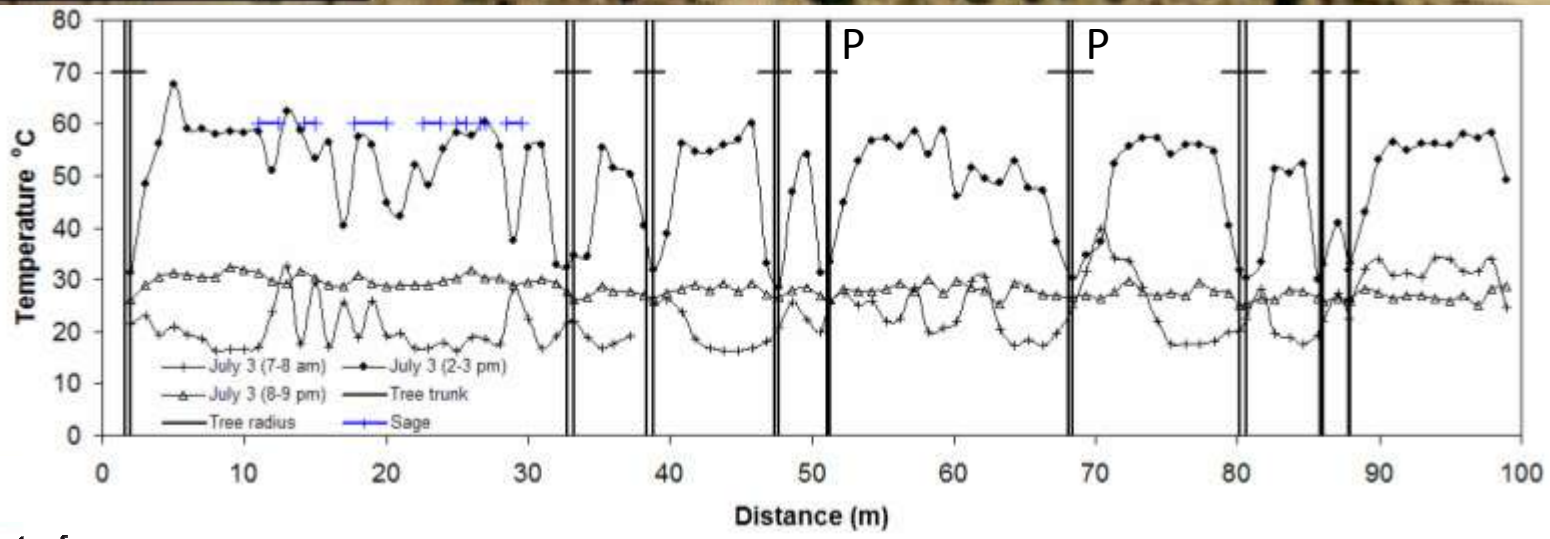
# MOAB 100M TRANSECT

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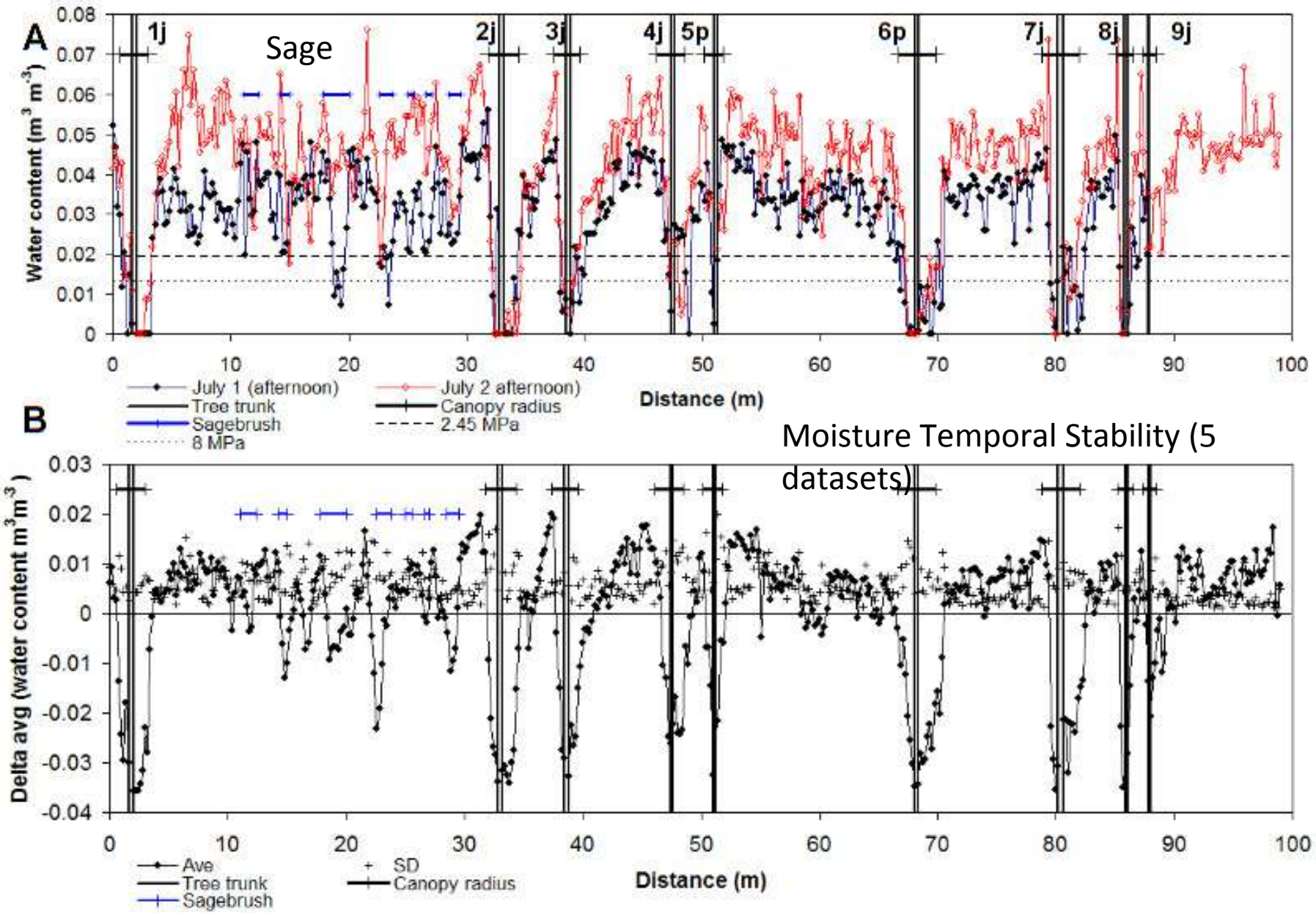
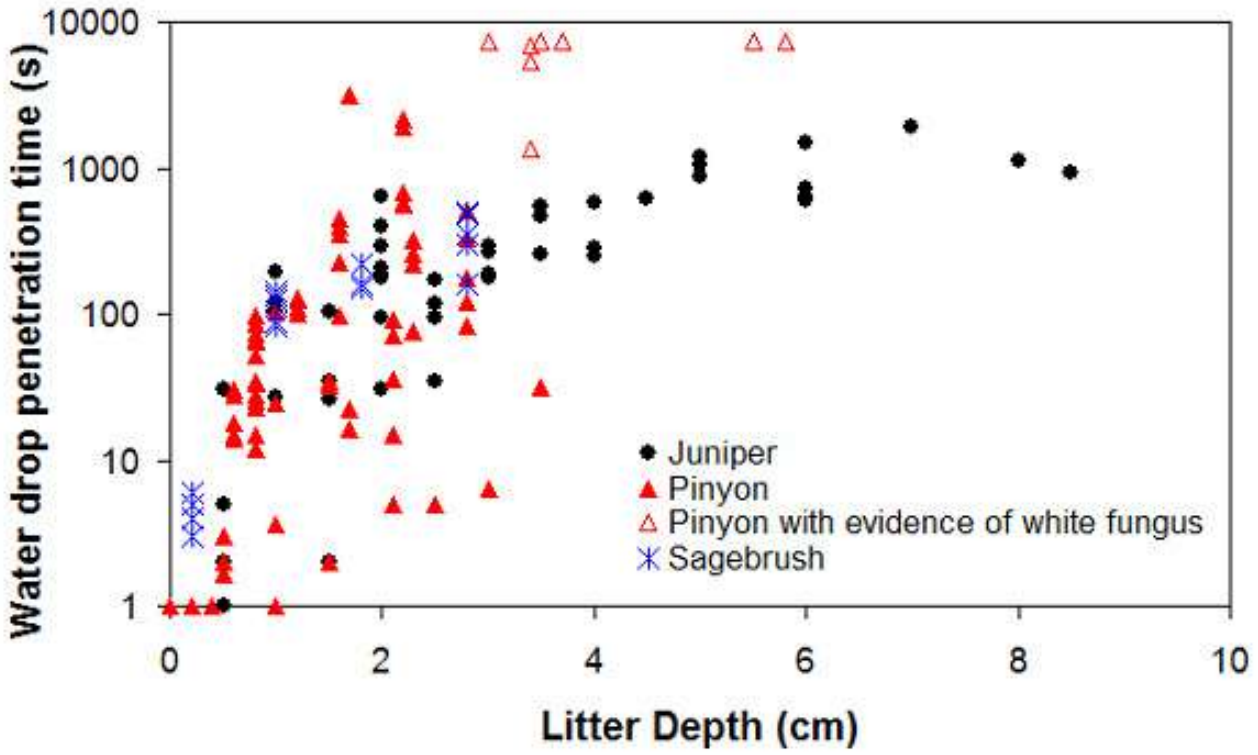
# 100 M SURFACE SOIL MOISTURE TRANSECT




