Linking plant strategies to complex subsurface hydrology to predict ecosystem carbon storage across Texas

Daniella Rempe

The University of Texas at Austin
College of Natural Sciences

TEXAS Geosciences
The University of Texas at Austin
Jackson School of Geosciences

Caroline Farrior, Assistant Professor, Integrative Biology

Daniella Rempe, Assistant Professor, Geological Sciences

Tim Keitt, Professor, Integrative Biology

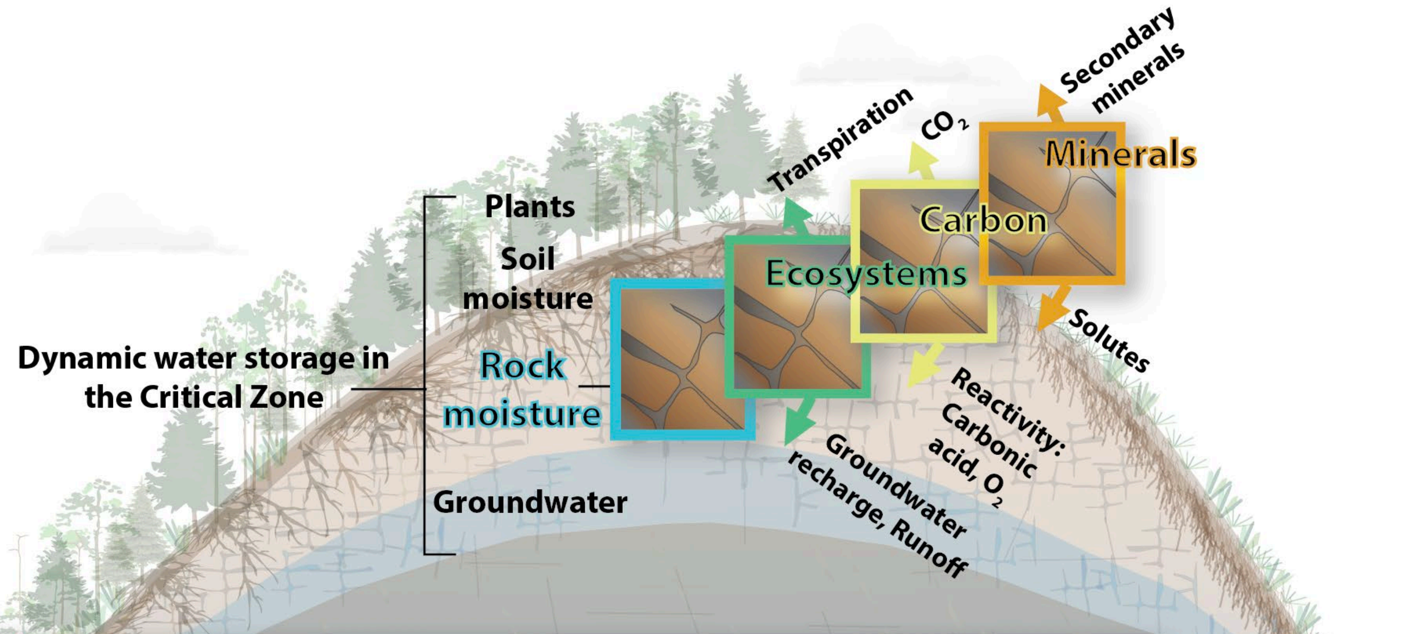
Amy Wolf, Assistant Professor, Integrative Biology

Ashley Matheny, Assistant Professor, Geological Sciences

Dana Chadwick (now at NASA JPL)

MOTIVATION

Uncover mechanisms needed to reduce uncertainties in the role of plants in response of Earth system



WB-VZ Water Storage	What are the dynamics of rock moisture storage and what key hydraulic processes drive these dynamics?
Consequences for Ecohydrology	How does rock moisture storage support transpiration and mediate water fluxes within the hydrological cycle?
Consequences for Carbon	How does rock moisture circulation mediate the stores and fluxes of organic carbon?
Consequences for Weathering	How does transport and storage of water and carbon impact solute export from the Critical Zone?

MOTIVATION

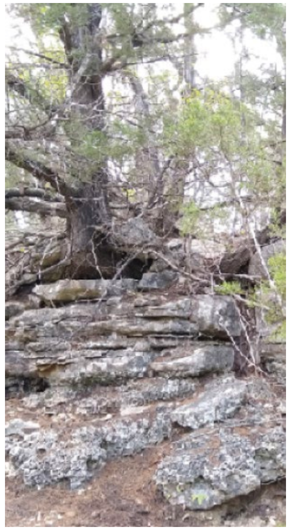
How does the competition for water and nutrients below the soil layer influence carbon allocation to tissues above and belowground, and mortality or long term carbon storage?

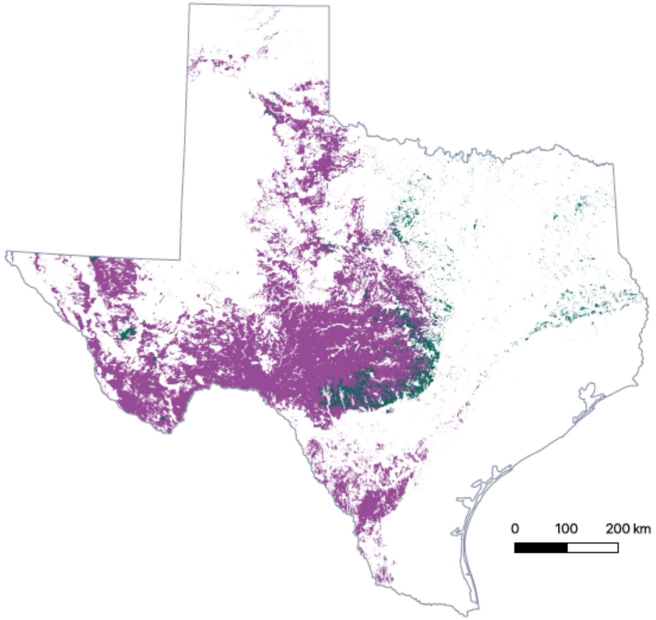
How do plants impact release and storage of inorganic carbon belowground?

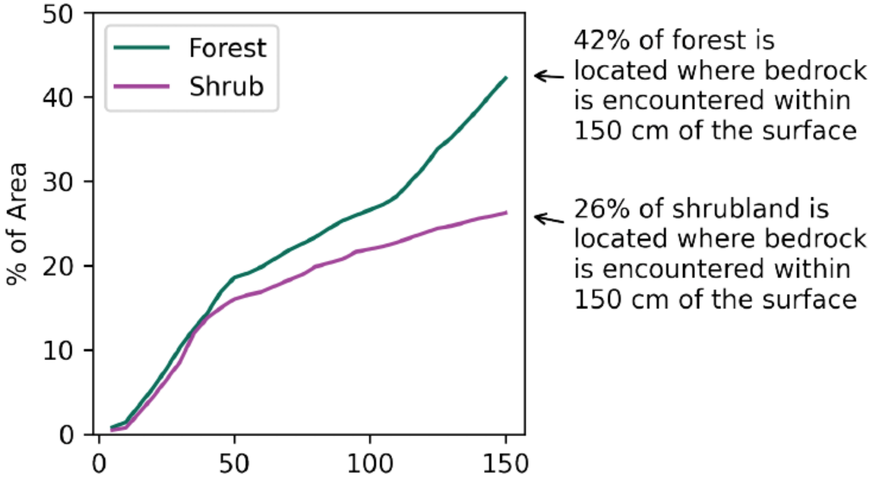
On geologic timescales, carbonate weathering is typically considered neutral. What is the transient impact of enhanced carbonate dissolution under higher atmospheric CO_2?

$$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3$$

$$Ca^{2+} + 2HCO_3 \rightarrow CaCO_3 + CO_2 + H_2O$$







Collaboration between biologists and geoscientists to achieve project tasks:

