Influence of Managed Forest Structure on Hillslope-scale Post-thinning Recovery and Water Yield

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Abstract

Forest management can enhance forest resiliency against natural disturbances such as fire, drought, or disease. Mechanical thinning, followed by a prescribed burn, is a useful technique to achieve a desired forest structure, usually maximizing large tree basal area or decreasing fuel loads, meant to protect against wildfire or reduce water stress in the western US. Changing forest structure can alter ecosystem function by reducing competition and exposing soil, modifying microclimates and creating suitable conditions for shrubs and grasses to encroach. Typically, forest treatments are expected to make the remaining trees more productive through competitive release, and an open canopy helps the understory to thrive. This enhanced plant water use often contradicts the expected result of increased streamflow following thinning. In mountainous terrain, water yield is further complicated by hillslope-scale processes of subsurface lateral flow and groundwater recharge. This research seeks to understand how management-derived forest structure influences hillslope-scale forest regrowth and water yield. We apply a spatially-distributed ecohydrologic model (RHESSys) to an experimental hillslope in the Sierra Nevada, CA. We incorporate multi-temporal Lidar observations and U.S. Forest Service Forest Inventory & Analysis (FIA) survey data to estimate post-thinning regrowth in treated plots in the watershed, which is used to verify RHESSys accuracy of vegetation regrowth. Then, we run long-term virtual thinning experiments to understand how the combination of thinning and prescribed burns in upslope and riparian sites separately and concurrently influences regrowth and water fluxes in these sites. We expect that an intermediate forest density will yield the most co-benefits in terms of carbon sequestration and water yield. However, these patterns will likely be modified along a hillslope, such that riparian forest stands will be less sensitive to the competitive release that thinning provides, whereas dense upslope forests will be highly sensitive to treatment since they are more water-limited. Water yield is likely to be confounded by multiple factors, including topography, whether a burn follows thinning to remove understory fluxes, and interactions between upslope thinning and processes of lateral flow and groundwater recharge when increased riparian water use compensates for additional upslope subsidies.

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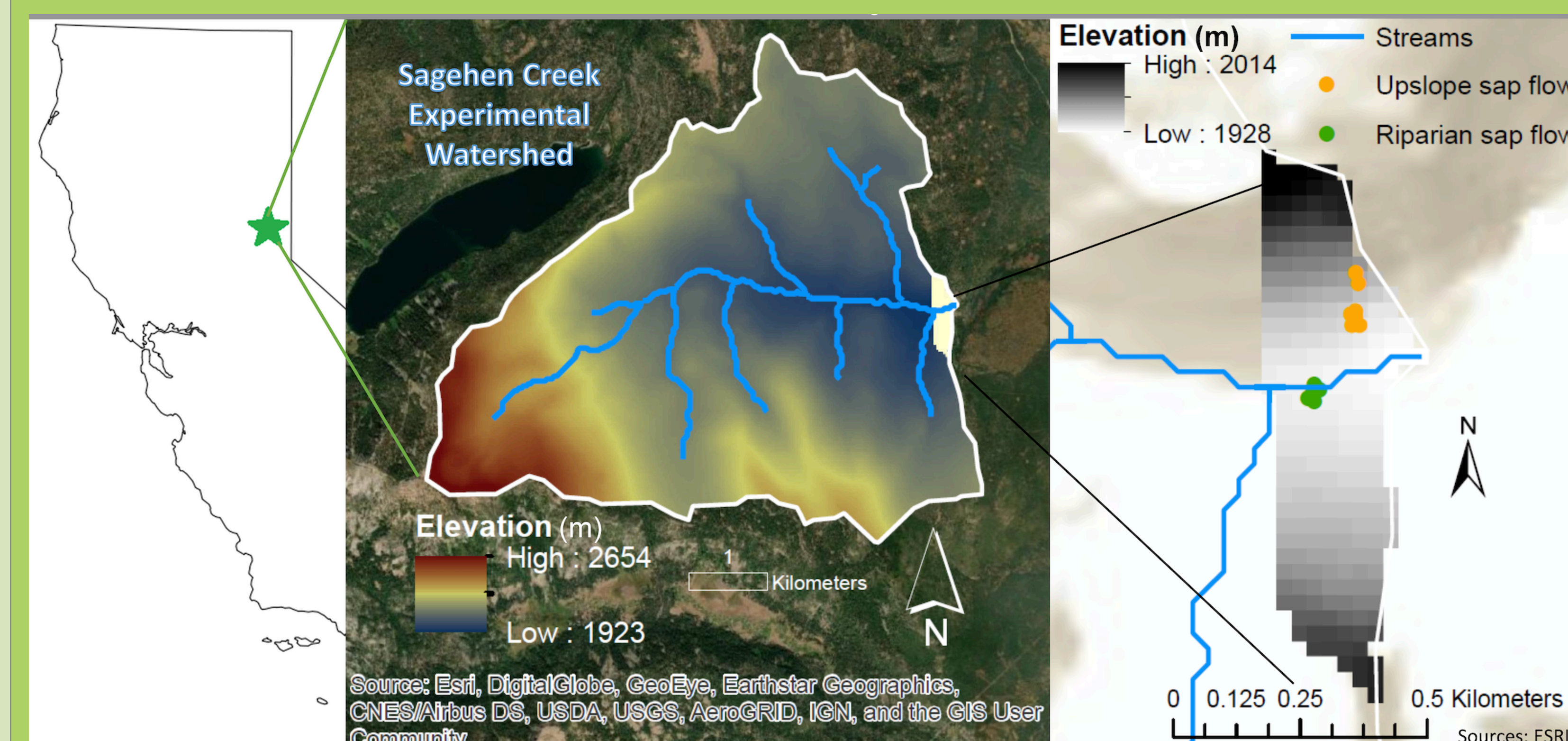
Study Site