Moisture Temporal Stability (5 datasets)

# SOIL WATER REPELLENCY



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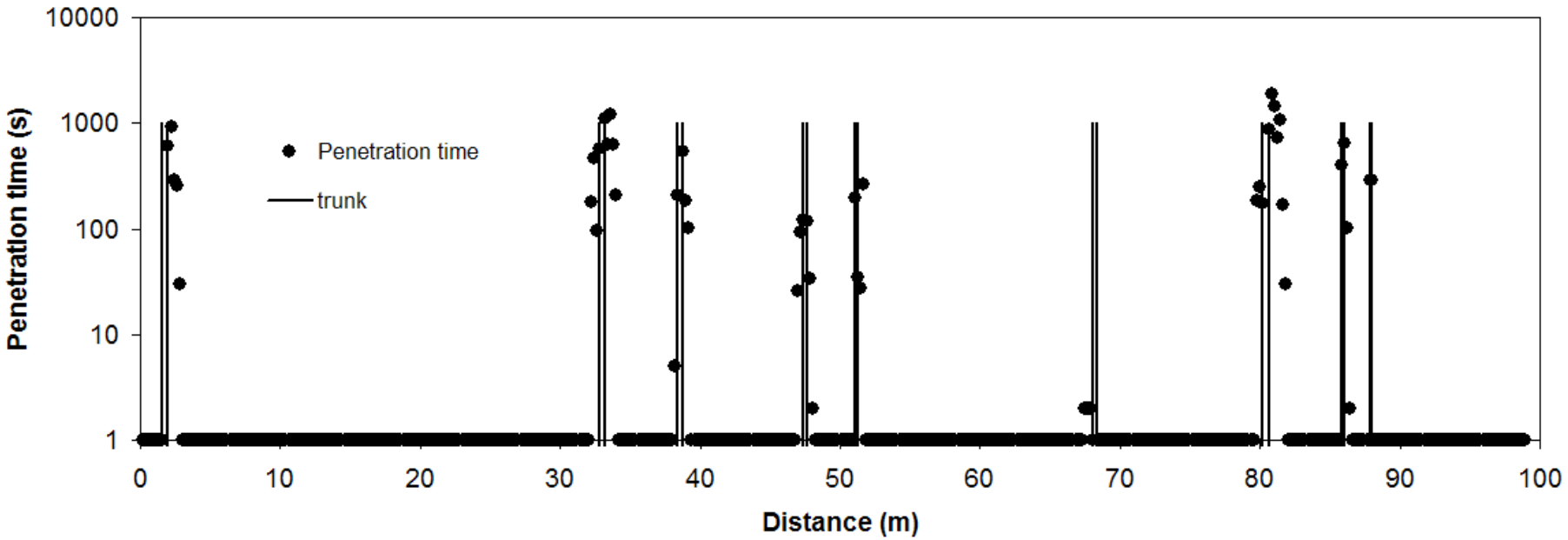
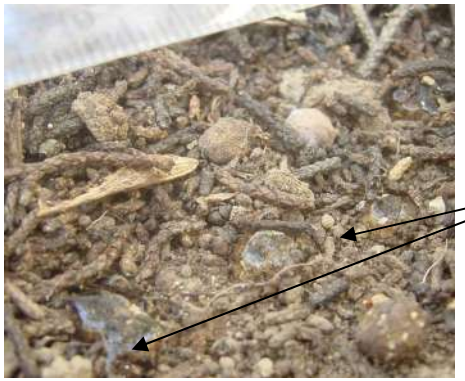
# TRANSECT SOIL WATER REPELLENCY



Water Drops

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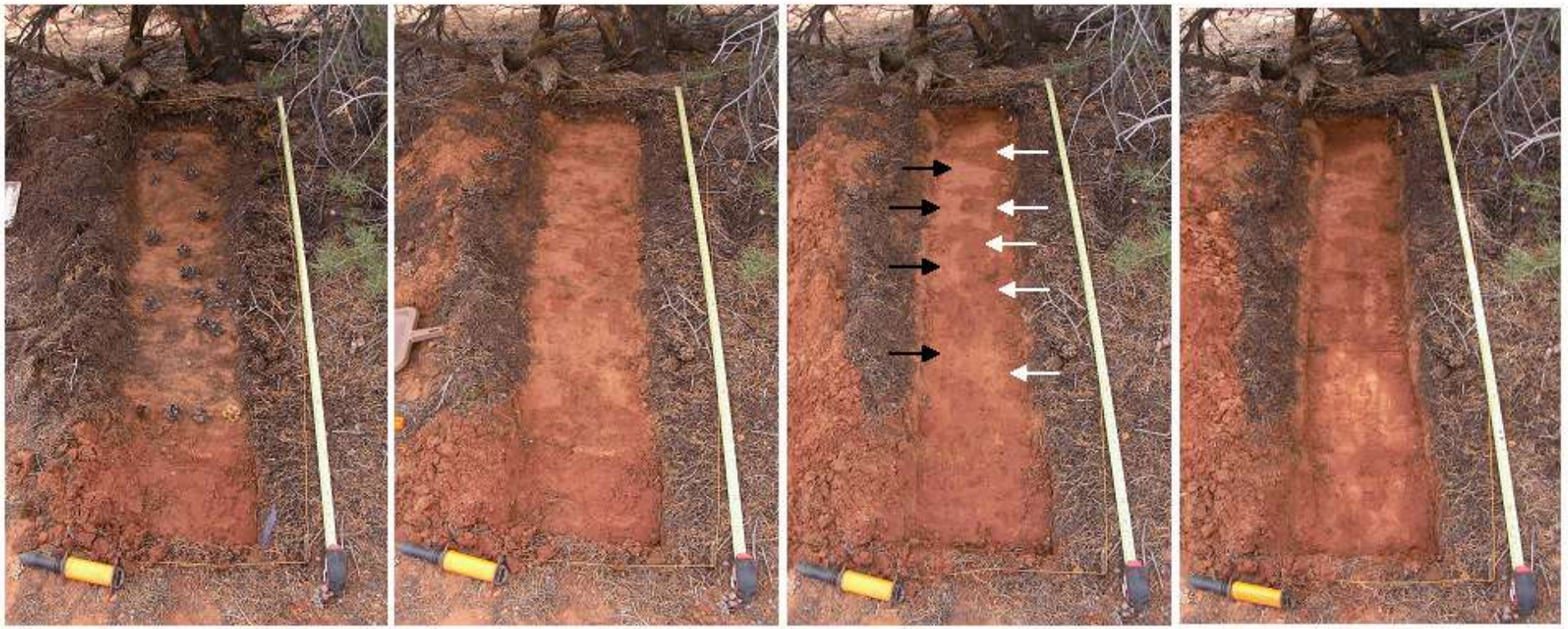
# SOIL MOISTURE WETTING PATTERNS

10mm in 20 minutes, 30mm / hr intensity



Litter removed | 4 cm of soil removed | 6 cm of soil removed | 10 cm of soil removed