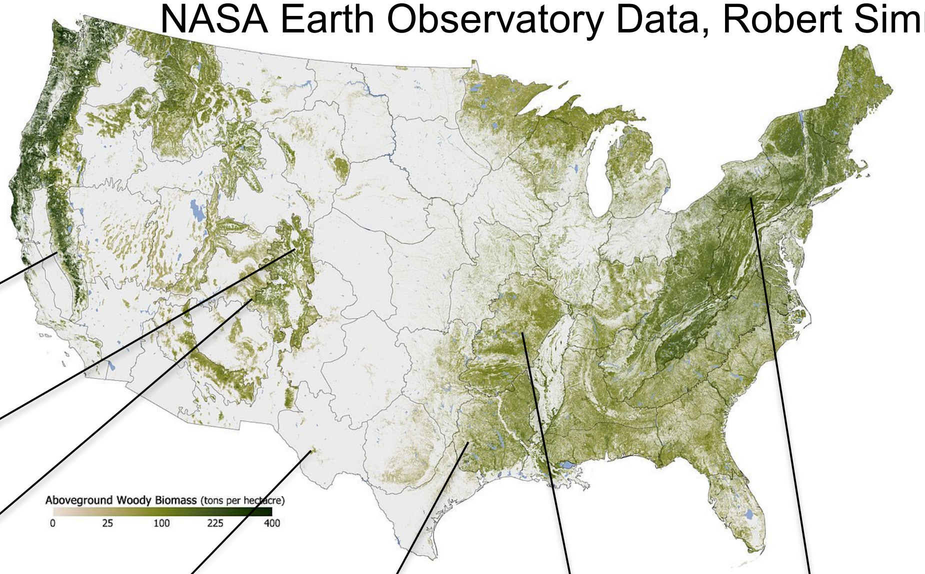
Novel field monitoring: Evidence for differences in plant water use and root respiration across different species compositions

Meta-analysis and remote sensing: Evidence for species specific access to bedrock water across Texas

Part 1: Meta-analysis

Aboveground woody biomass

NASA Earth Observatory Data, Robert Simmon



Erica McCormick
UT Austin

Granite

Sandstone

Slate

Tuff

Limestone

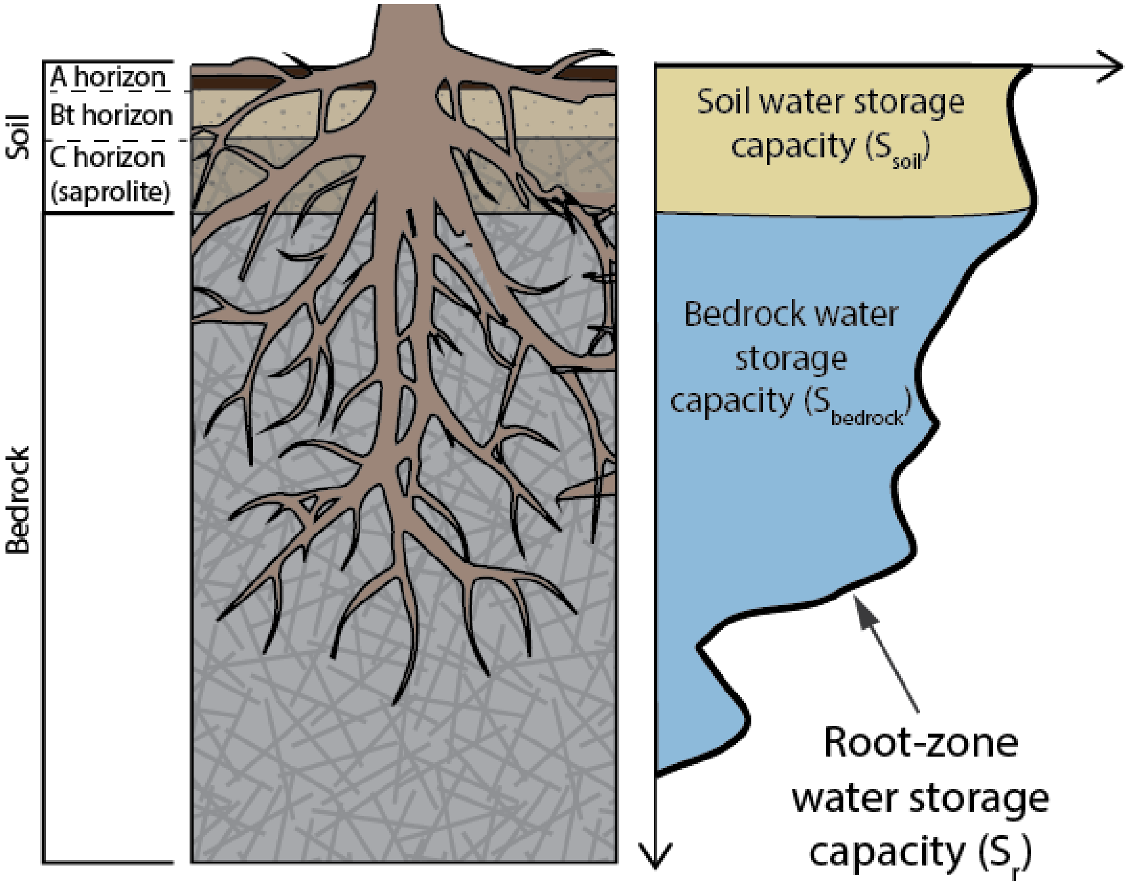
Limestone

Shale

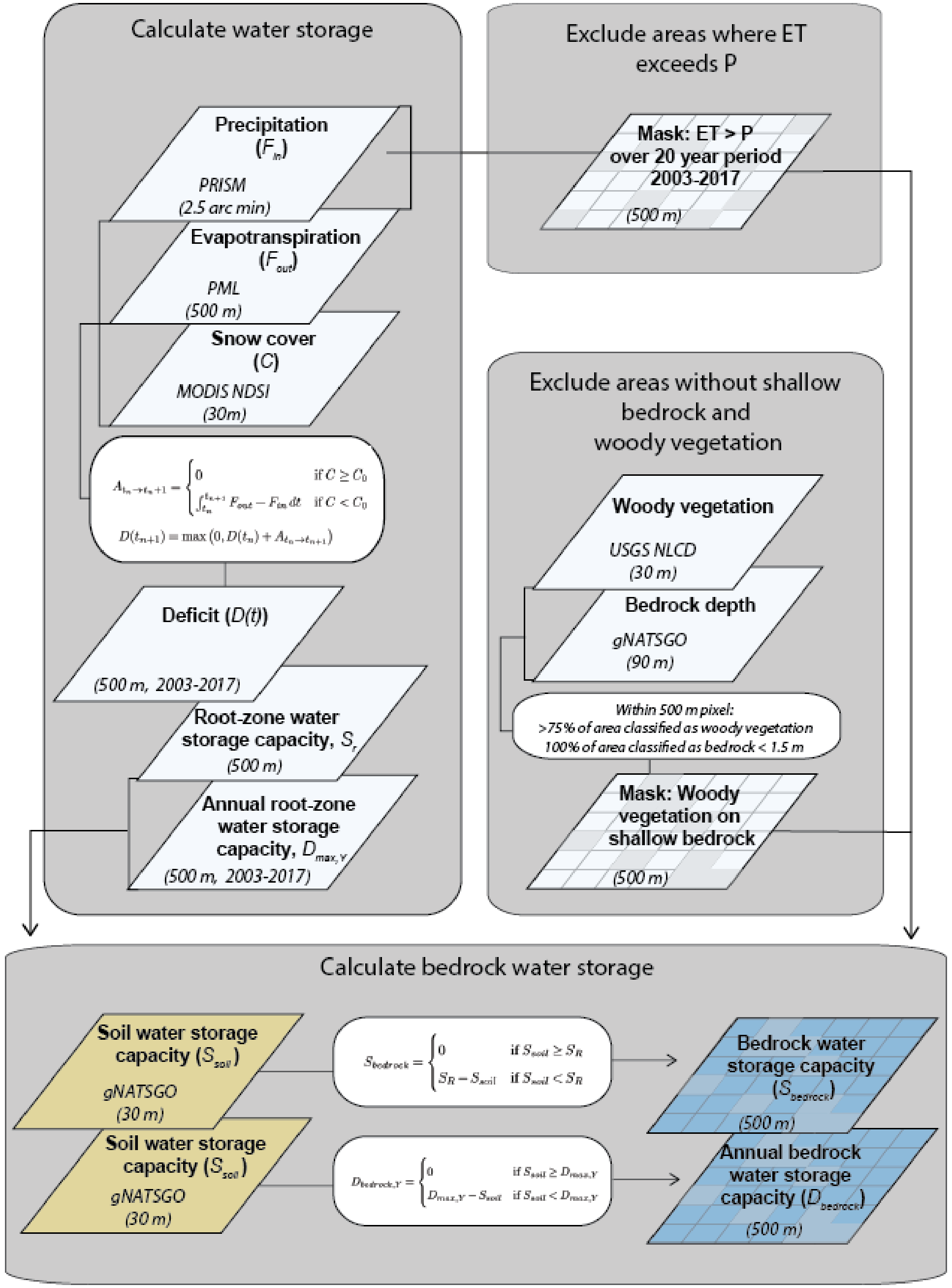
Area- What is the geographic extent of woody ecosystems that access bedrock water?