Sagehen Creek Experimental Watershed
Sierra Nevada, CA

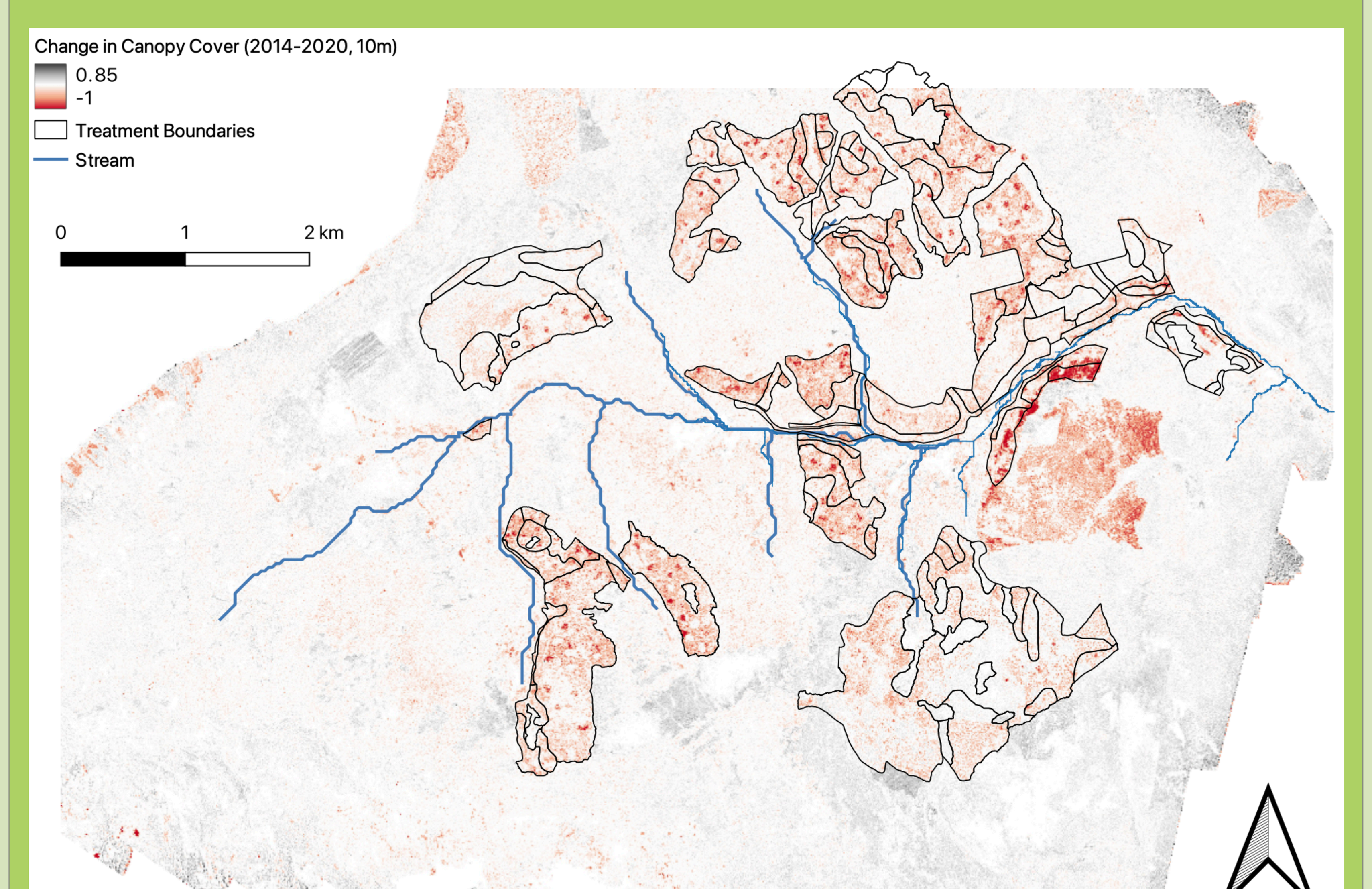
- Catchment area: 27 km²
- Mean Annual Precipitation: 850 mm
- Thinned in 2015-18 by USFS