Bypass flow under Juniper

Piston flow under bare soil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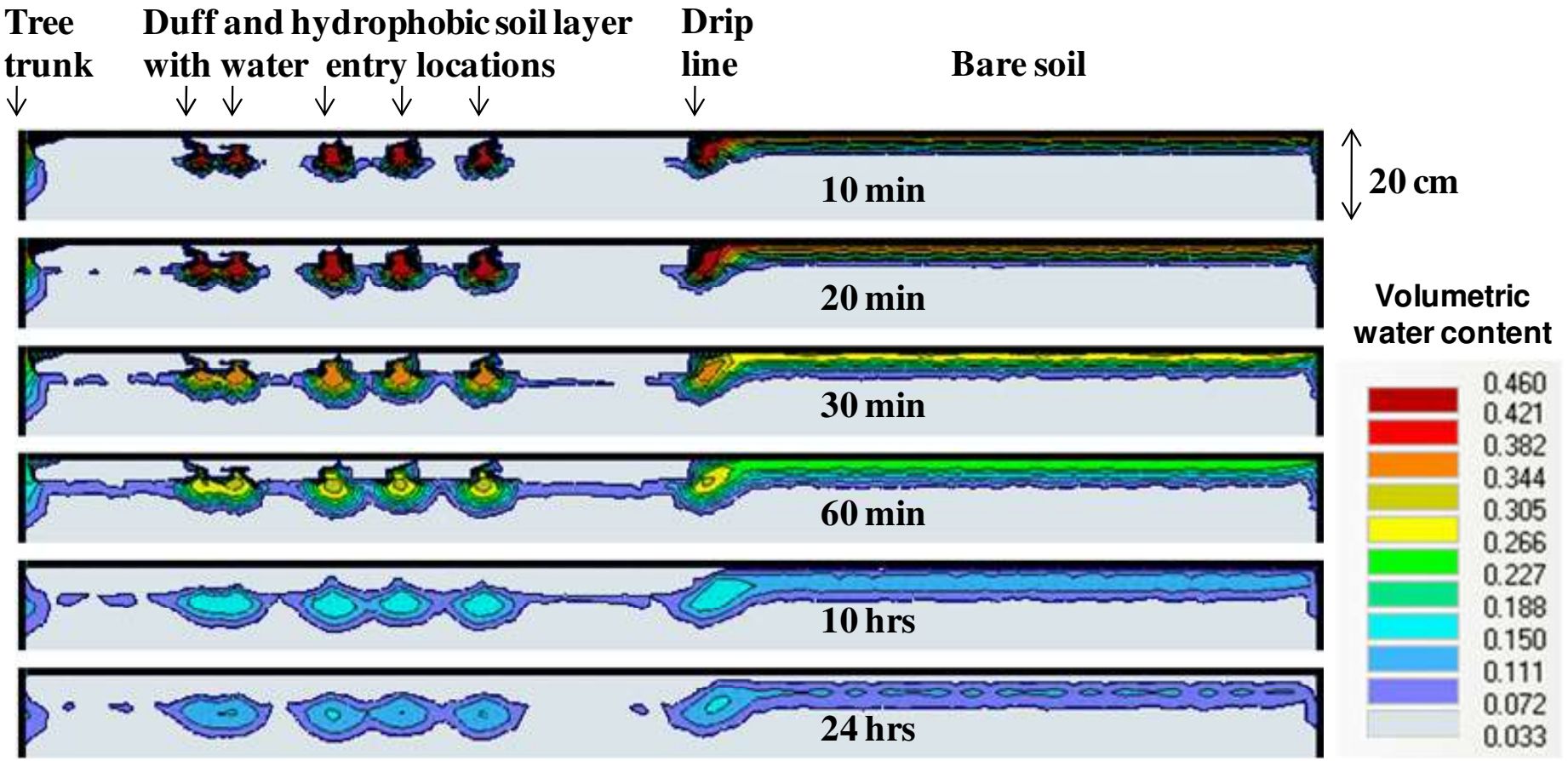
# MODELING THE WETTING PATTERNS (HYDRUS 2D)

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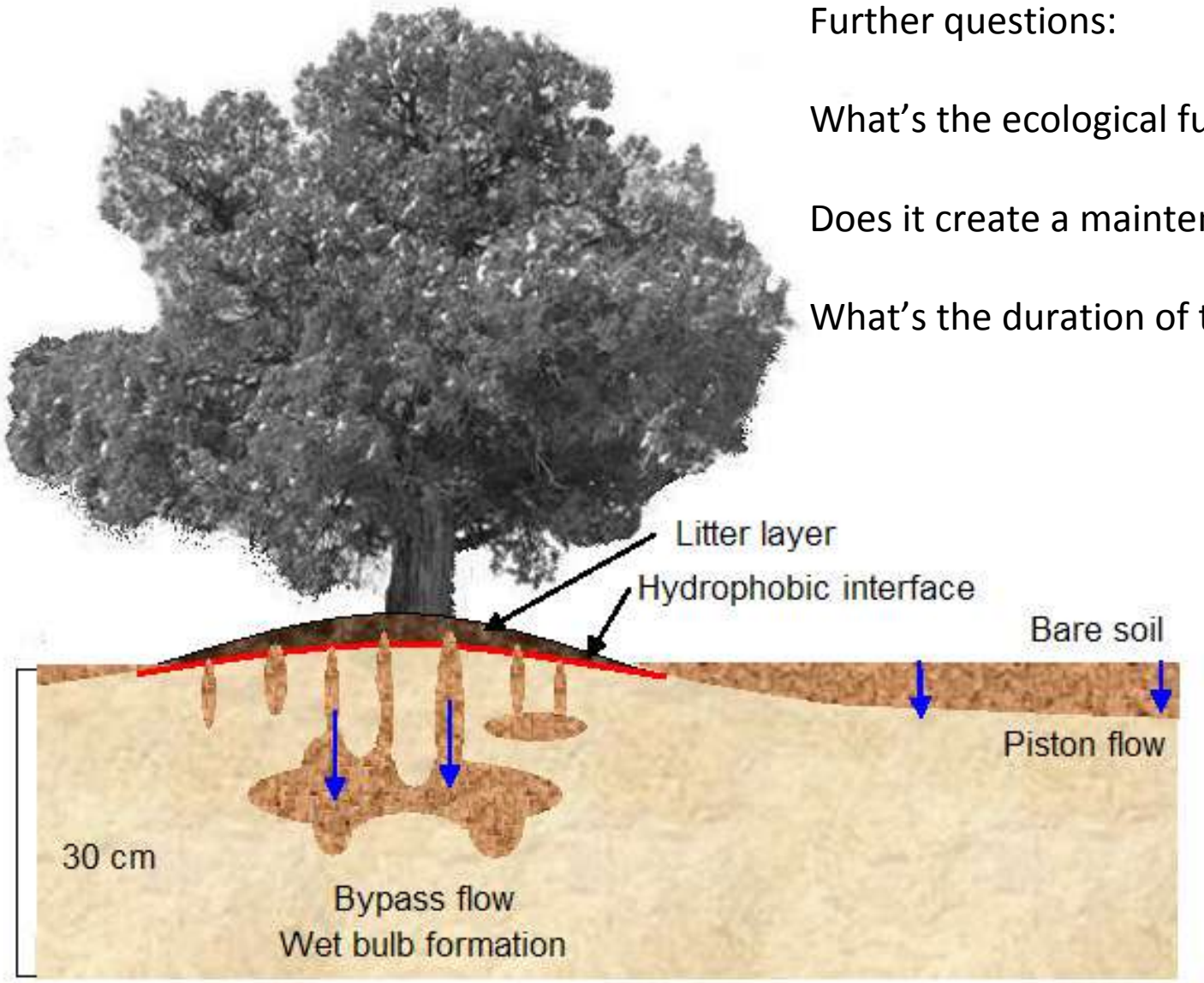
# CONCEPTUAL SOIL MOISTURE SEQUESTRATION




Further questions:

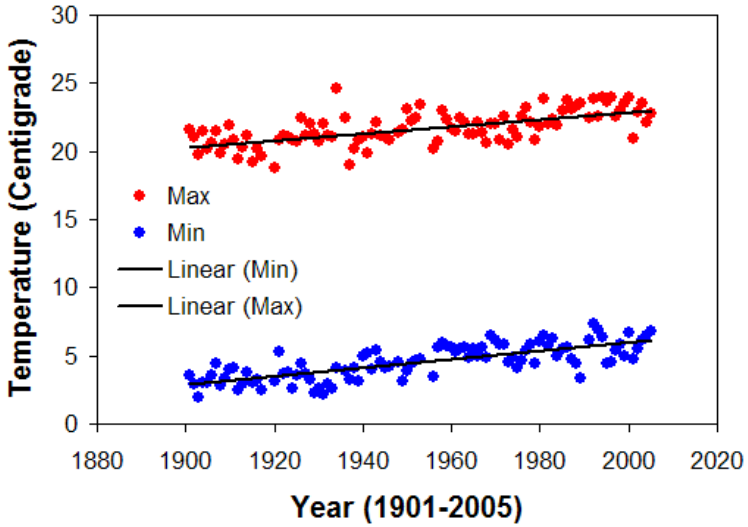
What's the ecological function of the water?