Magnitude- How much and under what time scales does *bedrock water* contribute to transpiration?

Evidence for largescale woody ecosystem dependence on water stored in bedrock

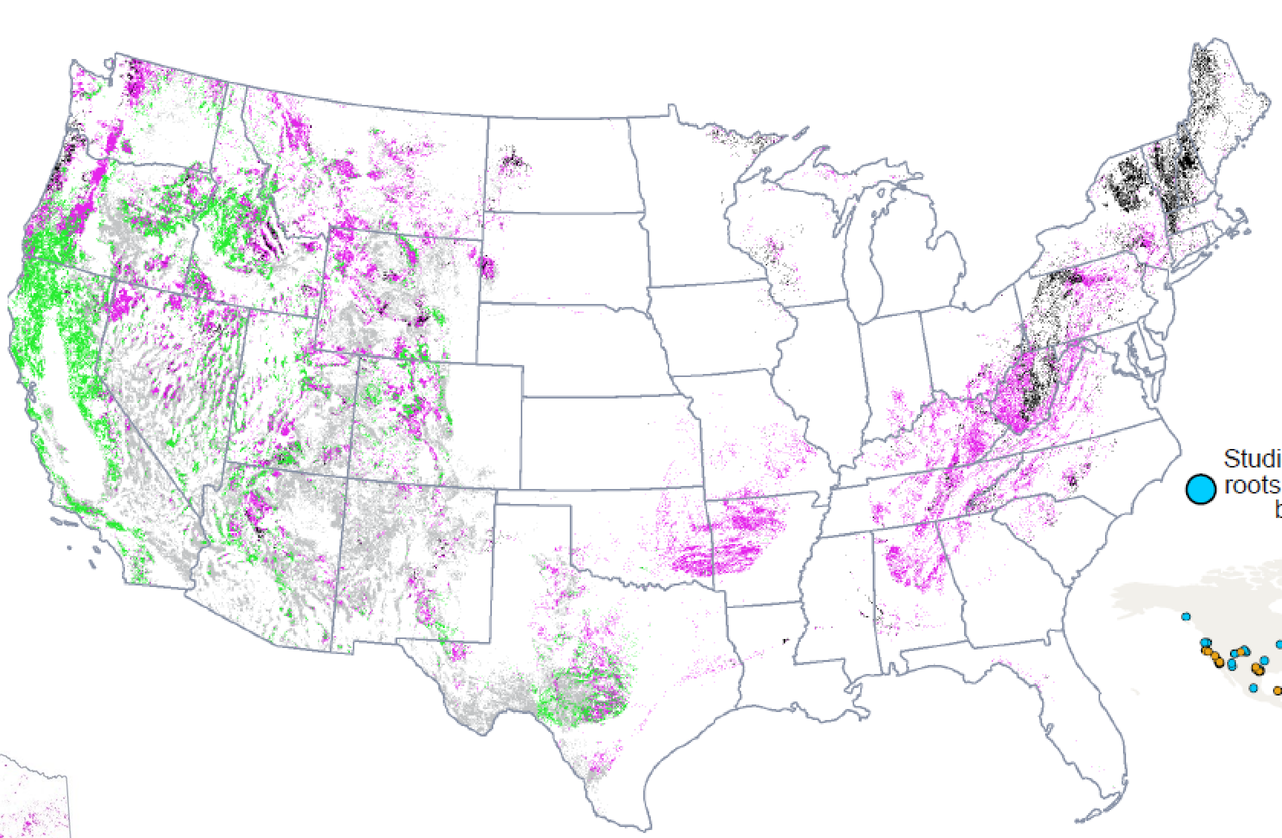


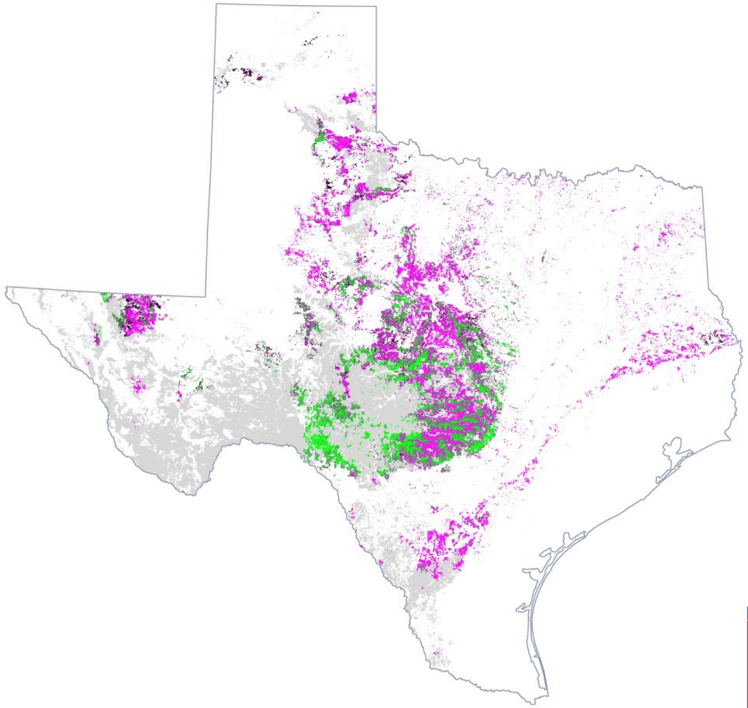
McCormick et al., 2021

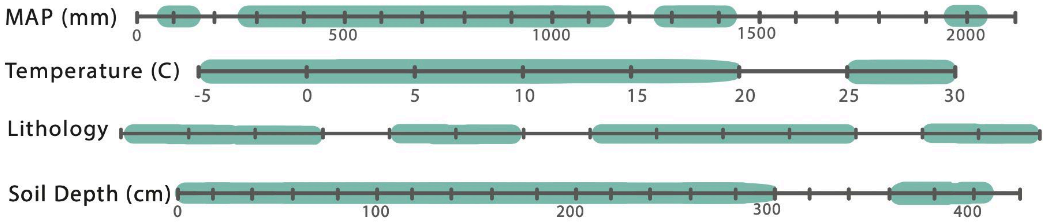


Evidence for largescale woody ecosystem dependence on water stored in bedrock