Research Questions

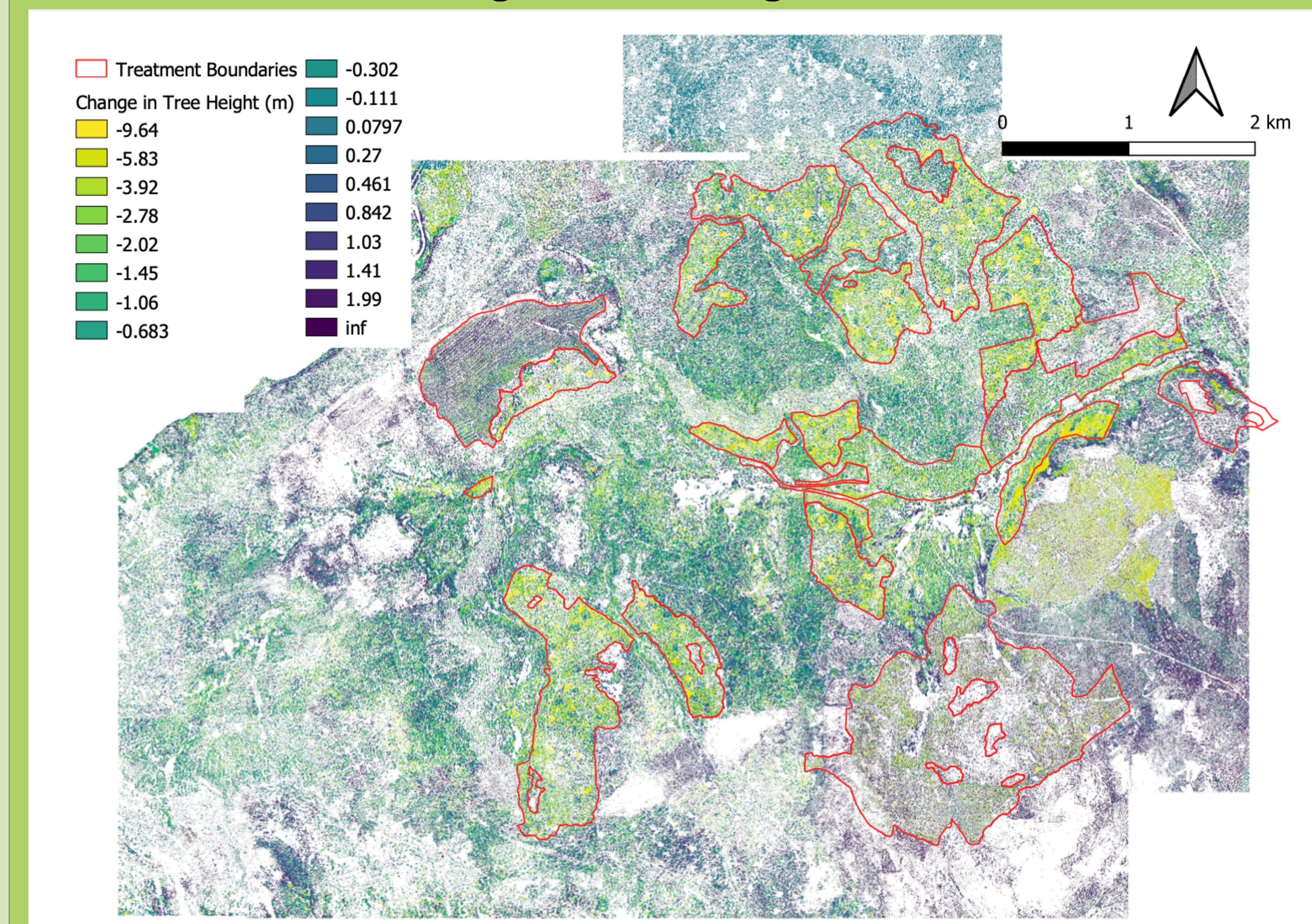
1) How do forest treatments change forest structural heterogeneity across space and over time? (Lidar analysis)
2) How do forest thinning treatments affect upslope and riparian sites differently? (Ecohydrologic model analysis)