Does it create a maintenance pool for the plant?

What's the duration of this moisture pool?

# Future work

- Woody invasion has been blamed for a reduction in recharge across the Western US
- Our current challenge is to determine from historical data if this is likely.



# Hydrus, 1D 2D & 3D

The program numerically solves the Richards' equation for saturated-unsaturated water flow and Fickian-based advection dispersion equations for heat and solute transport.

The **Flow equation** incorporates a sink term to account for water **uptake by plant roots**.

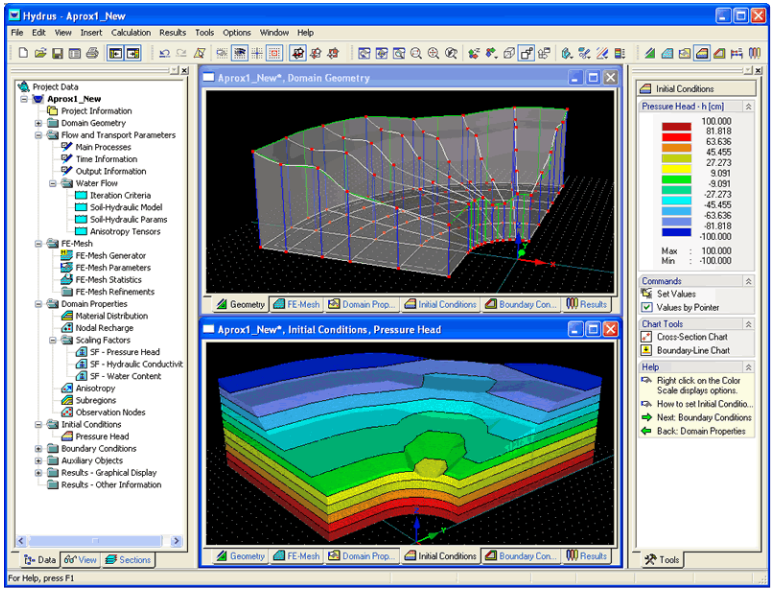
The **Heat transport** equation considers conduction as well as convection with flowing water.

The **Solute transport** equations consider advective-dispersive transport in the liquid phase, and diffusion in the gaseous phase.

Now coupled with **PHREEQC** model for equilibrium geochemistry

**Carbon dioxide** production and transport module

Geochemical **carbonate** chemistry module that considers transport, precipitation/dissolution, cation exchange, and complexation reactions for major ions.

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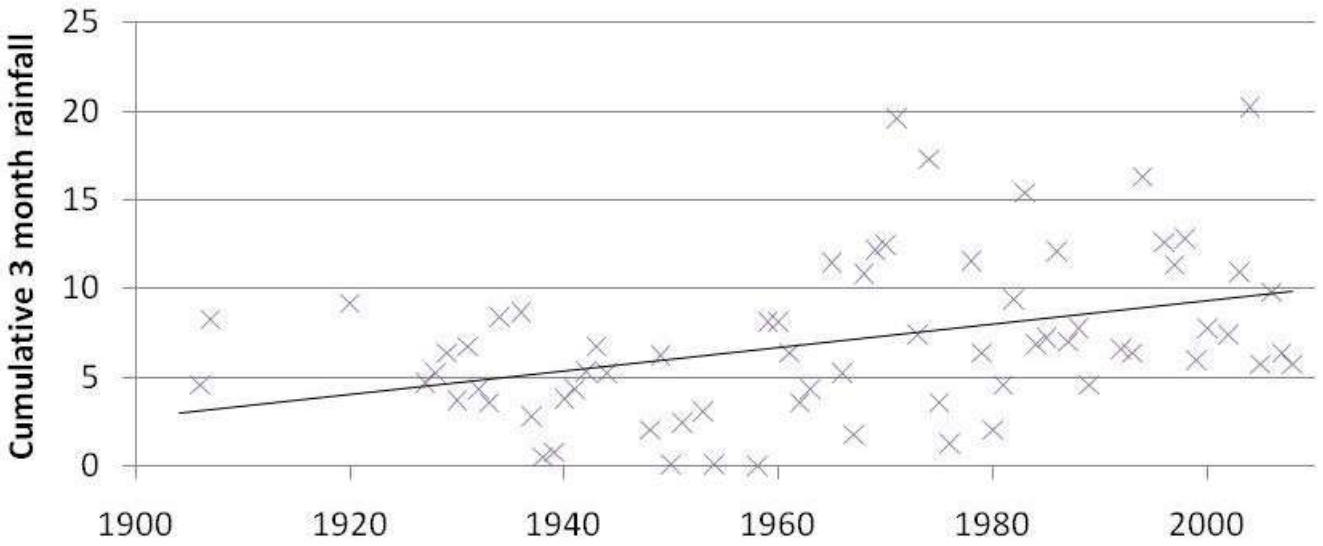
# More small events that don't wet the profile




This is the cumulative rainfall for oct-dec, that occurs in daily totals less than 0.25 cm/day. What we see is an increase in small events that don't wet the profile

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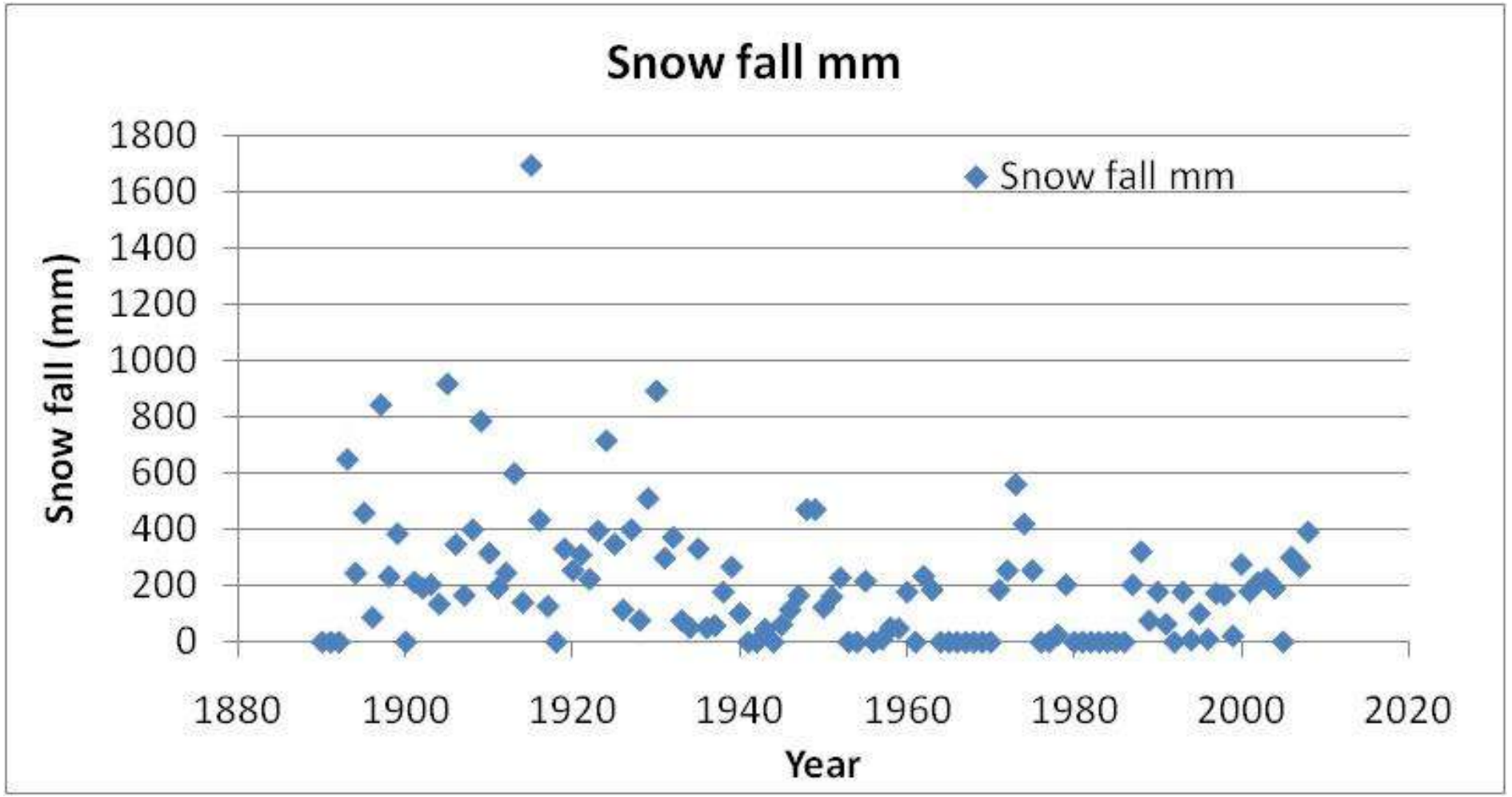
# Reduction in snow fall