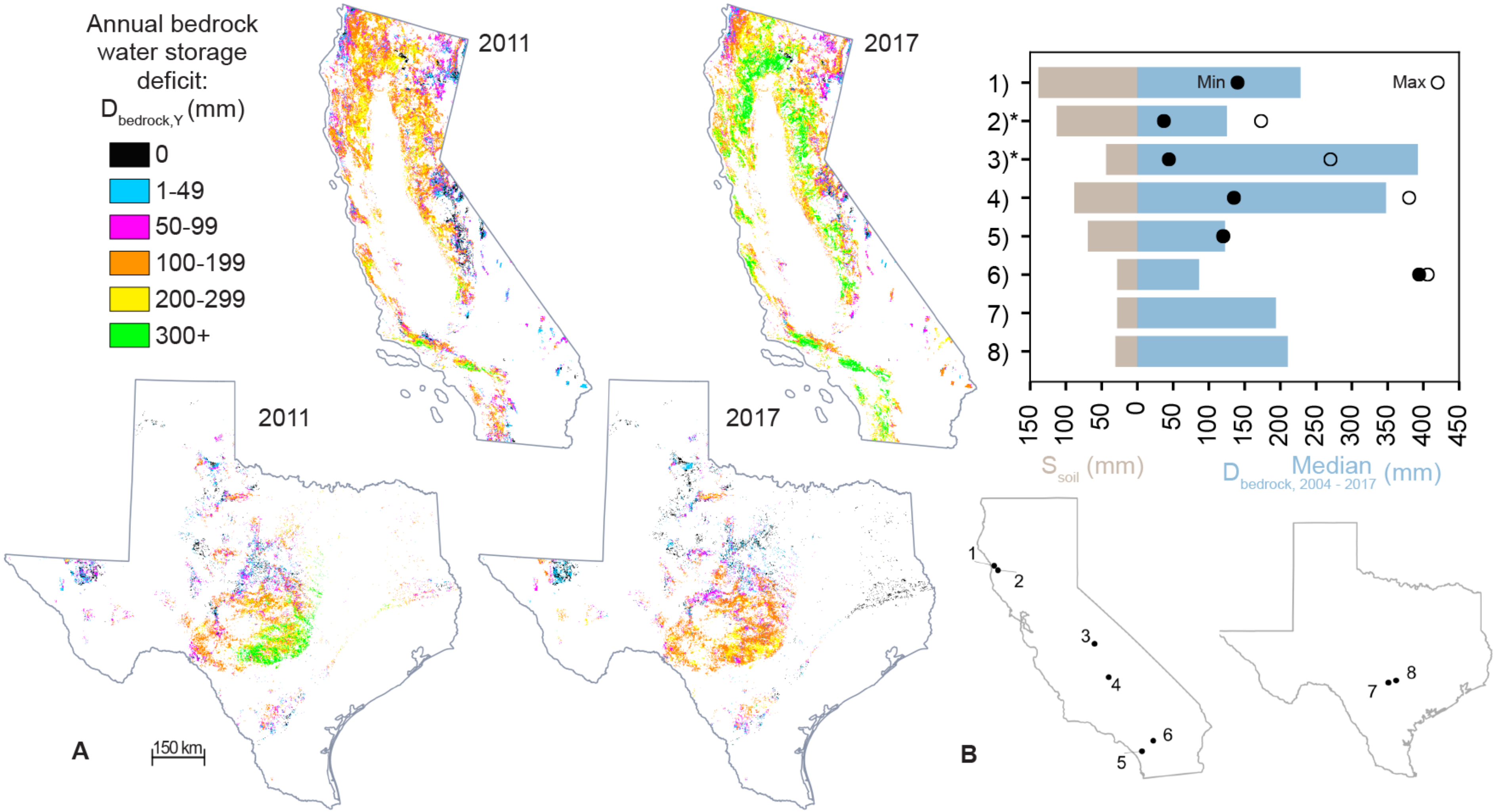
Over 50% of US forest accesses bedrock water





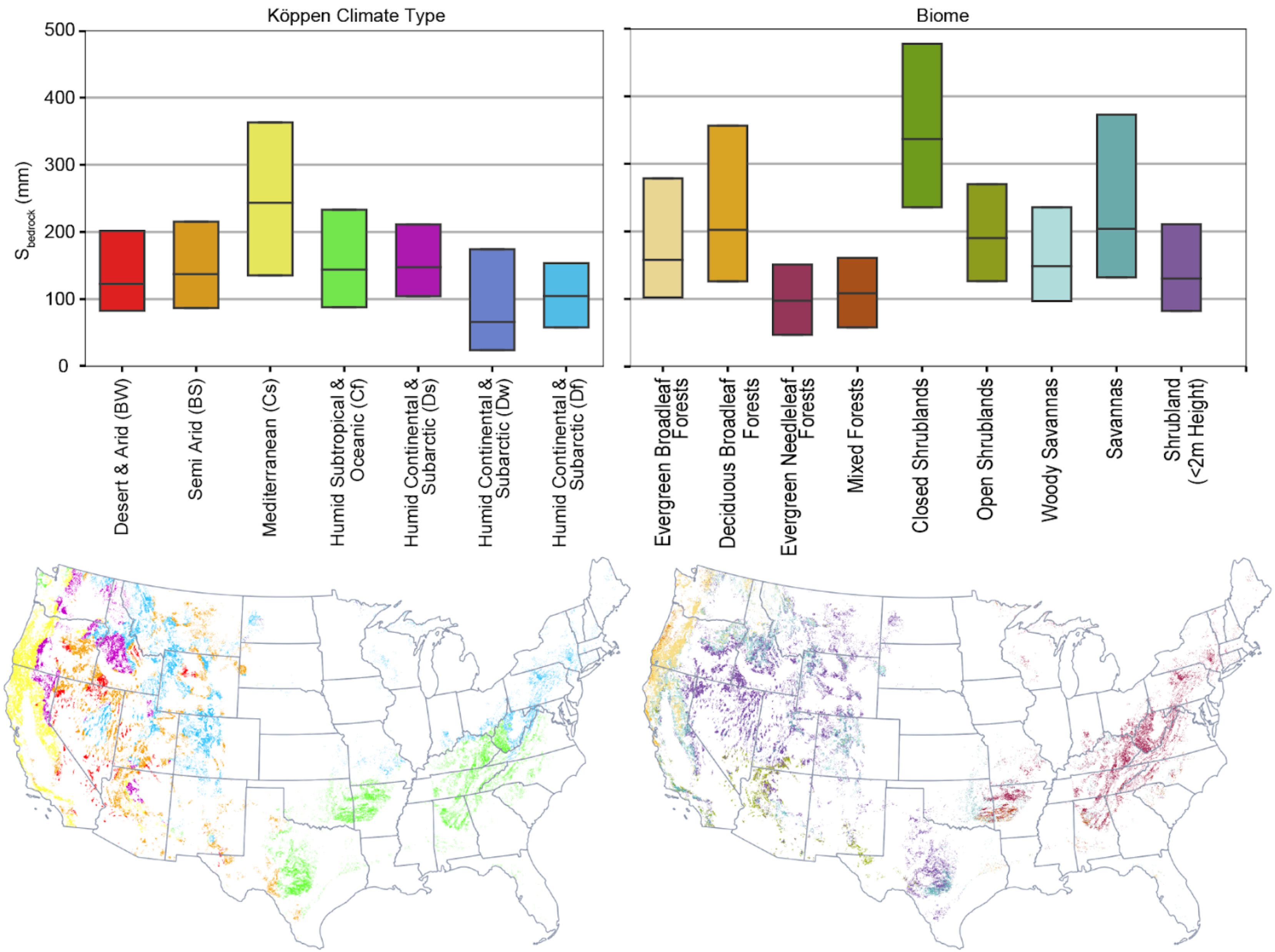


Evidence for largescale woody ecosystem dependence on water stored in bedrock



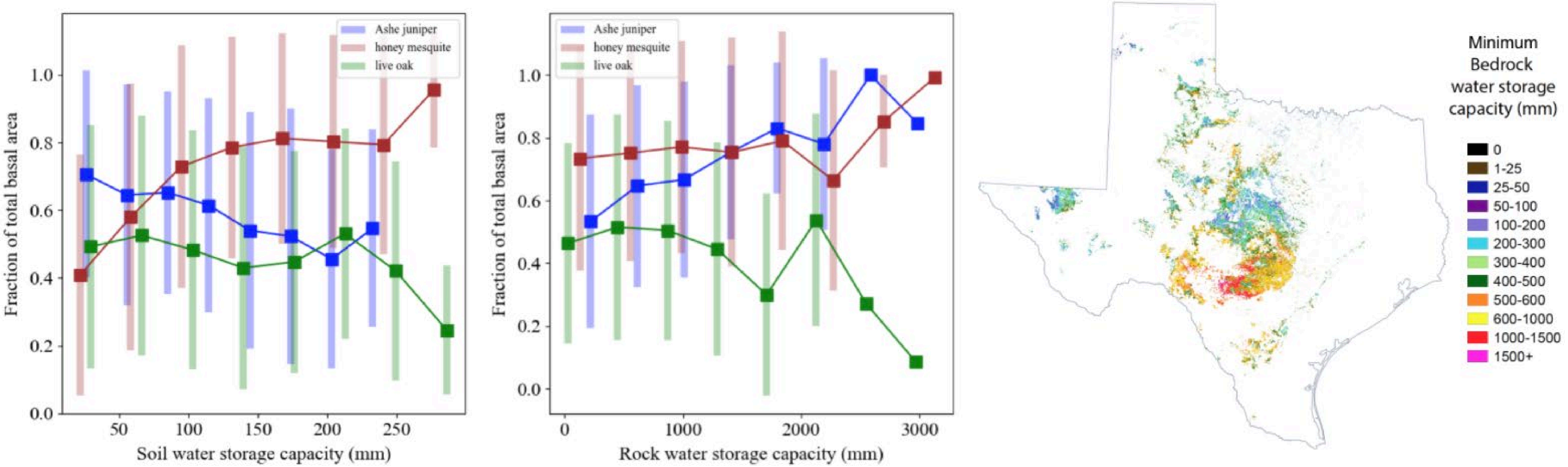
Magnitudes of annual bedrock water storage capacity are large and correspond well to existing field measurements

