Understanding the Impact of Plant Hydraulic Strategy on Forest Dynamics of the Southern Sierra Nevada Region

Junyan Ding, Chonggang Xu, Polly Buotte, Rosie Fisher
Mike Goulden, Lara Kueppers, Jackie Shuman, and Charlie Koven

The Ecosystem of Southern Sierra

Site	vegetation	Elevation (m)	Annual precipitation (mm/yr)	Mean Min T	Mean Max T
CZ1	Oak savanna	405	513	9.3	23.5
CZ2	Pine/Oak forest	1160	805	5.5	18
CZ3	Mixed pine forest	2015	1015	2.7	14.8
CZ4	Subalpine conifer forest	2700	1078	-1.9	10.2

Pine

Oak

(Goulden et al., 2012; Klos et al., 2017)

Objective

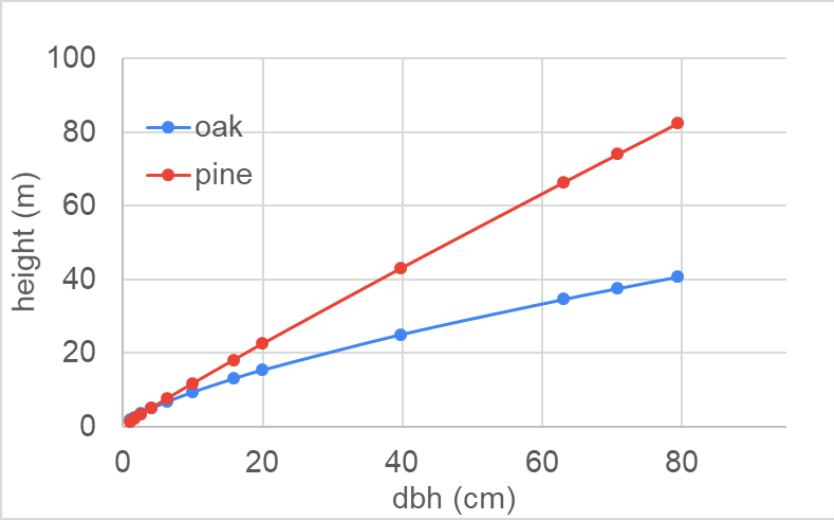
Using FATES-Hydro to investigate:

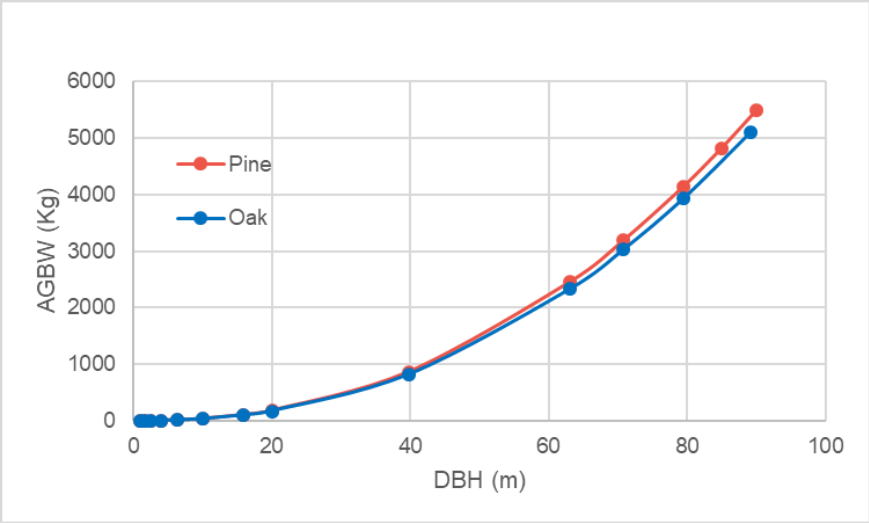
1. To what extent can hydraulic strategy affect the biomass, carbon and water flux of oak and pine forest along the elevation transect in the Sierra?