Lidar-derived Change in Canopy Cover with Fuel Treatment

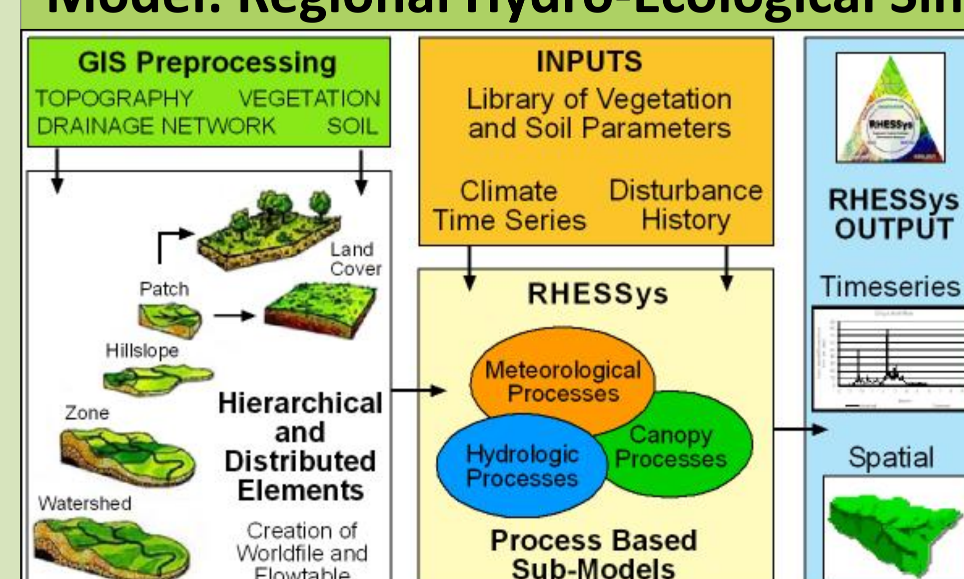


Graup, L. (2021). Preserving Mountains with Forest Management, CA 2020. National Center for Airborne Laser Mapping (NCALM). Distributed by OpenTopography. https://doi.org/10.5069/G96H4FMX.

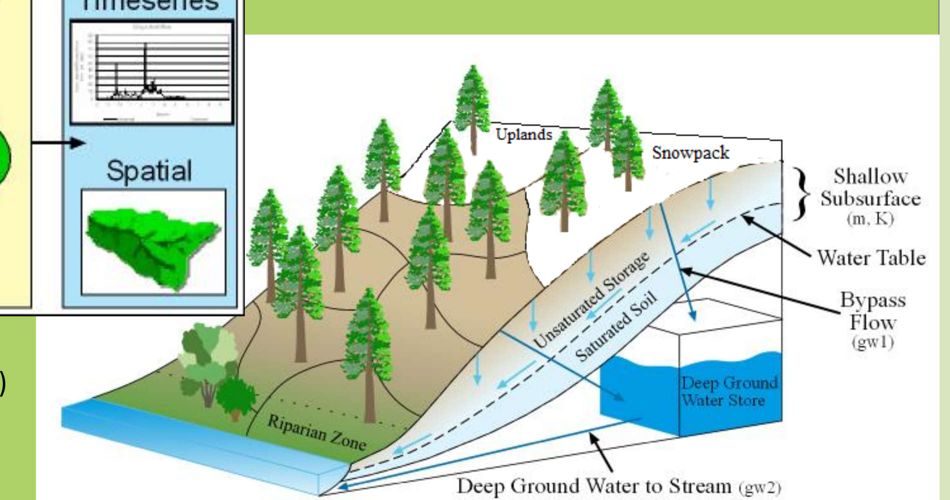
Tree Crown-scale Change in Tree Height with Fuel Treatment