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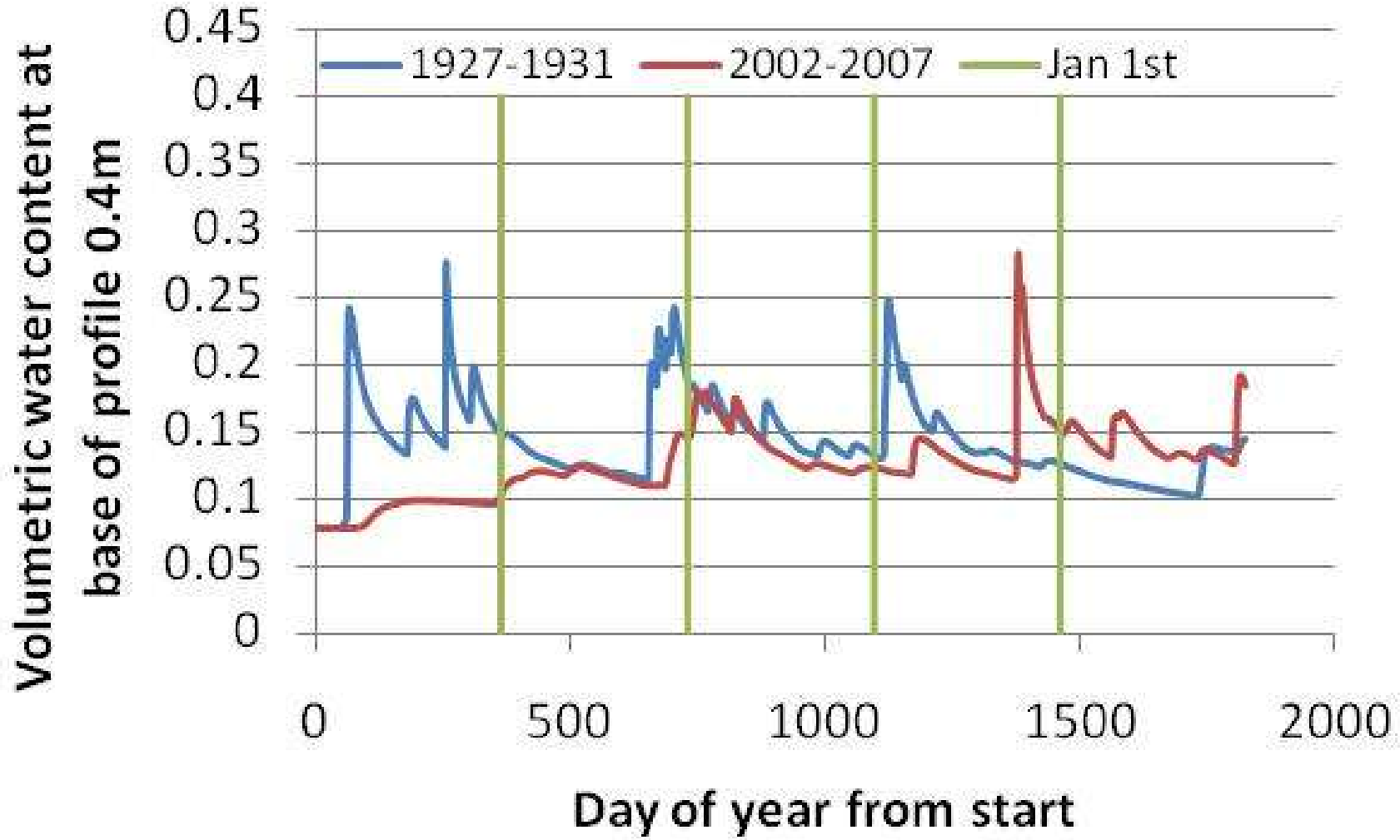
# Modeled soil moisture from historical rainfall & temp




Note the reduced moisture in the winter, due to small events for 2002+

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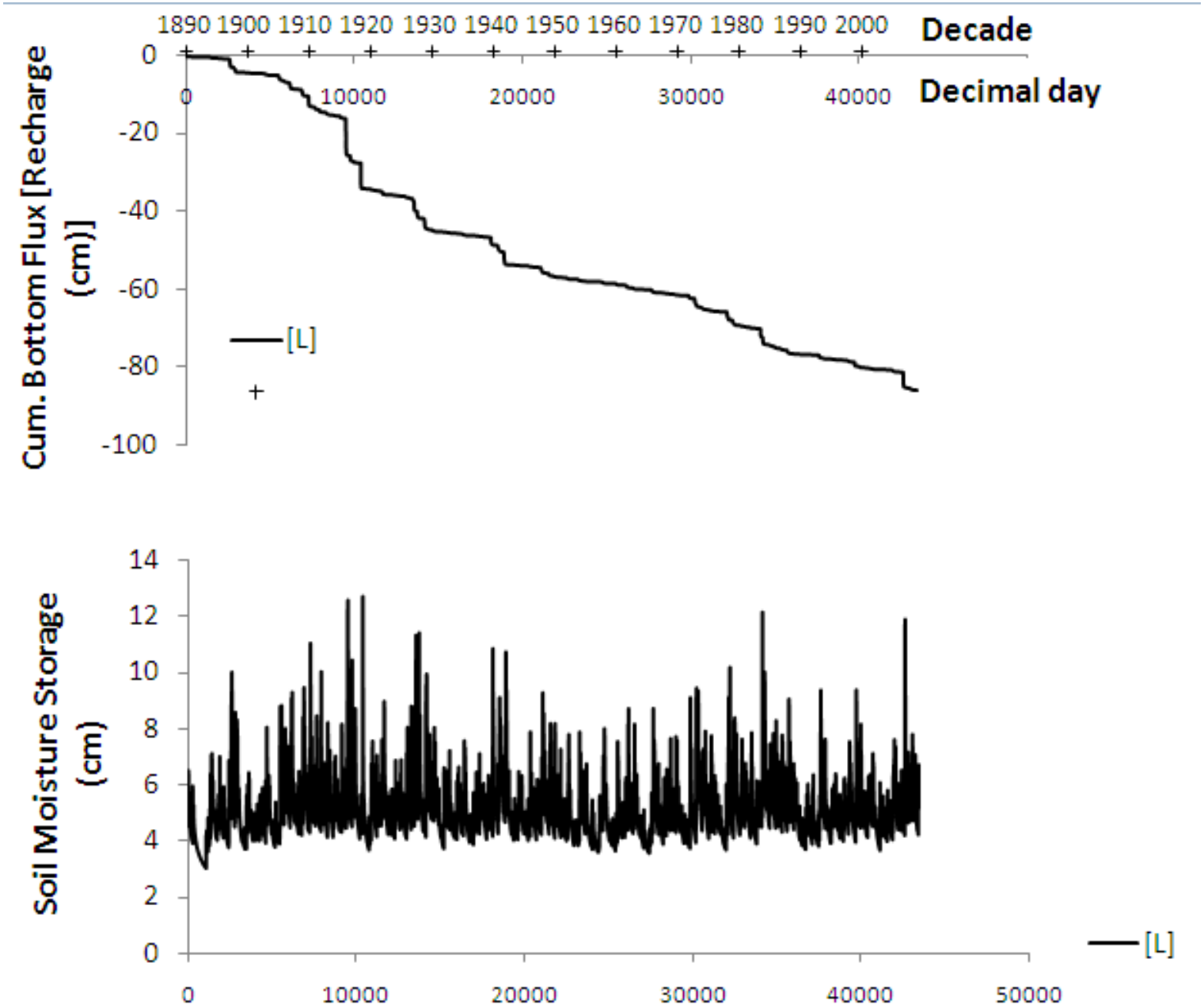
# Modeled recharge from base of soil profile



# Initial thoughts

- Appears from bare soil results that recahrge would have reduced simply due changing climate
- Has the apparent reduction in soil moisture added to warming in this area?