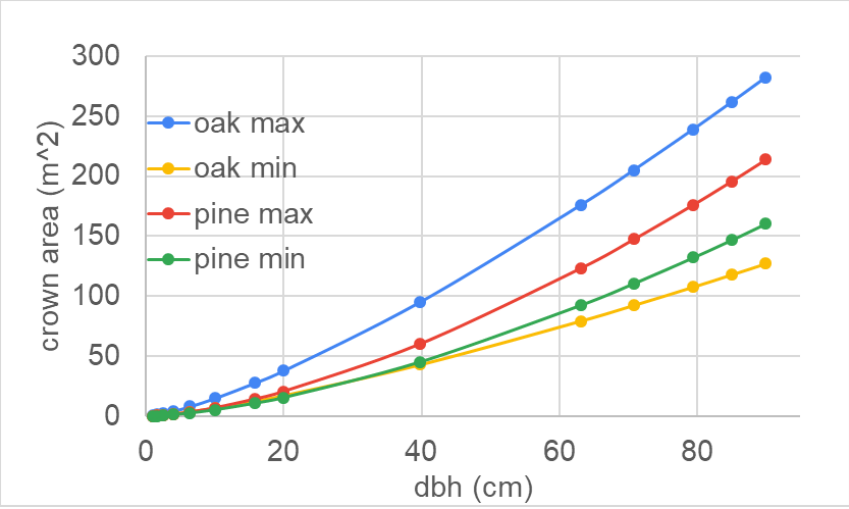
2. What are the most important hydraulic traits that control the composition of pine/oak forest under different climatic conditions in that region?

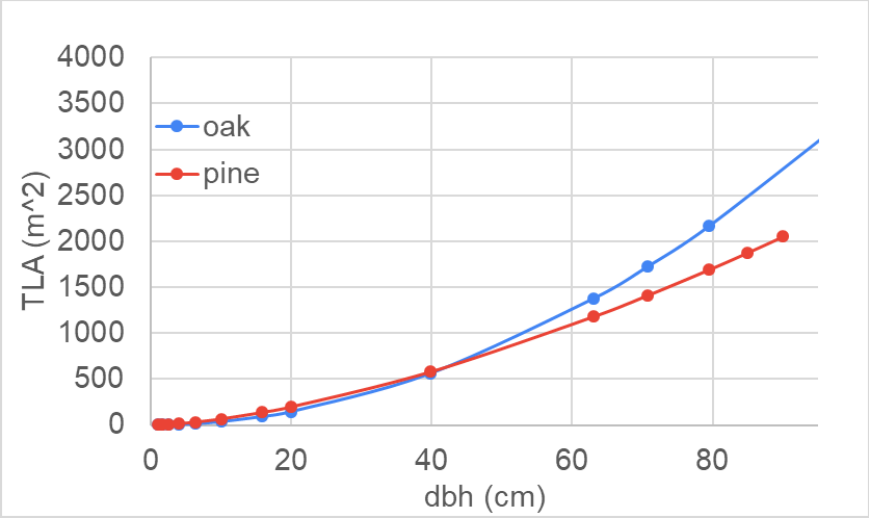
Methods – Represent Pine and Oak in FATES

Allometry







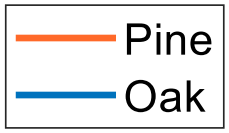


Methods – Represent Pine and Oak in FATES

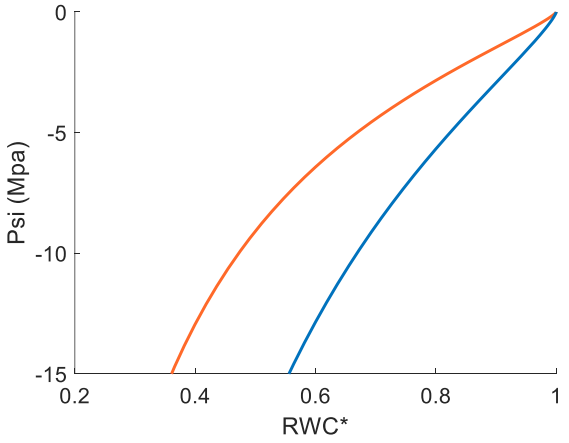
Physiology

Parameters	Oak (cold deciduous)	Pine (ever green)
SLA (m^2/gC)	0.012	0.008
Vcmax	70	50
bbslope	8	8
Leaf longevity (Yr)	1.2	4
wood density	0.6	0.4275
Cold mortality Threshold (C)	-1	-15
Storage cushion	4	1.3