Model: Regional Hydro-Ecological Simulation System (RHESSys)

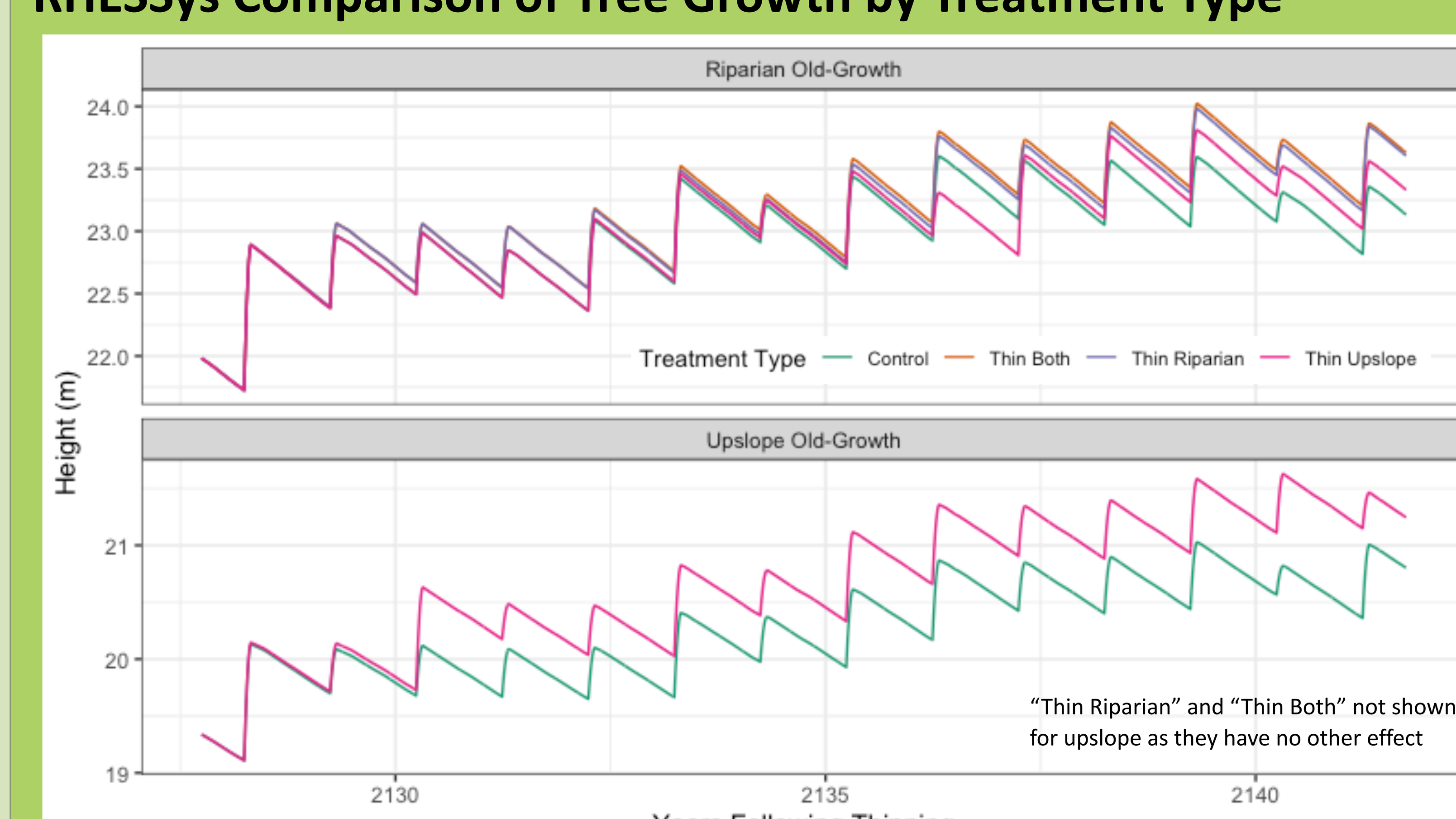


Hillslope Ecohydrology RHESSys Conceptual Model

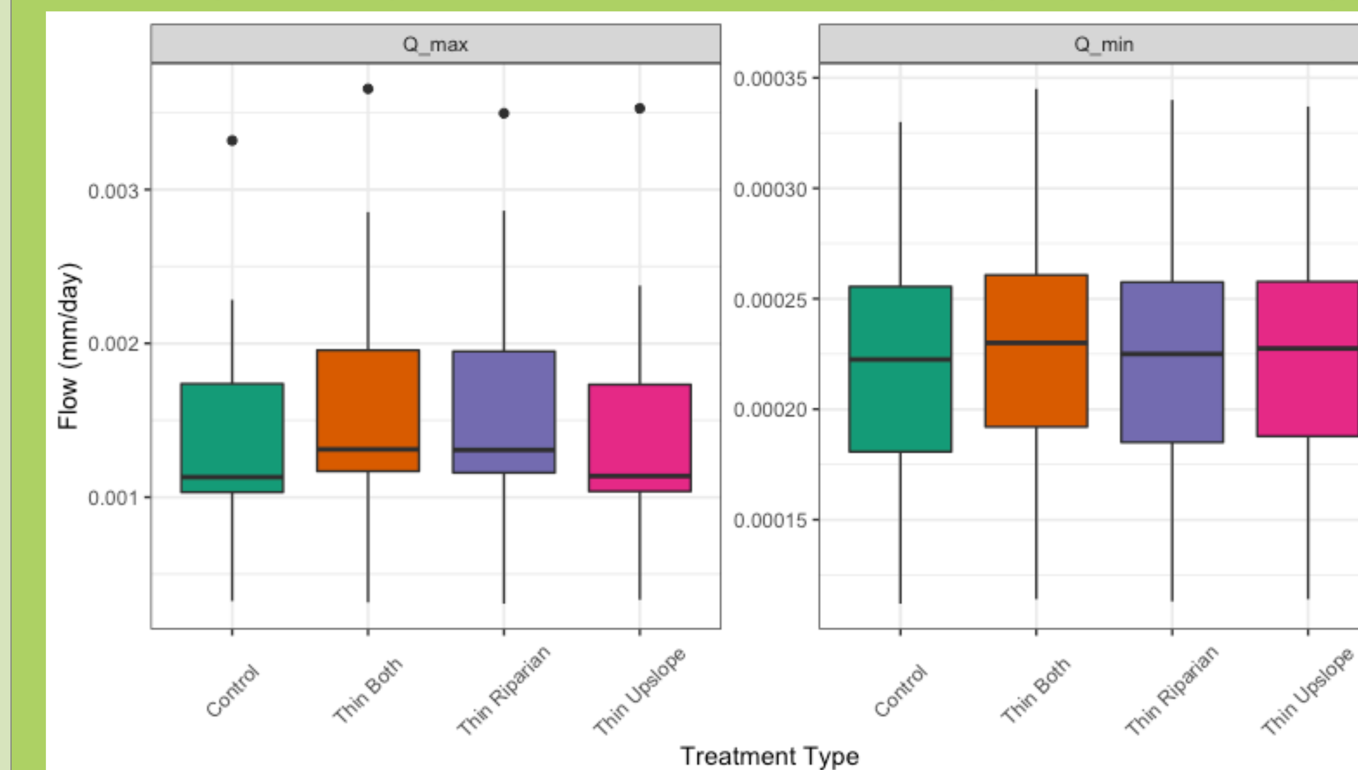


Graup, L.; Tague, C.; Harpold, A.A.; Krogh, S.K. (in review) "Subsurface Lateral Flows Buffer Riparian Water Stress Against Snow Drought." *JGR-Biogeosciences*