McCormick et al., 2021

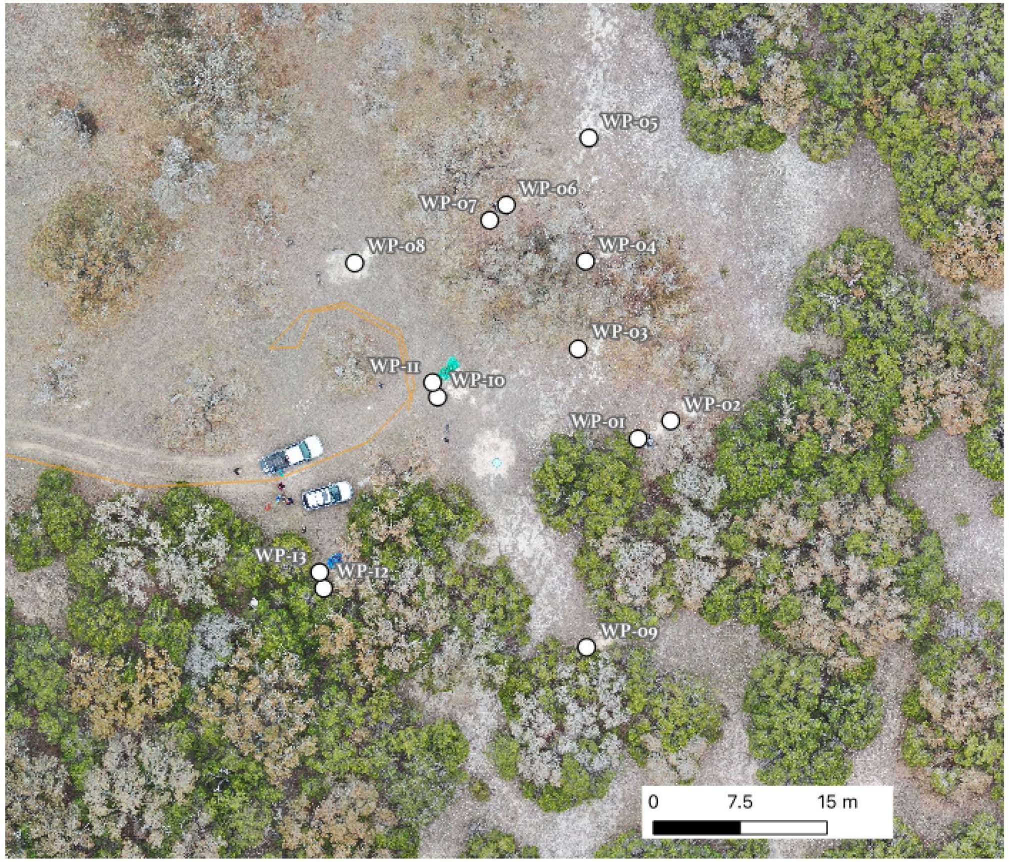


McCormick et al., 2021

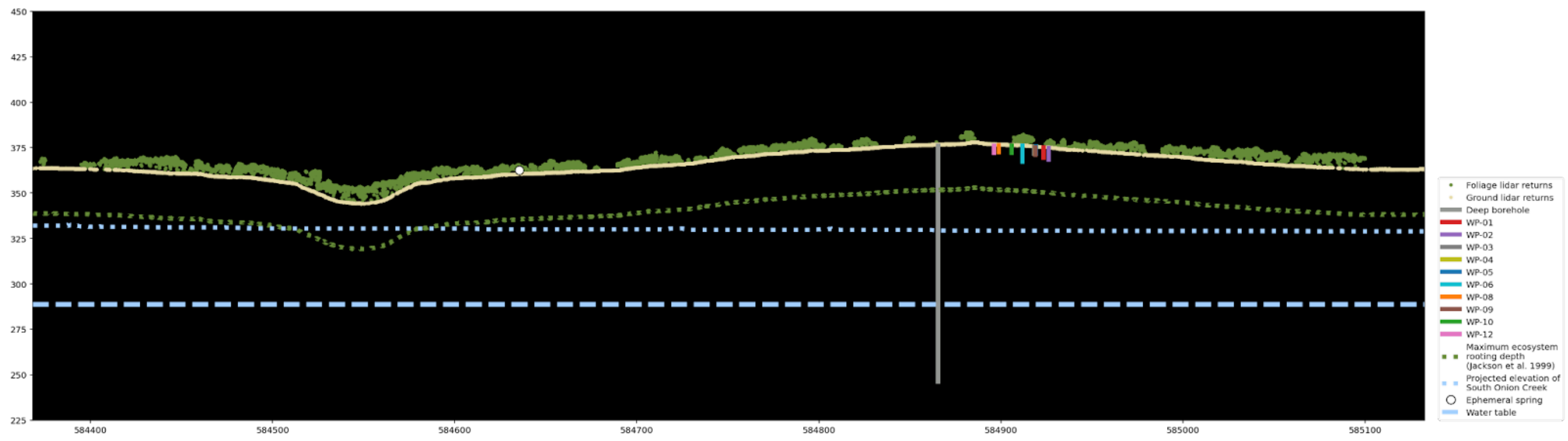
Next steps: Investigating evidence for species specific access to bedrock water across Texas