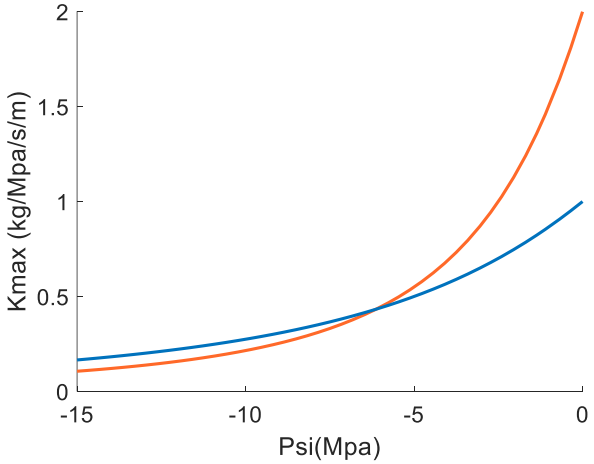
Xylem



P-V curve



Vulnerability curve



Methods – Sensitivity Analysis

Model setup

- 200 years run at CZ1 and CZ2 (GSWP3 met forcing 1980 – 2012)
- initialized from bare ground
- 3 treatments: 1pft-pine, 1pft-oak, and mixed pine and oak
- Global sensitivity analysis: 162 instances for each PFT , 216 instances for 2PFT

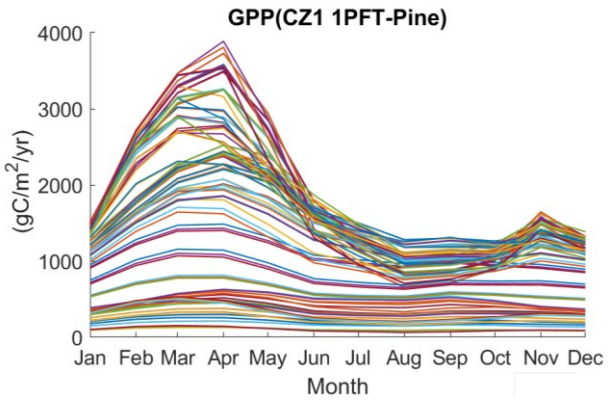
Sensitivity analysis

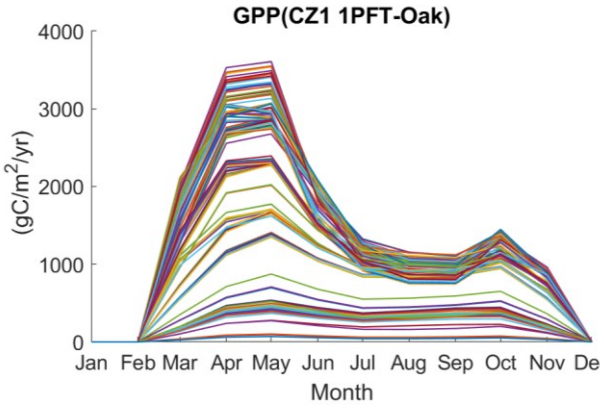
Parameters	Units	Description	Range of variation	
		Xylem	Pine	Oak
P50x	Mpa	xylem water potential at half loss of max conductivity	-2 ~ -3	-4 ~ -6
Kmax	kg/Mpa/m/s	maximum conductance of xylem	4 ~ 2	1.5 ~ 0.7
		Stoma		
P50gs	Mpa	leaf water potential of half closure of stoma	P50x ~ P75x	
ags	unitless	parameter control the rate of stoma closure	0.76 ~ 18, depends on P50gs	
		root		
l2fr	ratio	Fine root biomass to leaf biomass ratio	1 ~ 10	
srl	m/g	specific fine root length	120 ~ 30	
rs2	m	fine root radius	0.00005 ~ 0.002	