RHESSys Comparison of Tree Growth by Treatment Type

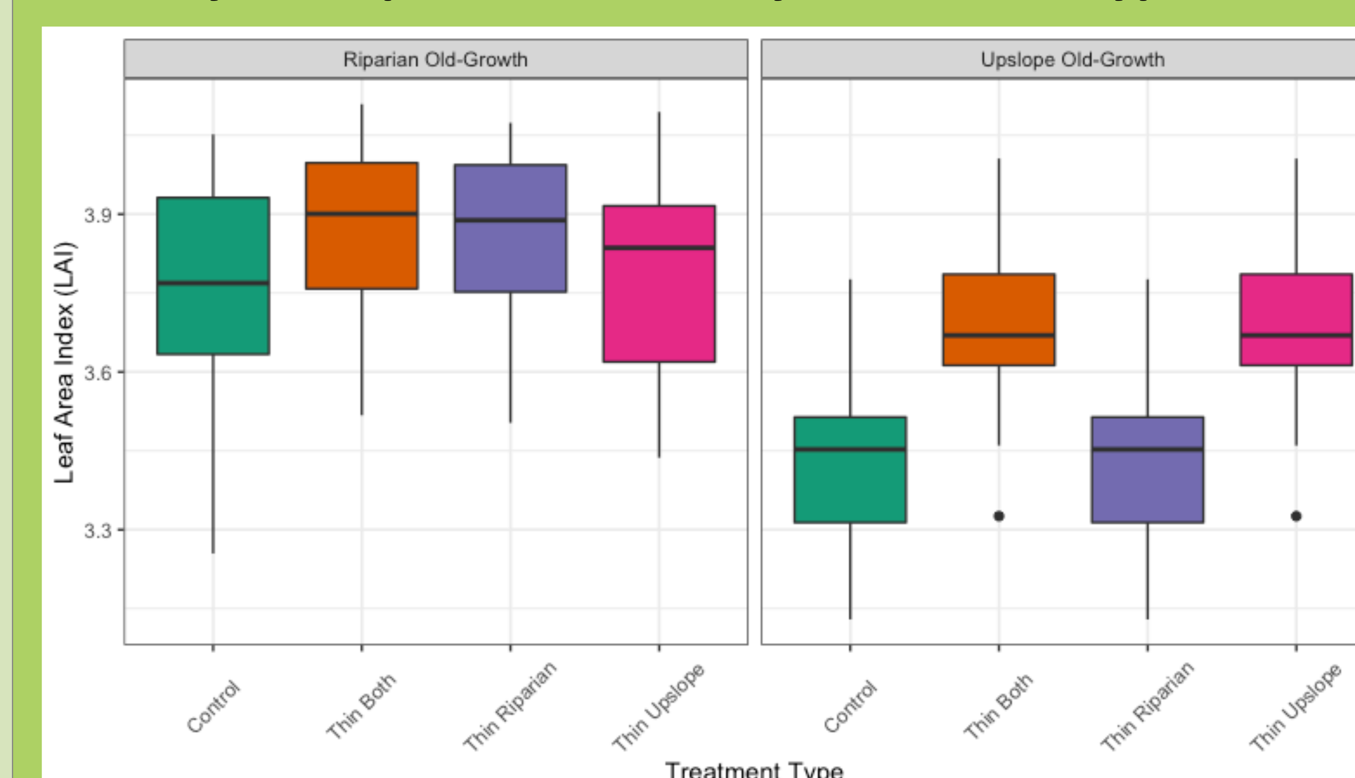


RHESSys Comparison of Streamflow by Treatment Type



Streamflow is described by Q_max, or annual peak daily flow, and Q_min, or annual minimum daily flow, across 15 years of post-thinning RHESSys simulations for different treatment types

RHESSys Comparison of LAI by Treatment Type



Maximum annual Leaf Area Index (LAI) is shown for upslope and riparian old-growth trees (remaining trees after thinning), across 15 years of post-thinning RHESSys simulations for different treatment types

Conclusions

- Impacts of treatment on minimum annual streamflow are minimal for all treatment types; minor increase in peak flow only if riparian trees are treated
- Substantial benefit of upslope thinning to productivity of remaining trees, including trees in downslope riparian area
- Riparian thinning shows more modest gains in productivity of remaining trees

Credits/Acknowledgments

github.com/RHESSys/RHESSys
fiesta.bren.ucsb.edu/~rhessys

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