# Conclusions

- Pinyon and Juniper trees modify their soil environment through development of soil water repellency.
- Soil moisture penetration depth, down the soil profile, was 3 times deeper in comparison to piston flow in the intercanopy.
- Do the trees sequester moisture, providing a maintenance soil moisture pool providing a competitive advantage?
- Given the moisture controls on biogeochemical cycling, how does this impact carbon and nitrogen dynamics?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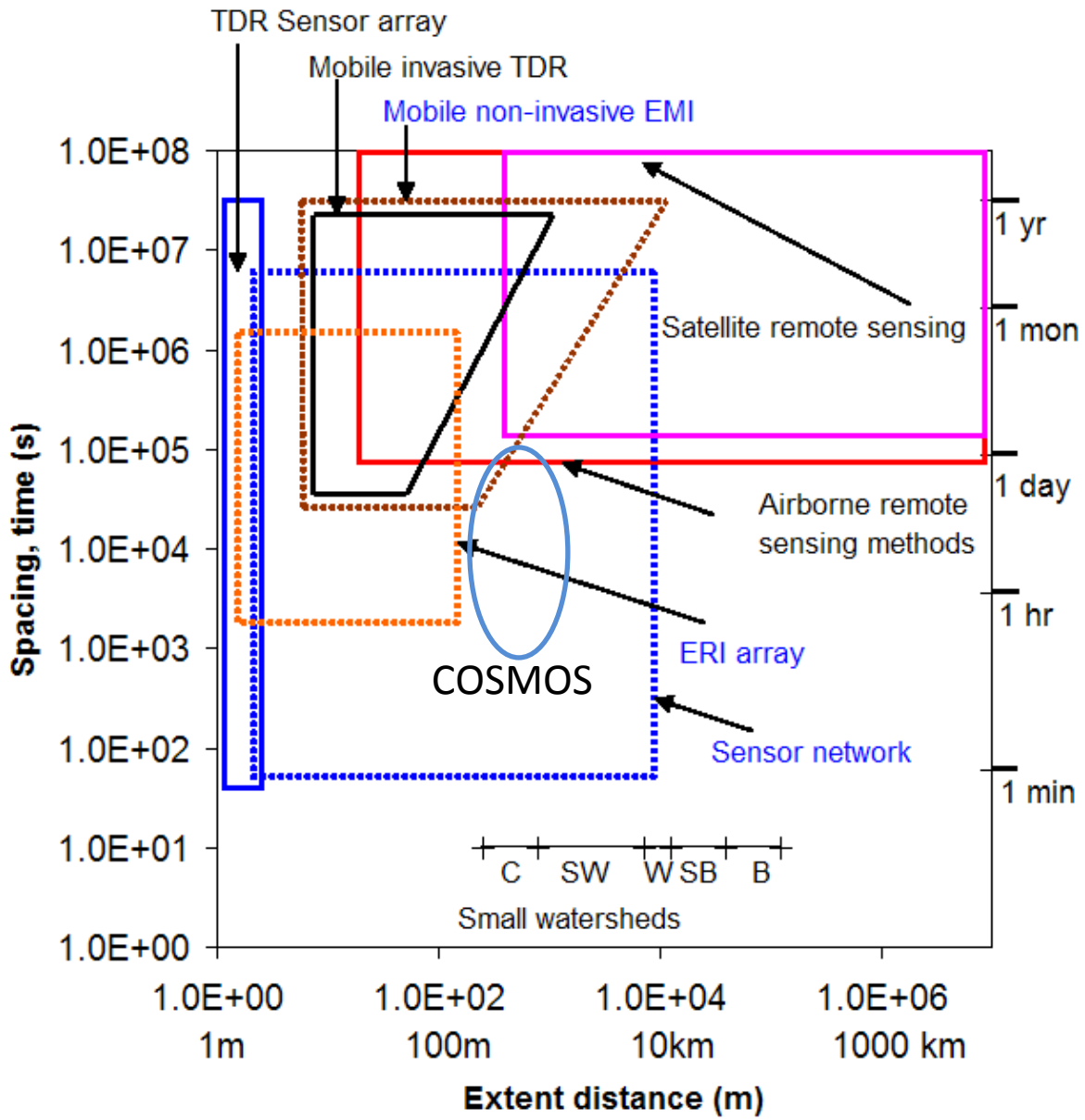
# MEASUREMENT CHALLENGES

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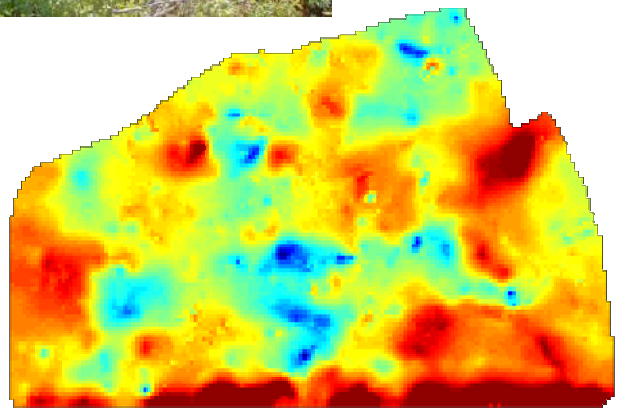
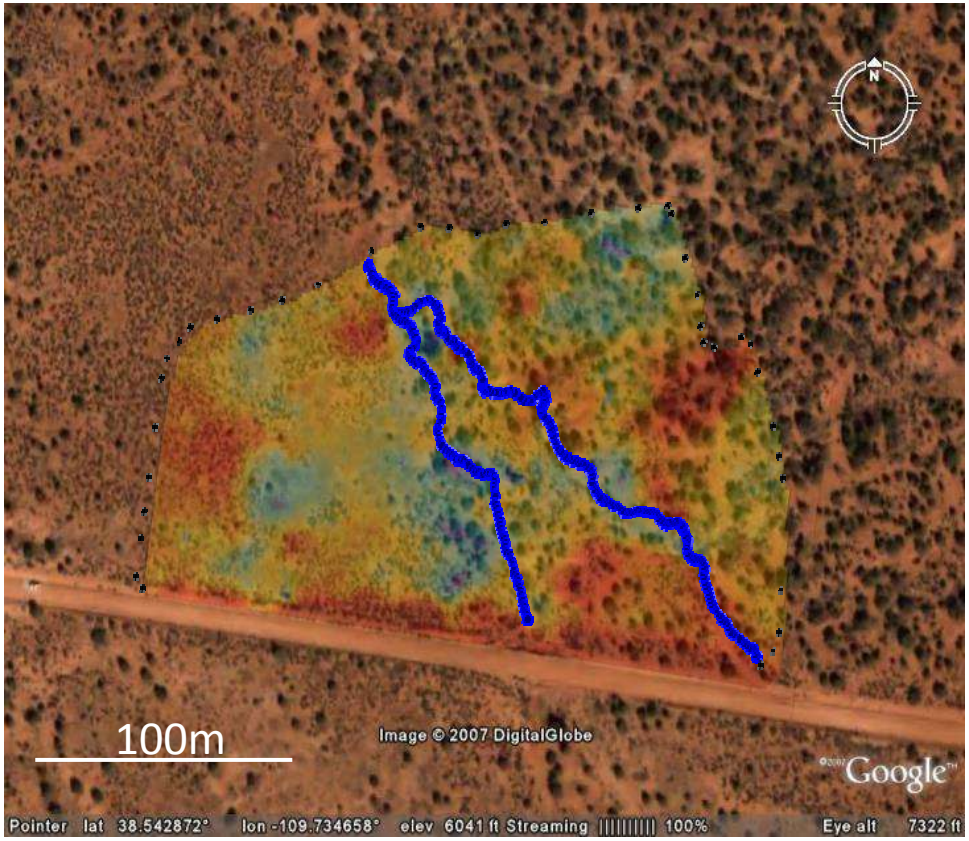
# UPSCALING USING GEOPHYSICAL IMAGING