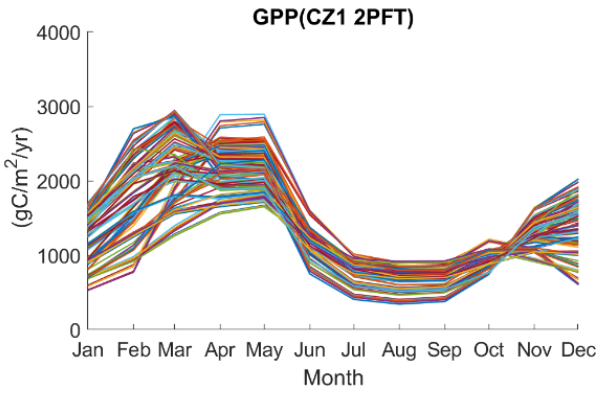
Results – 32 Yr. Averaged Monthly GPP

1pft pine | **1pft oak** | **2pft**

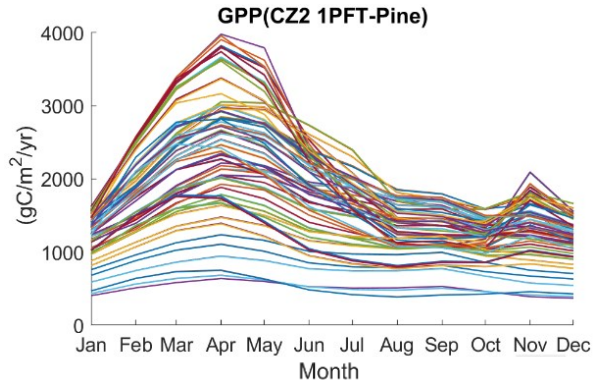
CZ1

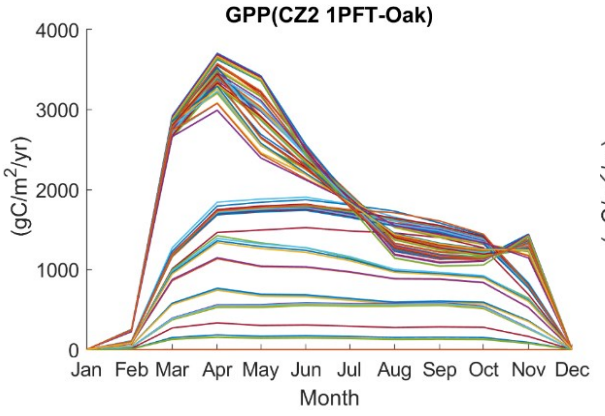


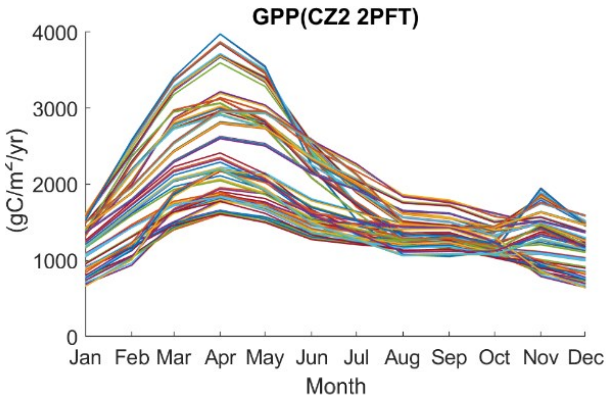




CZ2





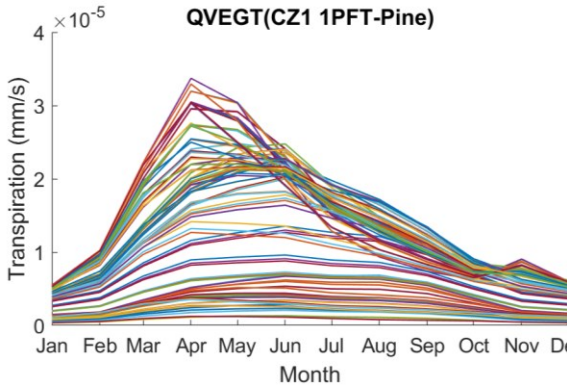


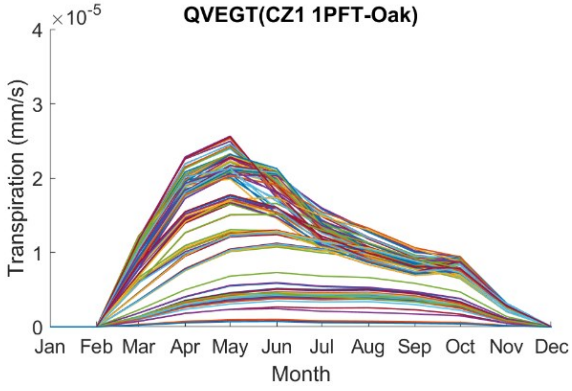
- **Large variation of magnitude and phase of simulated GPP seasonal cycle**
- **Great difference in seasonality of oak between two sites**

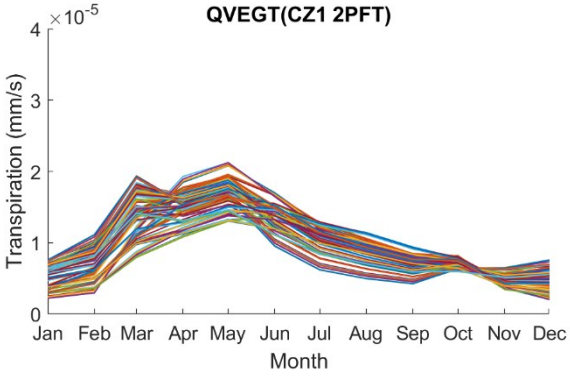
Results - 32 Yr. Averaged Monthly Transpiration

