**Forest Response to Extreme Drought and Thinning: UAV and ECOSTRESS-based estimates of Canopy Temperature and Evapotranspiration**

Semi-arid forests across the southwestern USA are being treated with mechanical thinning and prescribed burning to reduce the risks of catastrophic forest fires. In Arizona, the US Forest Service (USFS) is treating approximately 2 million ha over 20 years via mechanical thinning and prescribed burning (USDA, 2013). To measure the effects of forest thinning on drought resiliency, we have been monitoring thinned and non-thinned ponderosa pine forests in northern Arizona. Our study period since 2018 has included extreme drought year 2021 as well as average precipitation (2018) and wet years (2022-2023). Our forest spectroscopy data and extensive, hourly soil moisture data since 2018 have demonstrated that the thinned stands had significantly greater soil moisture than non-thinned stands in 2021, 2022, and 2023 as well as significantly greater vegetation water content. These differences were further enhanced during the extreme drought year 2021.

Using an unoccupied aerial vehicle (UAV) thermal sensor and ECOSTRESS satellite images of land surface temperature (LST), we monitor thinned and non-thinned forest canopy temperature response to drought. The UAV LST and ECOSTRESS LST estimates in average and drought years consistently indicate significantly higher LST in thinned stands than non-thinned stands. During the regional drought in 2021, thinned stands in both datasets continued to have significantly higher canopy temperatures, but non-thinned forest canopy temperature increases are significantly greater than thinned canopy temperature increases. This indicates that thinned forest canopy temperatures are better buffered than non-thinned stands during extreme drought. Interestingly, LST estimates in the non-thinned stands are significantly different between the two datasets: ECOSTRESS data indicate much lower LST in non-thinned stands compared to the UAV LST. This might be partially due to the geolocation accuracy of the ECOSTRESS data, which has positional errors of up to several pixels, since our non-thinned forest covers a relatively small area.

Using ECOSTRESS evapotranspiration (ET) data (Fisher et al., 2020), we also estimate thinned and non-thinned forest ET. Consistent with the temperature results, ECOSTRESS ET data show significantly greater ET in non-thinned stands than thinned stands across years. Our study area, which was thinned in 2018, still show significantly lower ET in thinned stands compared to non-thinned stands. While non-thinned stands show significantly greater ET due to high tree density and basal area (Simonin et al., 2007; Hamberg et al., 2022), trees in these stands compete for limited soil water. Taken together, our results indicate that non-thinned stands with high evaporative cooling demands experience significantly greater water stress than thinned stands during drought years. Furthermore, in water-limited Arizona, the thinning has resulted in water savings via ET reductions by 3mm/day in each ECOSTRESS pixel, on average. We are field-validating the ECOSTRESS ET results using a large network of sapflow sensors across our study area. Our results indicate ECOSTRESS data can be used to understand the ecohydrological impacts of regional-scale thinning efforts on drought resiliency across larger spatial extents.

References

Fisher, J. B., Lee, B., Purdy, A. J., Halverson, G. H., Dohlen, M. B., Cawse‐Nicholson, K., et al. (2020). ECOSTRESS: NASA's Next Generation Mission to measure evapotranspiration

from the International Space Station. Water Resources Research, 56, e2019WR026058. https://doi.org/10.1029/2019WR026058

Hamberg, L., J. Fisher, J. Ruppert, J. Turecek, D. Rosen, and P. James. 2022. Assessing and modeling diurnal temperature buffering and evapontranspiration dynamics in forest restoration using ECOSTRESS thermal imaging. Remote Sensing of Environment: 280: 113178

Simonin, K., Kolb, T. E., Montes-Helu, M., & Koch, G. W. 2007. The influence of thinning on components of stand water balance in a ponderosa pine forest stand during and after extreme drought. Agricultural and Forest Meteorology, 143(3-4), 266-276.

United States Department of Agriculture (USDA). 2013. Draft Environmental Impact Statement for the Four-Forest Restoration Initiative. Coconino and Kaibab National Forests, Coconino County, Arizona.