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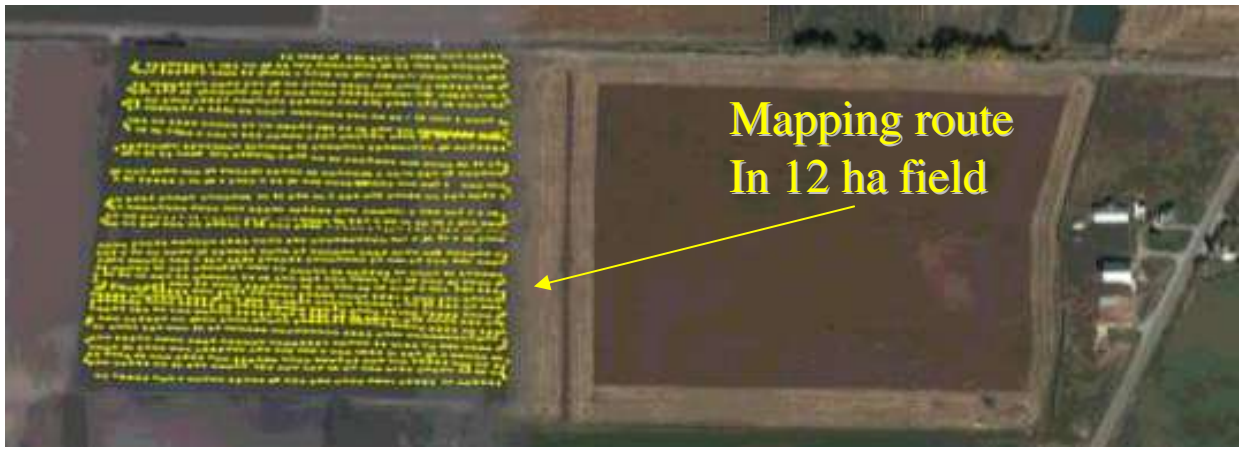
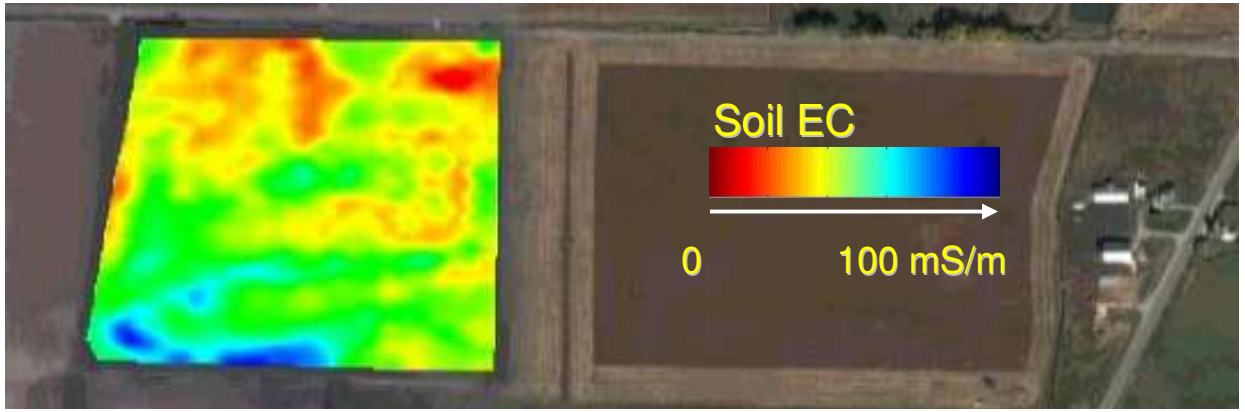
# Electromagnetic Induction Imaging




ECa
Soluble salts
Water content
Clay %

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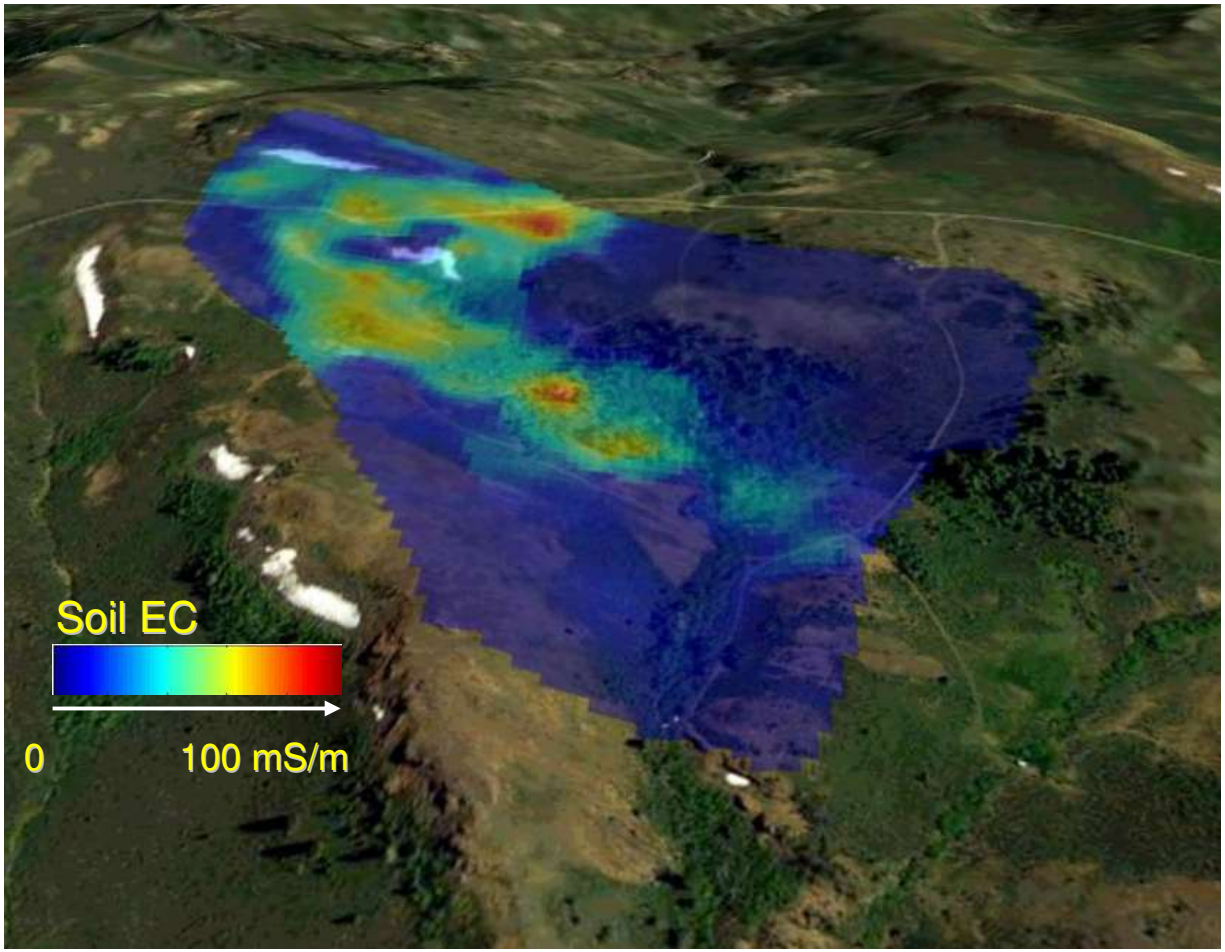
# REYNOLDS CREEK EXPERIMENTAL WATERSHED, USA




How are vegetation patterns related to soil properties? If there are distinct hierarchies, EMI soils information may help in rangeland restoration efforts.