1pft pine | **1pft oak** | **2pft**

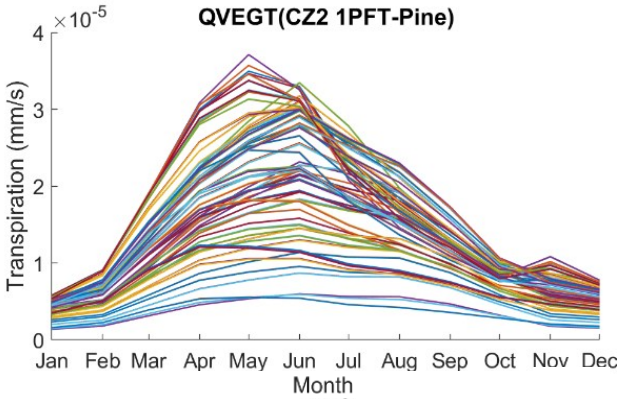
CZ1

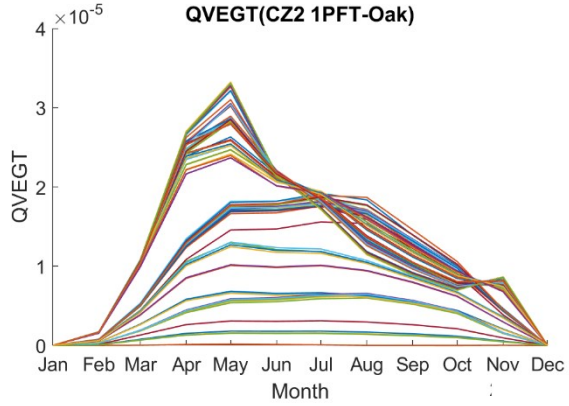


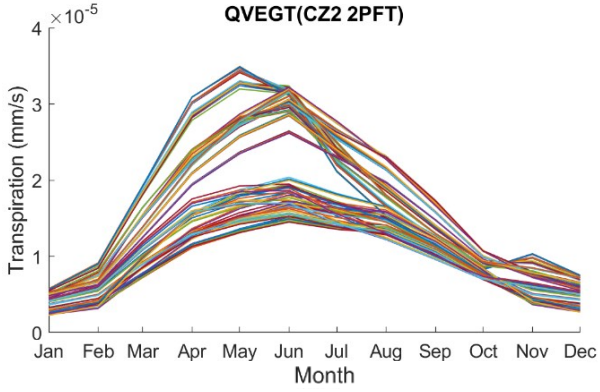




CZ2



