Linking Subsurface Complexity and Ecohydrologic Processes in Semi-arid Forests

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Abstract

Rock moisture can be an important contributor to forest transpiration and growth. Limited work has been done studying the effects of rock moisture (subsurface water stored in fractured, weathered rock) on transpiration rates — especially in water-limited environments. Semi-arid forests like the Gordon Gulch catchment (west of Boulder, CO) exhibit complex water budget systems where water sources are not completely understood. Here, we compare transpiration rates from plots on opposing aspects with regard to soil moisture and potential rock moisture storage as inferred from shallow seismic refraction surveys. We calculated the transpiration rates of ponderosa pine and lodgepole pine trees with sap flow data collected from June to September 2014. Potential storage for rock moisture is estimated based on qualitative analysis of shallow seismic refraction line data. While one would expect areas with higher soil moisture on average to have higher transpiration rates, our results showed the contrary: the plot with less soil moisture on average exhibited 25% higher transpiration rates. By qualitatively analyzing the seismic line images, we found that this phenomenon could possibly be explained by rock moisture. The plot with higher transpiration also had more fractured, weathered bedrock below that could potentially store more water in rock moisture. Rock moisture is an important component of the complex water budget system in Gordon Gulch. Further imaging of the subsurface is key to advance our understanding on how water is being used and moved in similar environments. Our research provides insight into rock moisture's potential effects on water usage via transpiration in water-limited environments.

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GAGE National Science Foundation's Geodetic Facility for the Advancement of Geoscience

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1. Overview: Transpiration and Rock Moisture

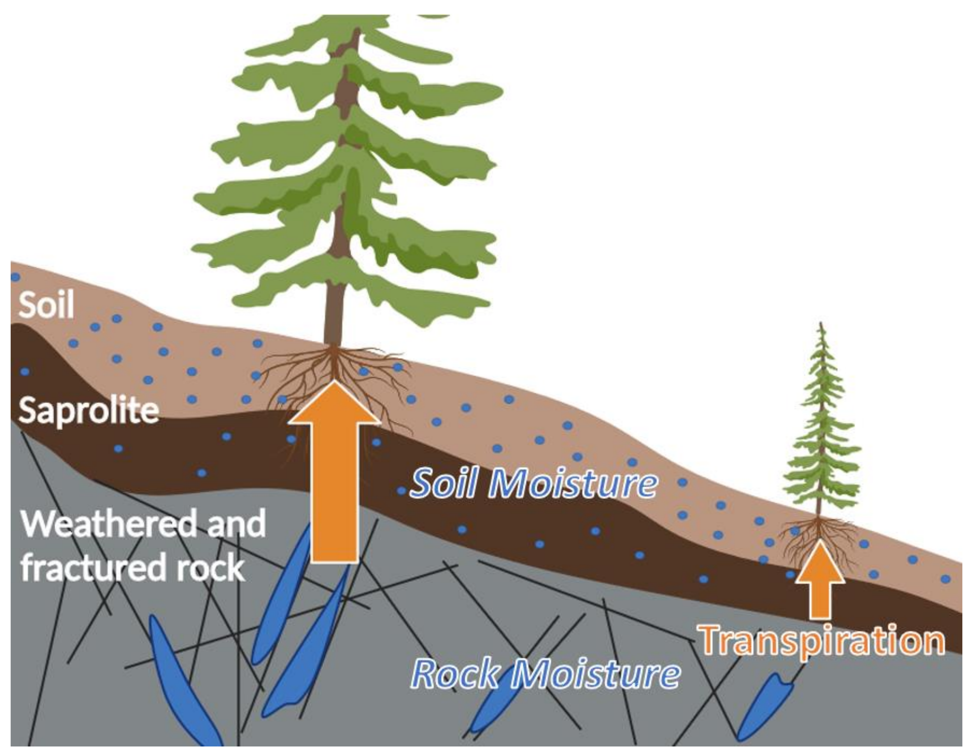

Figure 1. Soil horizon, soil moisture and rock moisture, and transpiration by trees.

Motivation: Subsurface water storage is crucial for tree growth. With a warming climate and more frequent and extreme droughts, it is important to understand how and at what rate water is being used by trees and where that water is being stored and coming from.

Research Question:

How does subsurface rock complexity affect water use, movement, and availability via transpiration and rock moisture?