Part 2: Monitoring of carbon stores and fluxes and their drivers



Inventorying above ground carbon and water vapor fluxes

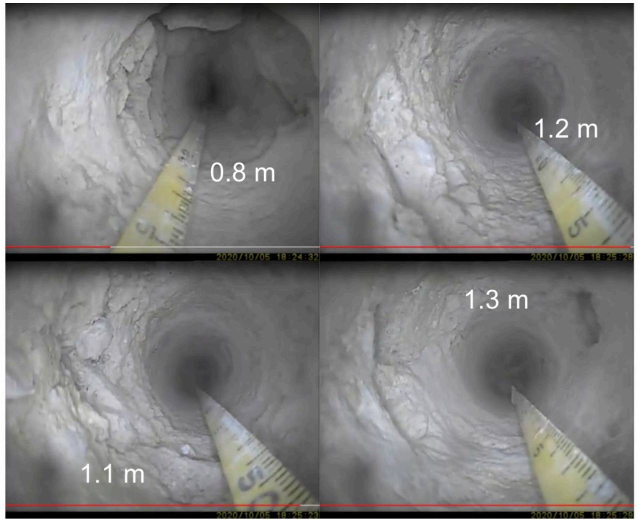


Eddy covariance: Above ground carbon and water vapor fluxes

Ecohydrologic monitoring: Carbon and water storage in plants

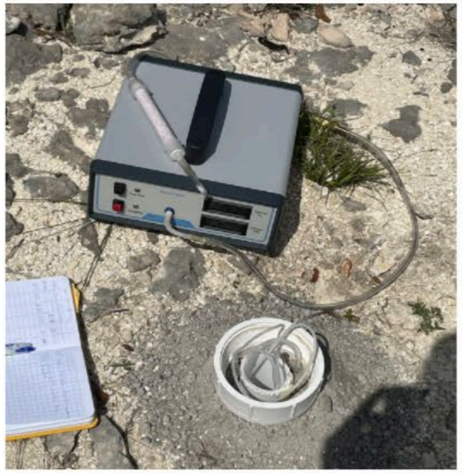


Drilling and subsurface characterization



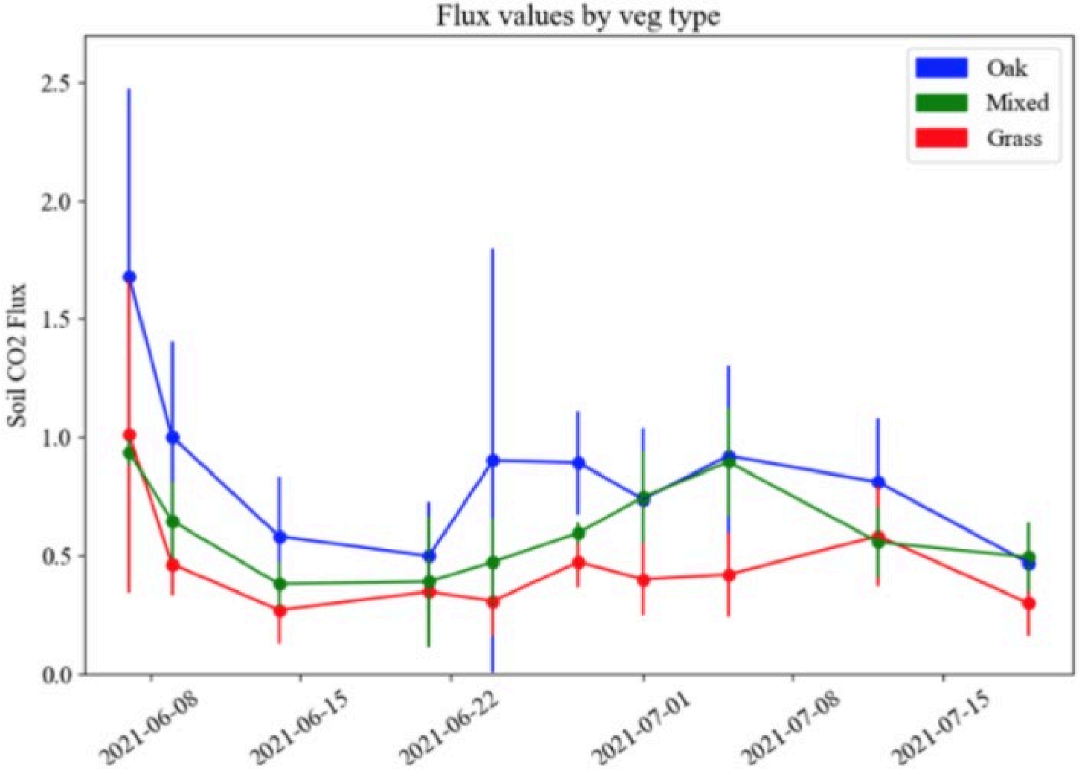
Belowground gas monitoring



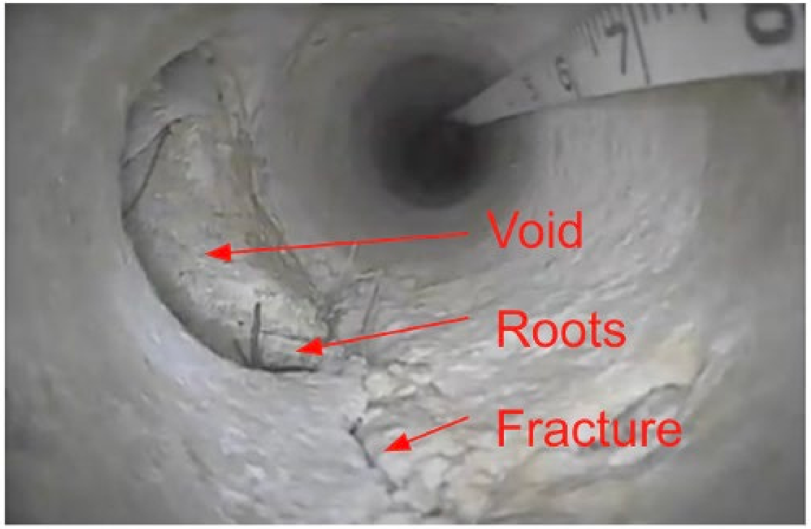



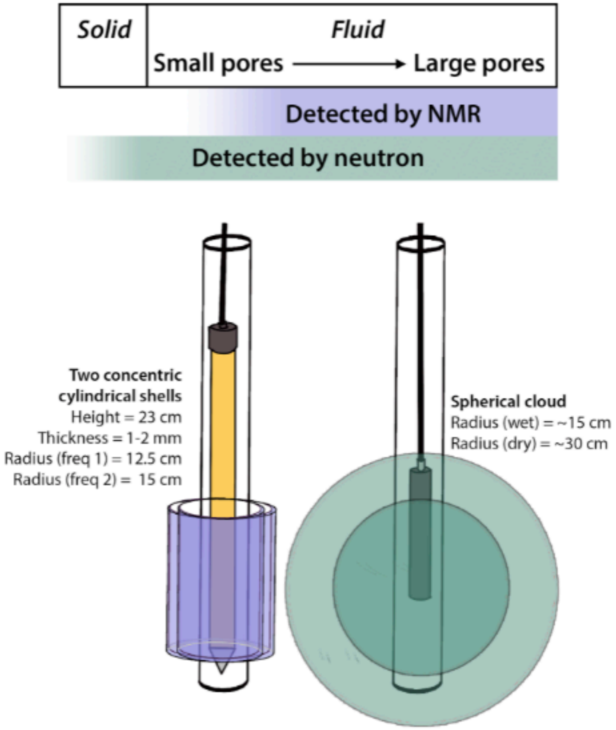

Linking belowground monitoring to soil carbon dioxide efflux

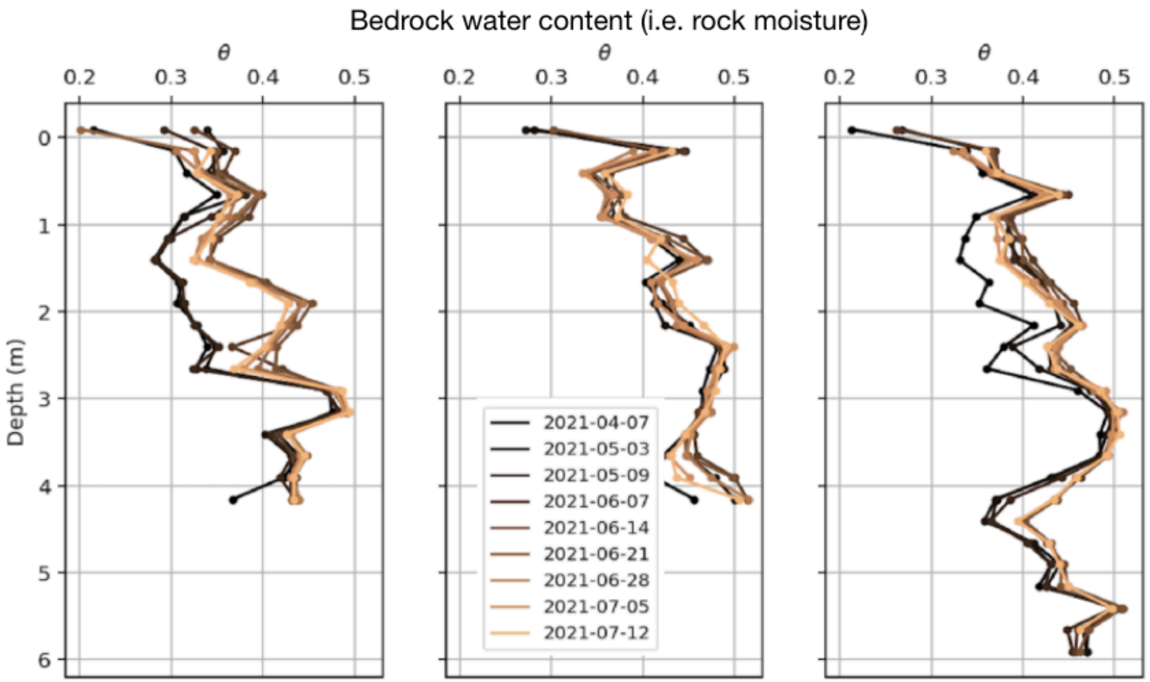
CO_2 fluxes, aggregated by vegetation cover type