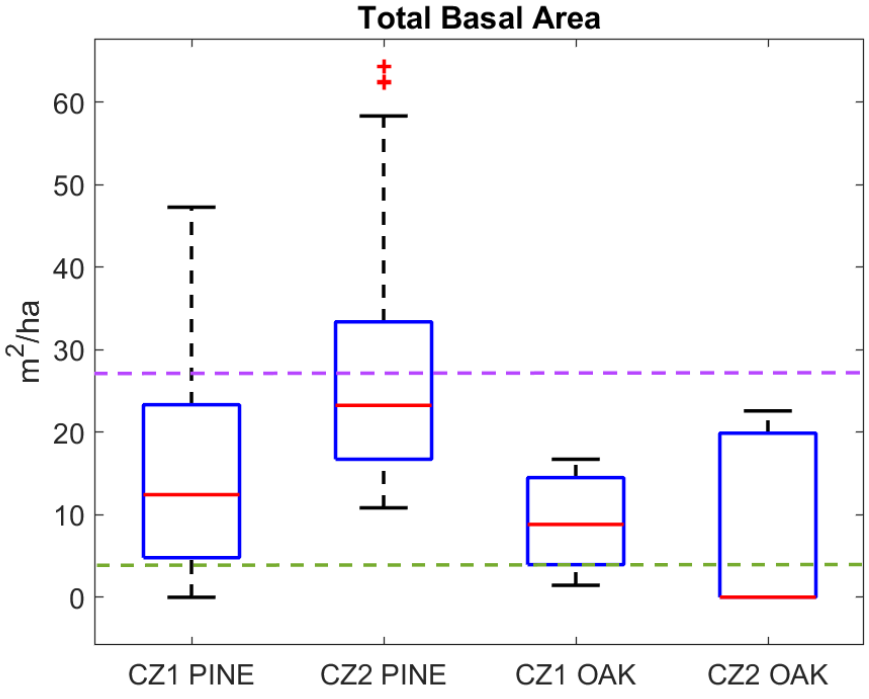




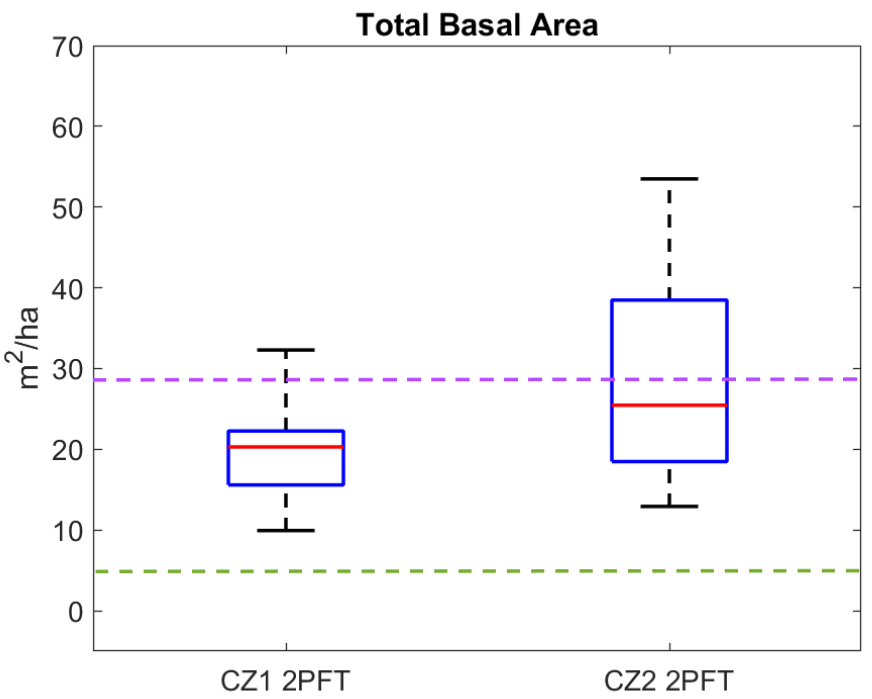
- **Large variation of magnitude and phase of simulated seasonal cycle of transpiration**