Background:

- Trees draw up water from subsurface water storage, whether that be soil moisture or rock moisture (moisture in fractured bedrock).
- We don't fully understand how water is being used and stored in semi-arid forests.
- Previous work investigated soil moisture effects on transpiration, but the effects of rock moisture are not fully understood.
- It is important to determine how rock moisture can mitigate stress in plants as our climate changes.

2. Study Site and Methods

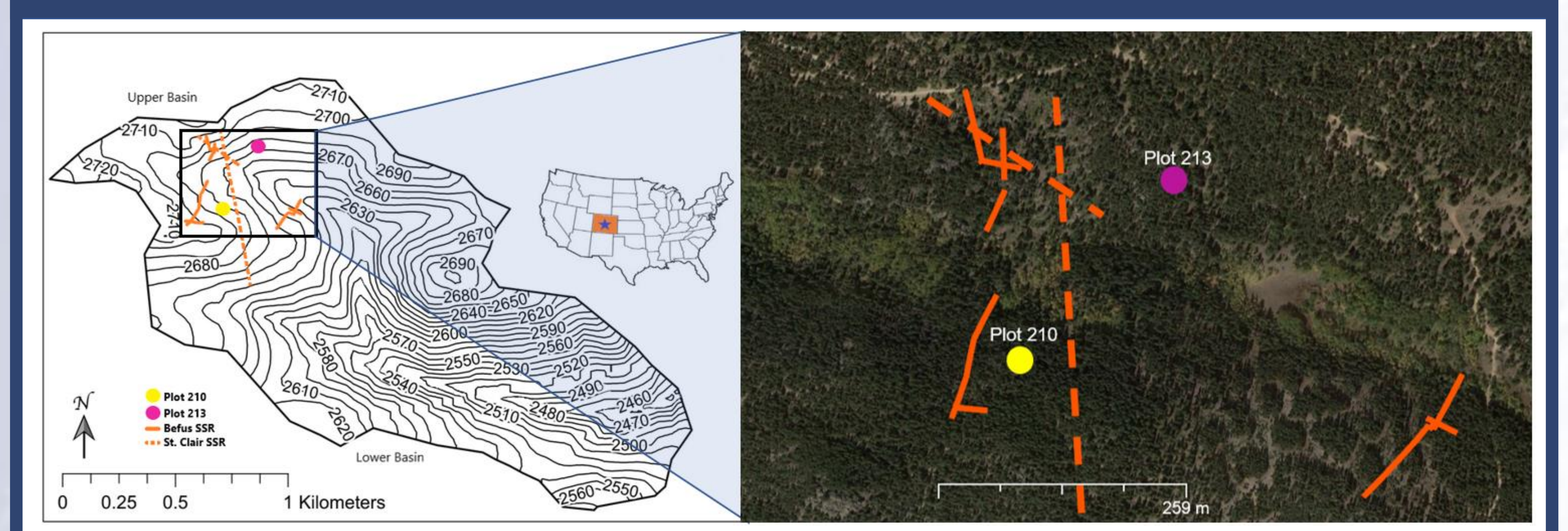

Figure 2. Map of our study site (Gordon Gulch catchment near Boulder, CO, USA).[1]

Data Collection:

- Sap flow sensors installed in eight trees at both plots[2]
- Transpiration, soil moisture, vapor pressure deficit, and rain totals collected every 30 minutes from June until September 2014.

Surface Seismic Refraction:

- Used seismic line data from a previous study in proximity to the study site.[1]
- Interpreted seismic line images for amount of fractured bedrock (potential for rock moisture).