Belowground moisture monitoring



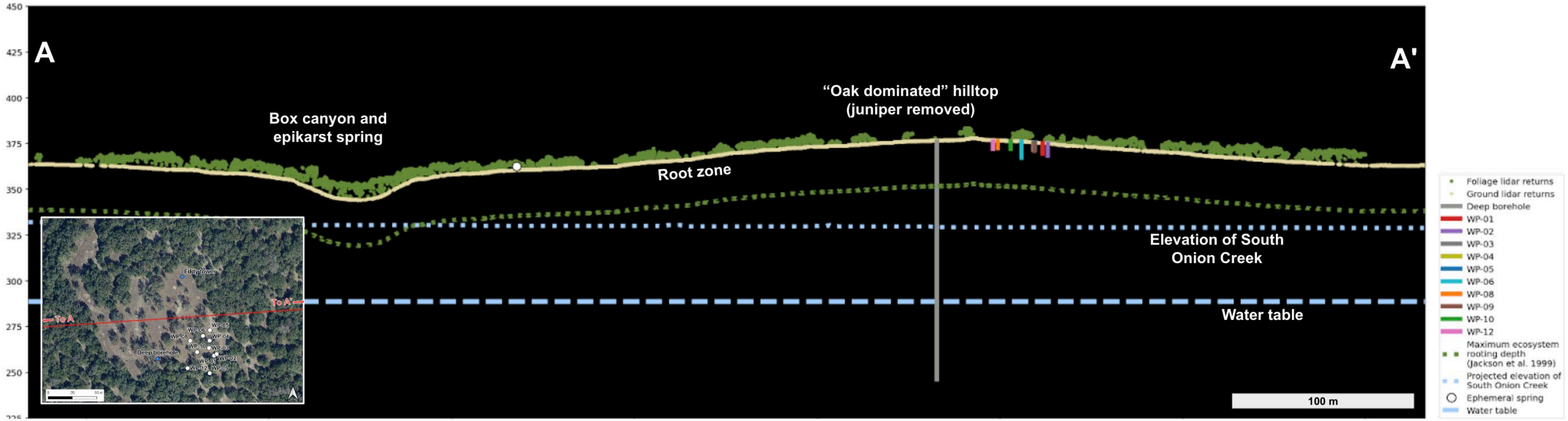


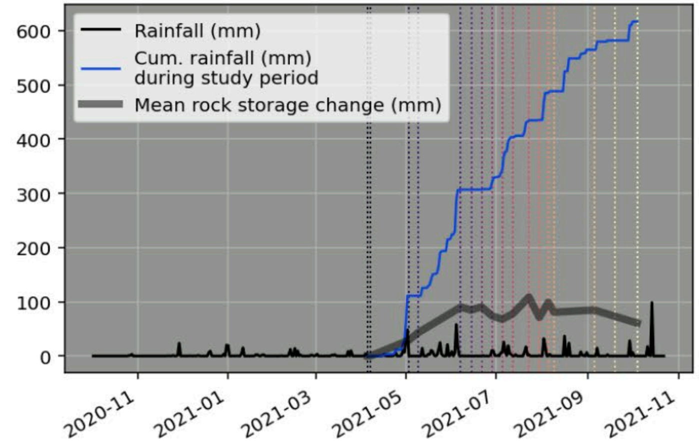


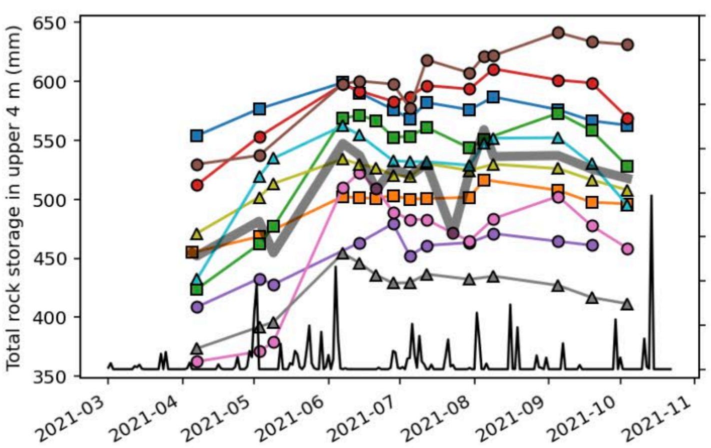
Mixed: Live oak (*Quercus virginiana*) and Ashe juniper (*Juniperus asheii*)

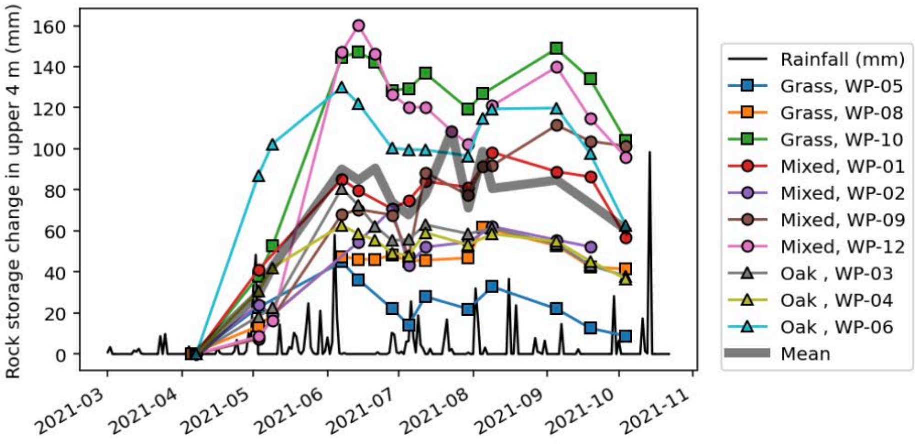
Grass: C3/C4 Grasses (Oak and Juniper excluded)

Oak: Live oak (*Quercus virginiana*) (Juniper excluded)


A
A'
Box canyon and
epikarst spring
"Oak dominated" hilltop
(juniper removed)
Root zone
Elevation of South
Onion Creek
Water table
100 m
Eddy tower
To A
To A'
Deep borehole
Foliage lidar returns
Ground lidar returns
Deep borehole
WP-01
WP-02
WP-03
WP-04
WP-05
WP-06
WP-08
WP-09
WP-10
WP-12
Maximum ecosystem rooting depth (Jackson et al. 1999)
Projected elevation of South Onion Creek
Ephemeral spring
Water table


Rainfall (mm)
Cum. rainfall (mm) during study period
Mean rock storage change (mm)

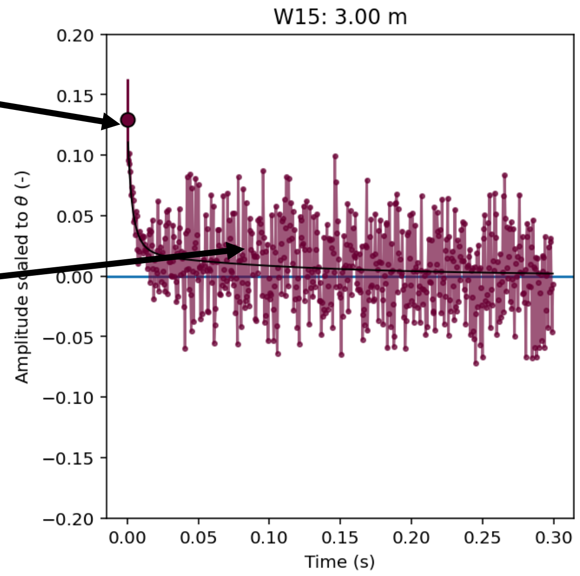

Total rock storage in upper 4 m (mm)
Rainfall (mm)


Rock storage change in upper 4 m (mm)
Rainfall (mm)
Grass, WP-05
Grass, WP-08
Grass, WP-10
Mixed, WP-01
Mixed, WP-02
Mixed, WP-09
Mixed, WP-12
Oak , WP-03
Oak , WP-04
Oak , WP-06
Mean

Nuclear magnetic resonance

The initial amplitude is directly proportional to water content

The decay rate is controlled by the surface area to volume ratio of water in pores