Results – Total Basal Area

Single PFT



2PFT



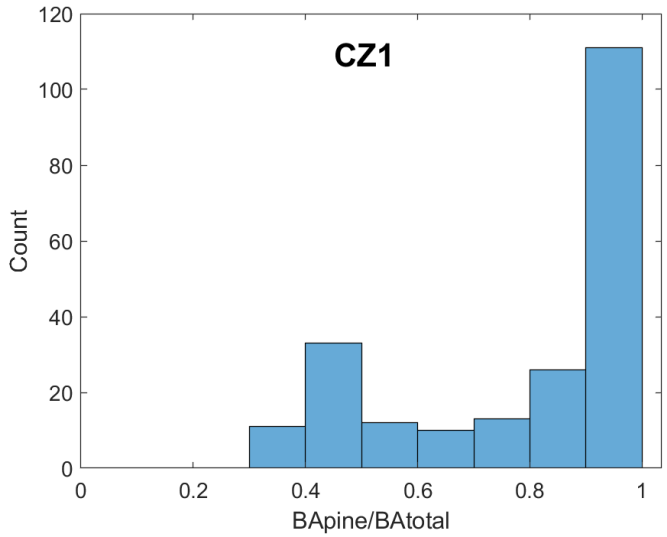
Observed total BA of CZ1

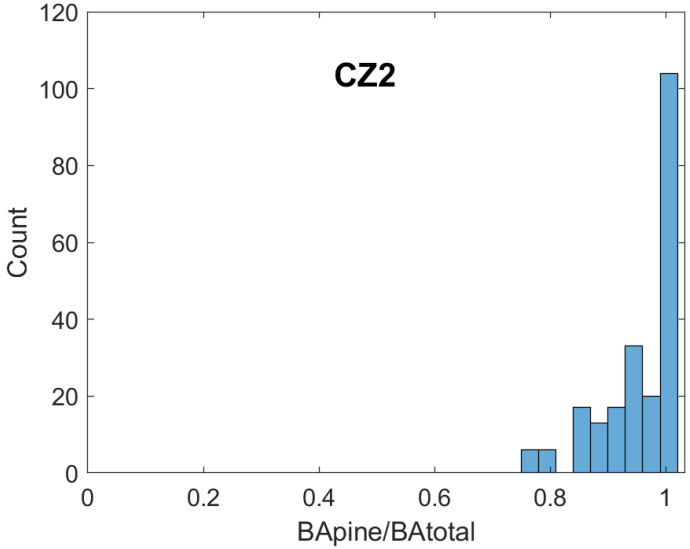
Observed total BA of CZ2 (2010)

- Large variation of basal area
- Most impactive parameters: l2fr (oak with l2fr>2 all died at cz2), ags, p50gs

Results – Relative dominance

Proportion of pine basal area to total basal area



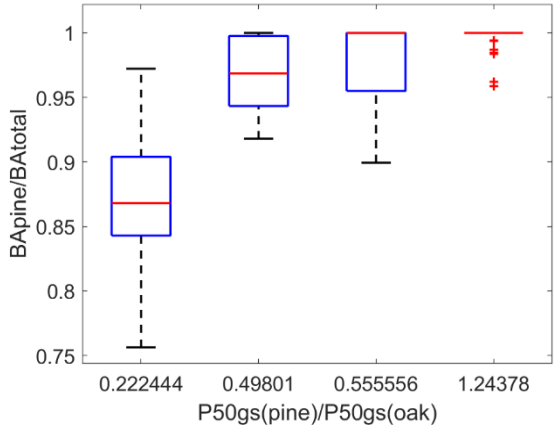


Factors control the relative abundance:

CZ1

?

CZ2: P50gs ratio



Summary

- Differ in hydraulic strategy can result in great variation of GPP, transpiration and basal area of forest at Southern Sierra region
- Major hydraulic traits in control: fine roots to leaf biomass ratio (l2fr), leaf water potential at half closure of stoma (P50gs), and stoma closure rate (ags)
- The difference in stoma strategy is the major control of the relative abundance of pine and oak at Southern Sierra
- Underestimated drought mortality of pine, overestimated carbon starvation mortality of oak