3. Results of Subsurface Storage Analysis

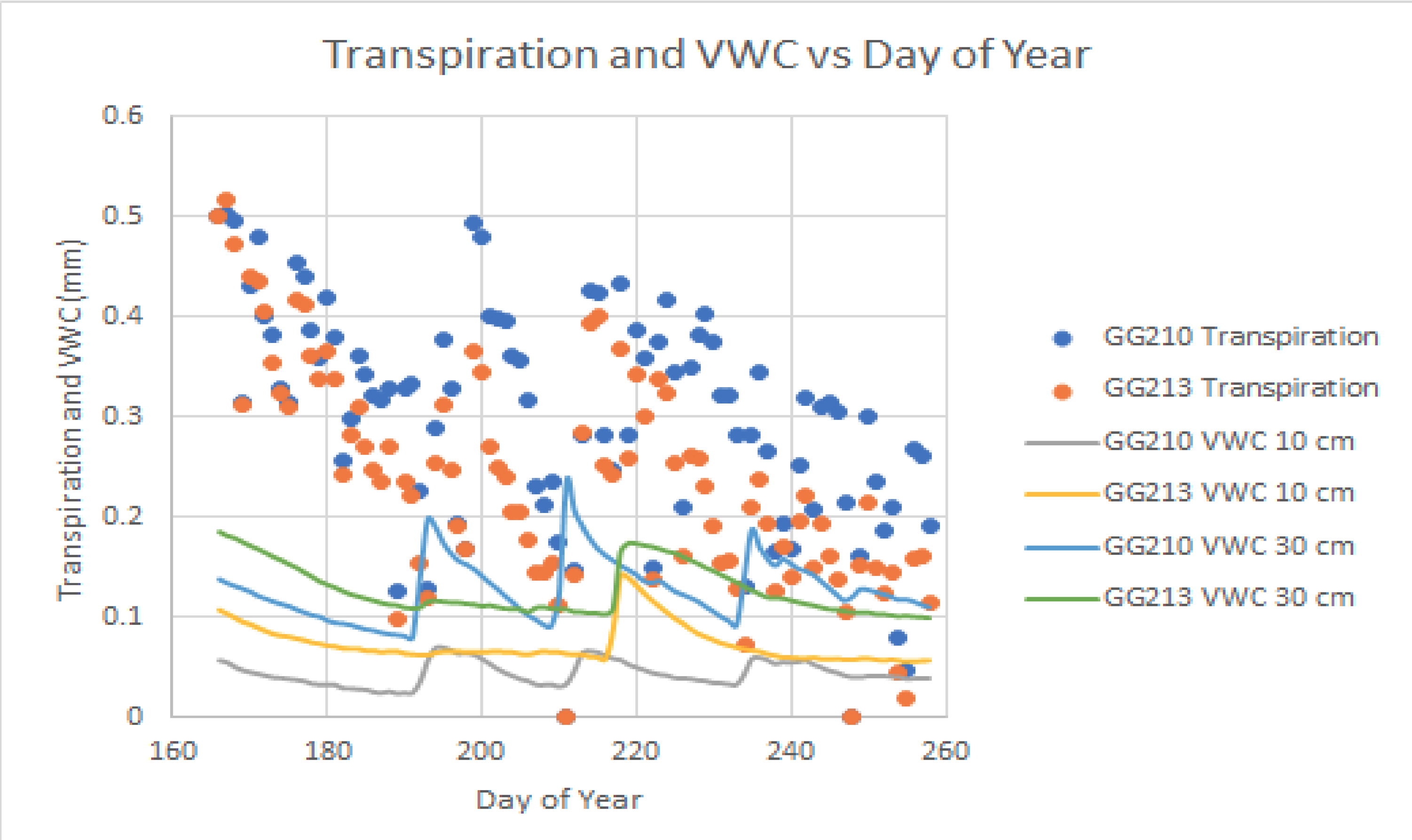

Figure 3. Transpiration and volumetric water content daily averages at both plots.