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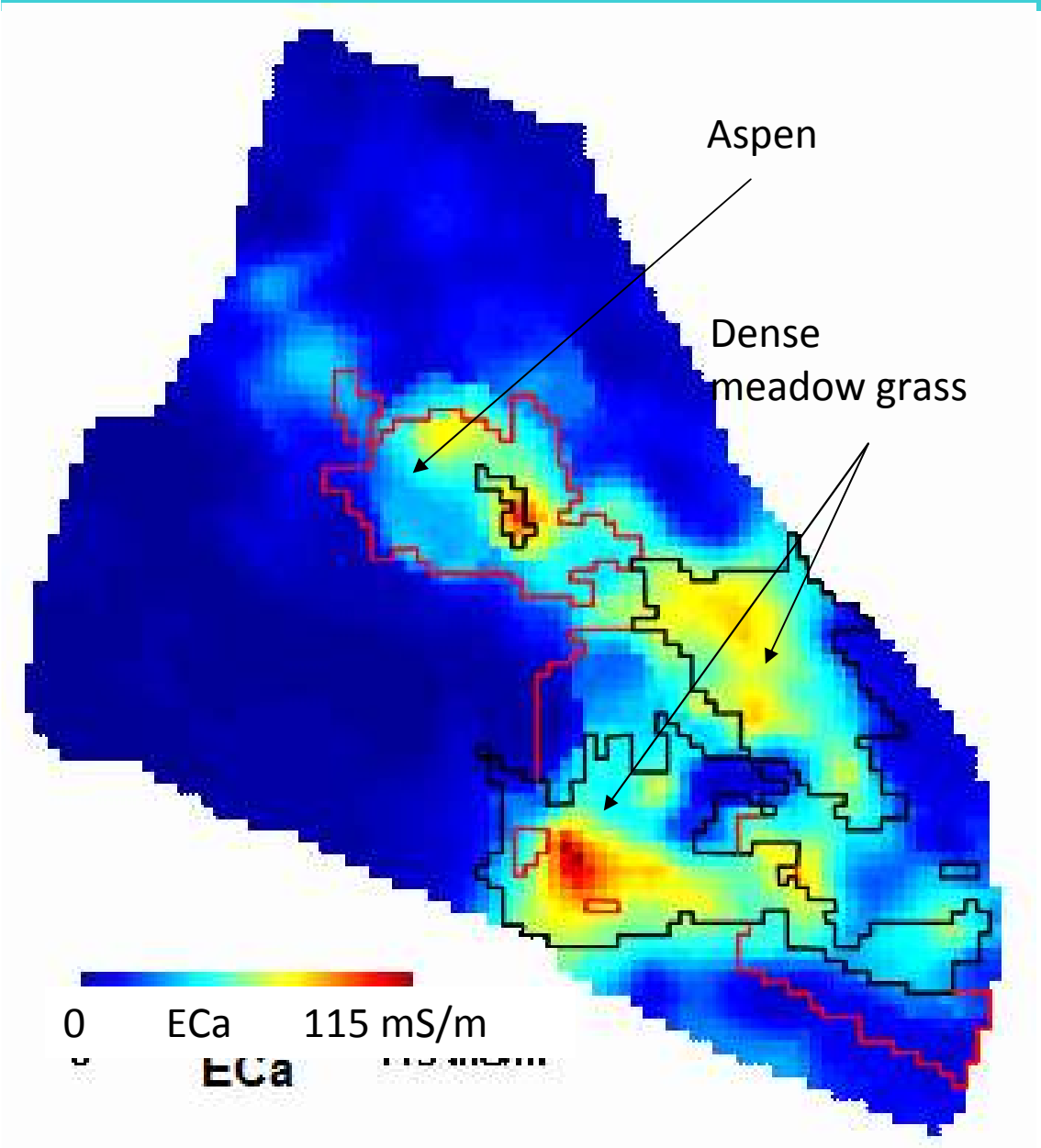
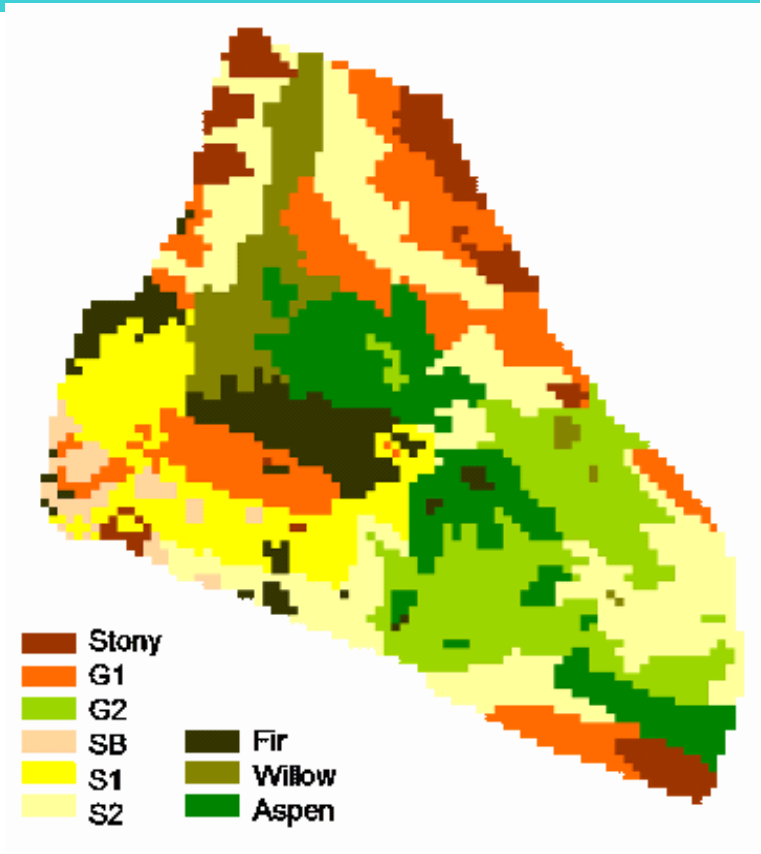
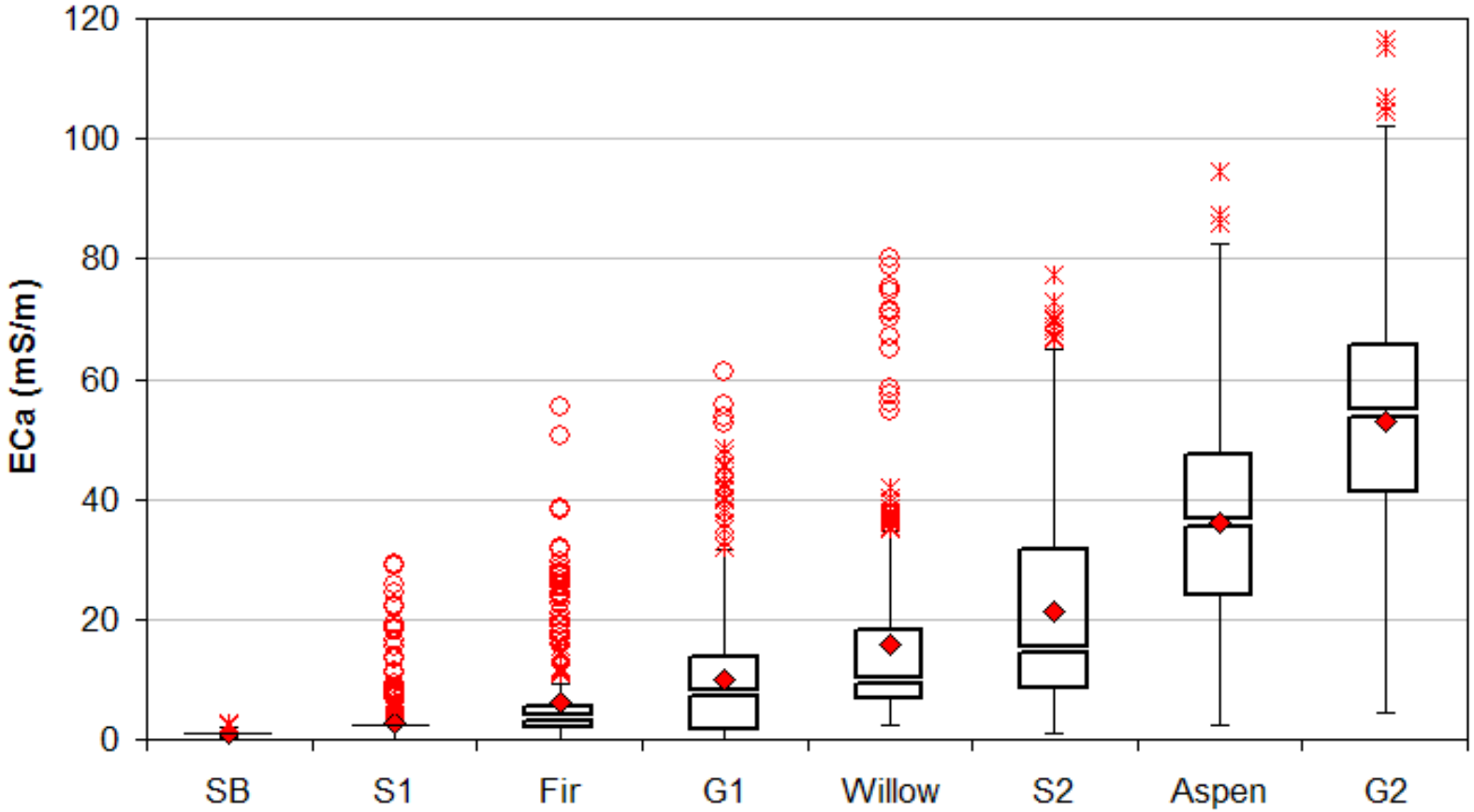
# EM IMAGING OF THE WATERSHED




Ground cover

# VEGETATION PATTERN AND EMI RESPONSE




Strong vegetation link with soils can be viewed as a resource cascade rather than a direct link to soil properties.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