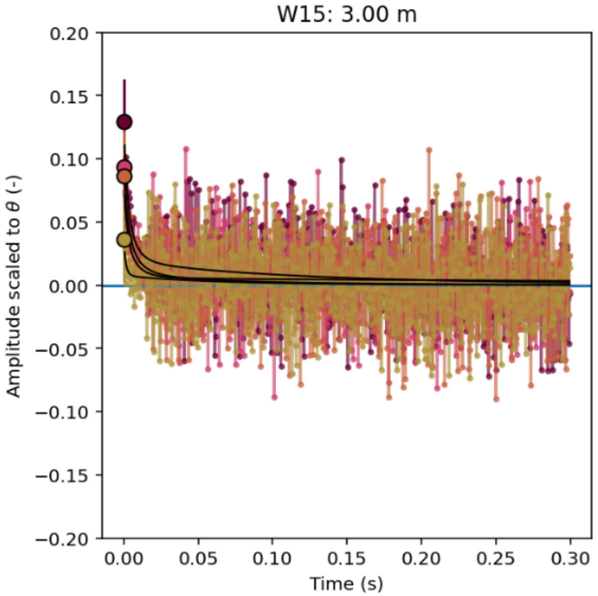


Logan Schmidt,
UT Austin

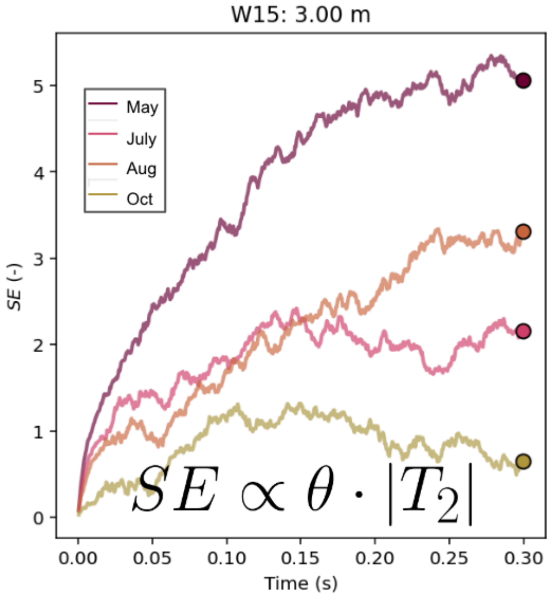
NMR: Documenting fluids in fractures in-situ

There are different ways to characterize NMR relaxation (for simplicity)

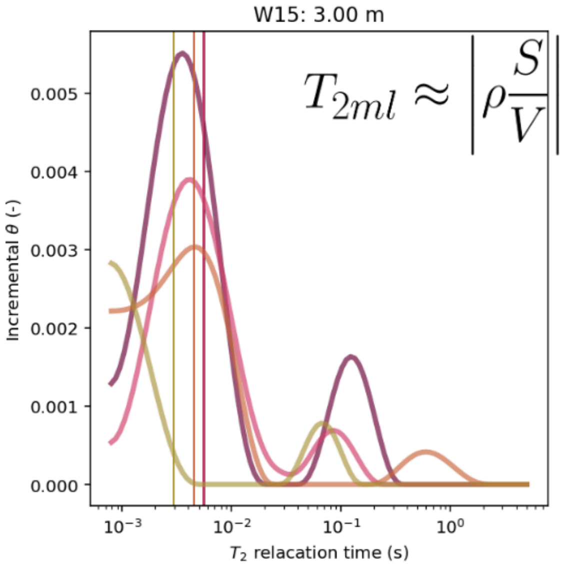
Decay curve



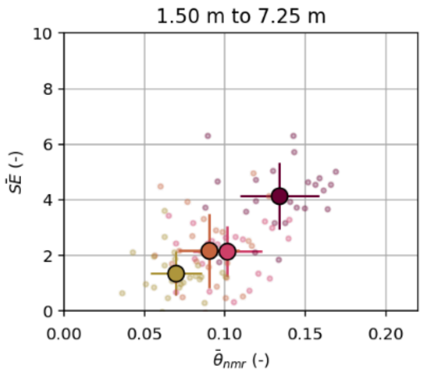
Sum of decay curve



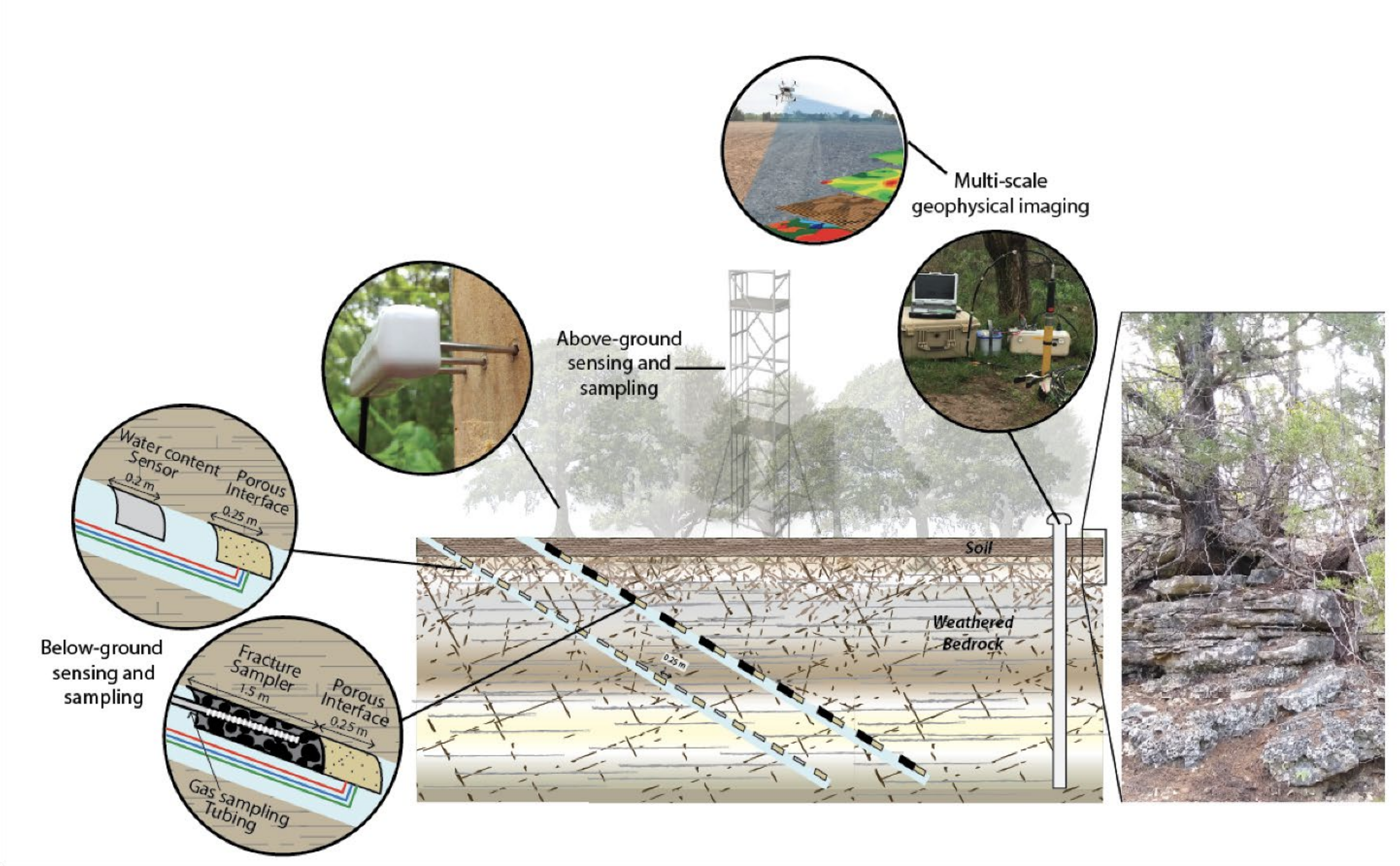
T_2 distribution



This allows us to relate water content and water mobility in a pseudo water retention curve



Next steps



Complete establishment of testbed infrastructure for long-term monitoring and hypothesis testing at field site

Conduct routine monitoring of carbon fluxes

Seek funding for subsurface monitoring infrastructure for sampling fluids draining from root zone

Conduct drone-based lidar to estimate changes in above ground carbon storage

Complete regional scale remote sensing and forest inventory analyses for evaluation of theoretical framework of ecosystem carbon storage, species competition, and water availability

Thank you.

Daniella Rempe
rempe@jsg.utexas.edu
Jackson School of Geosciences
University of Texas at Austin