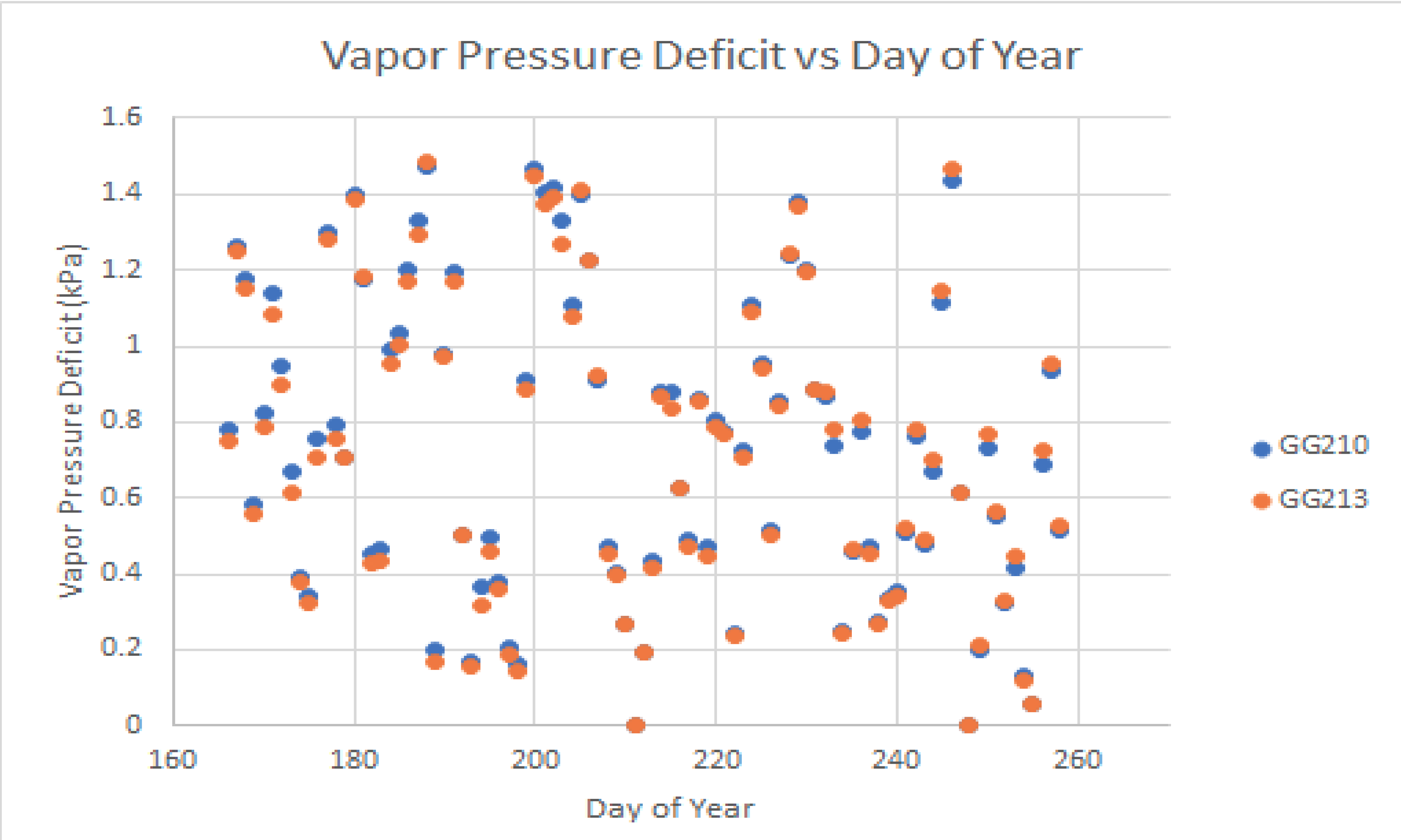

Figure 5. Vapor pressure deficit daily averages at both plots.

