H31G-0690 (AGU 2014)

Modeling the effects of tree-to-shrub type conversion on streamflow in California's Sierra Nevada

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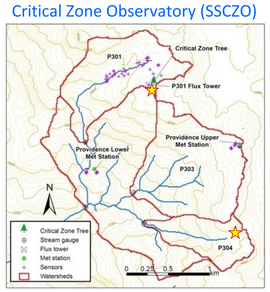
Motivation

Climate change may lead to vegetation type conversion in California, which can influence watershed hydrology. To advance our understanding of how sensitive hydrologic processes are to shifts in vegetation type, we asked:

1. How do water availability and use change for dominant tree and shrub species during the peak growing season in a southern Sierra Nevada forest ecosystem?
2. What is the best way to integrate physiological responses of trees and shrubs into a process-based ecohydrology model?
3. How do physiological differences between shrubs and trees scale up and affect streamflow under vegetation type-conversion scenarios?

Materials and Methods

Sites in Southern Sierra Nevada Critical Zone Observatory (SSCZO)



FIELD SAMPLING

Time: 6 April 2014 – 24 October 2014

Plant physiological responses:
Predawn leaf water potential (MPa)
Stomatal conductance (G_s)

Species (5 indls/spp/site)**:**

Trees

Abies concolor (White fir)

Calocedrus decurrens (Incense cedar)

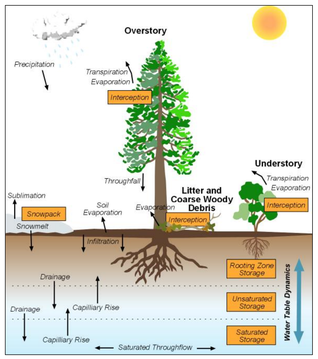
Shrubs

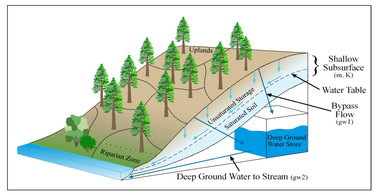
Arctostaphylos patula (Greenleaf manzanita)

Ceanothus cordulatus (Mountain whitehorn)

ECOHYDROLOGIC MODELING

Field data were used to parameterize RHESSys, a physically-based ecohydrologic model for simulating hydrologic and carbon fluxes at watershed scales.





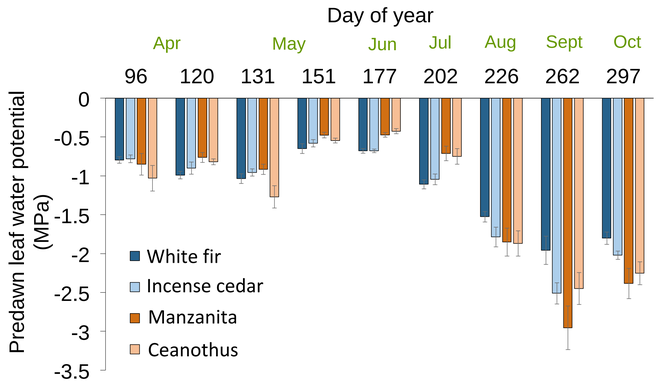
Modeling details:

- Watershed (P301) – 0.99 km^2
- Field-based parameterization
- 100% tree → shrub
- Conversion scenarios: Shrubs = 1/4th & 1/8th tree LAI

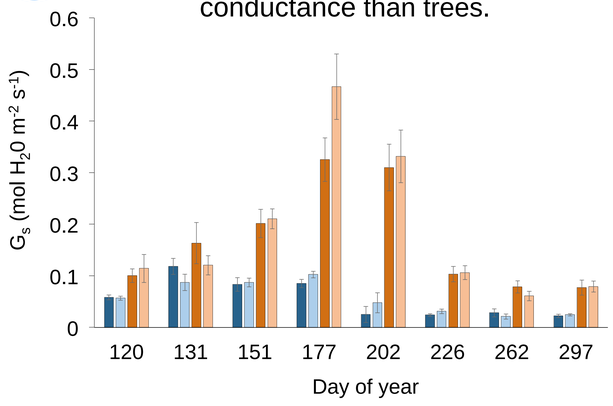
Results

1) Plant ecophysiological observations

1a Trees and shrub do not show consistent differences in access to water.

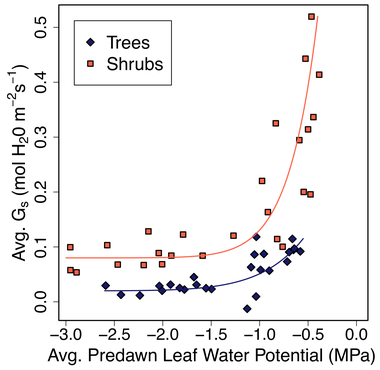


1b Shrubs maintain higher stomatal conductance than trees.

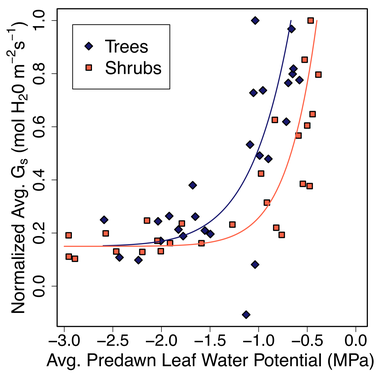


2) Ecohydrologic model parameterization

2a Shrubs exhibit higher stomatal conductance at high water availability.

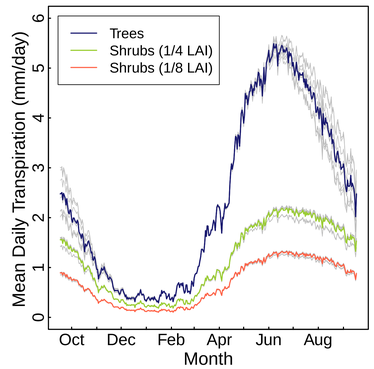


2b Normalized stomatal conductance shows similar functional response.

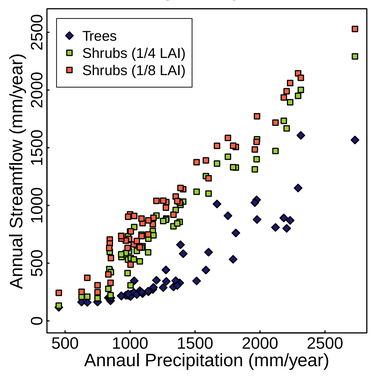


3) Modeled streamflow

3a Transpiration is most sensitive to variation in leaf area index.



3b Post-conversion changes in streamflow are greatest during wet years.



Summary

1. Shrubs have higher per-leaf area conductances compared to trees during the growing season (early Spring-late Fall), however, model results suggest that the greater leaf area of trees still leads to higher total transpiration fluxes by trees.
2. Normalized stomatal conductance reveals a similar sensitivity of trees and shrubs to changes in water availability.
3. Reducing leaf area at the watershed scale had greater impact on modeled transpiration than did integrating field observations due to deep soils at the SSCZO.
4. Streamflow increased following 100% tree-to-shrub type conversion. More realistic scenarios (e.g. partial watershed conversion) are needed to substantiate these results.

Acknowledgements Funding support for this research was provided by the California Energy Commission with help from the Southern Sierra CZO. We would like to thank Rodney Feddema and Josie Lesage for their excellent assistance in the field and post-processing of samples in laboratory.