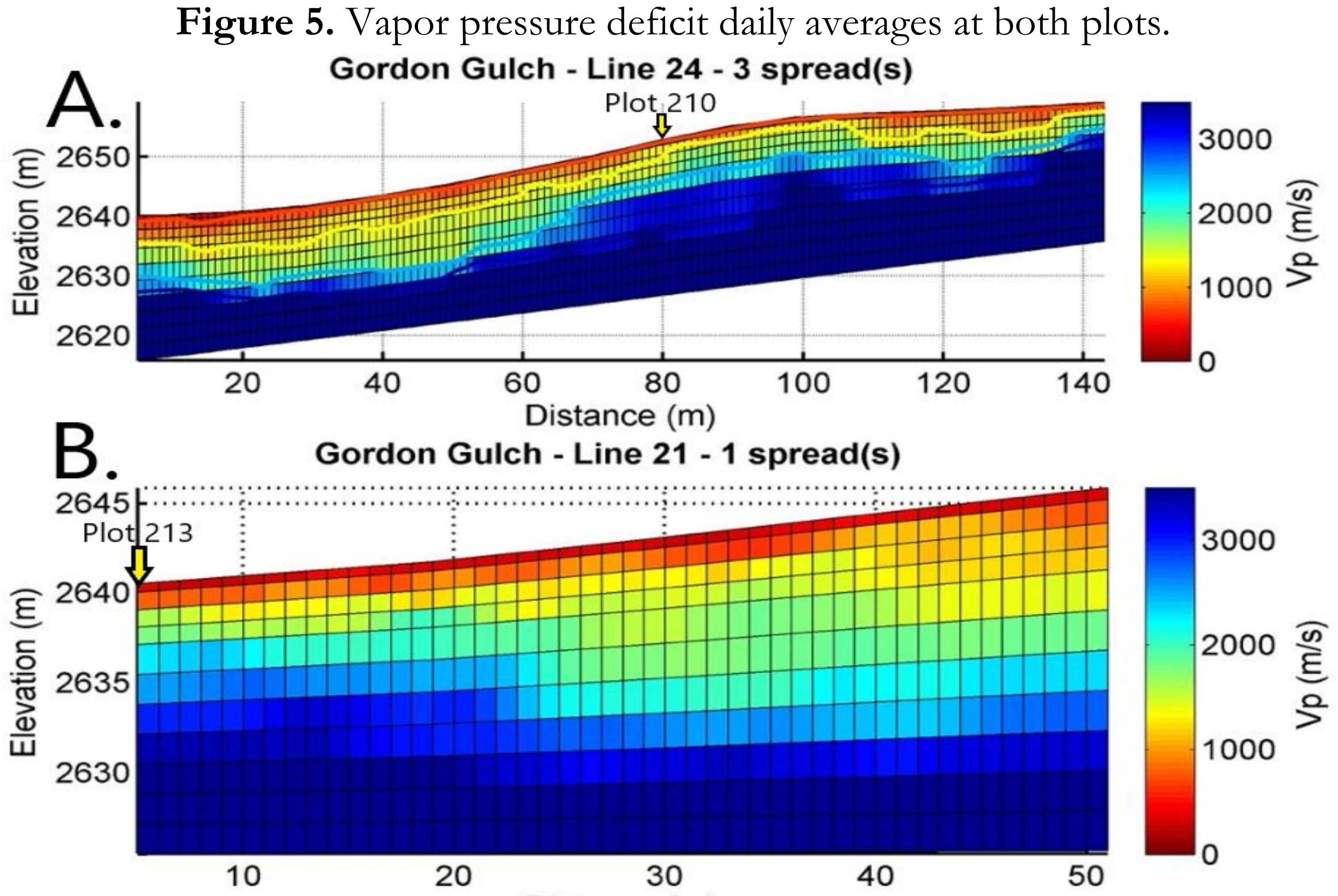

Figure 6. Seismic line images at both plots. A. is near Plot 210 and is scaled in 10-meter intervals. B. is near Plot 213 and is scaled in 5-meter intervals.[1]

4. Discussion

Plot Comparisons					
	Total Transpiration (mm)	Total Rain (mm)	Soil Moisture at 10-cm depth (mm)	Soil Moisture at 30-cm depth (mm)	Depth of fractured bedrock (m)
GG210 (N-facing)	28	27	4	12	10
GG213 (S-facing)	22	53	7	12	5

Figure 7. Table comparing both plots' totals of transpiration, rain, soil moisture, and depth of fractured bedrock.[1]

Discussion:

Why are transpiration rates higher at GG210 compared to GG213 when soil moisture and total rainfall was lower?

- One explanation could be a difference in atmospheric drivers between the two sites. However, vapor pressure deficits at plots are similar, so we know that the atmospheric drivers are similar.
- A possible explanation would be water storage in rock moisture. GG210 has twice as deep fractured bedrock compared to GG213.
- One can hypothesize that GG210 has more storage for rock moisture in the deep subsurface than GG213.

Total transpiration rates were roughly half of expected values due to sap flow data not correcting for tree wounding, which can lead to low results of 50% or more.[3]

5. Conclusion

Conclusion:

By analyzing the transpiration rates of our two plots and their differences, we were able to get a better idea as to how subsurface complexity affects ecohydrologic processes in a semi-arid forest.

We found that:

- Rock moisture can potentially mitigate the stress undergone by plants due to drought and warming temperatures.
- Rock moisture can possibly explain the higher transpiration rates where soil moisture and total rainfall is lower.

6. References and Acknowledgements

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