Ecological adaptations of white pine species across three elevation zones: The value of landscape common garden studies in evaluating phenotype by environment interactions in the Lake Tahoe Basin



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Common garden studies and phenotype x environment interactions

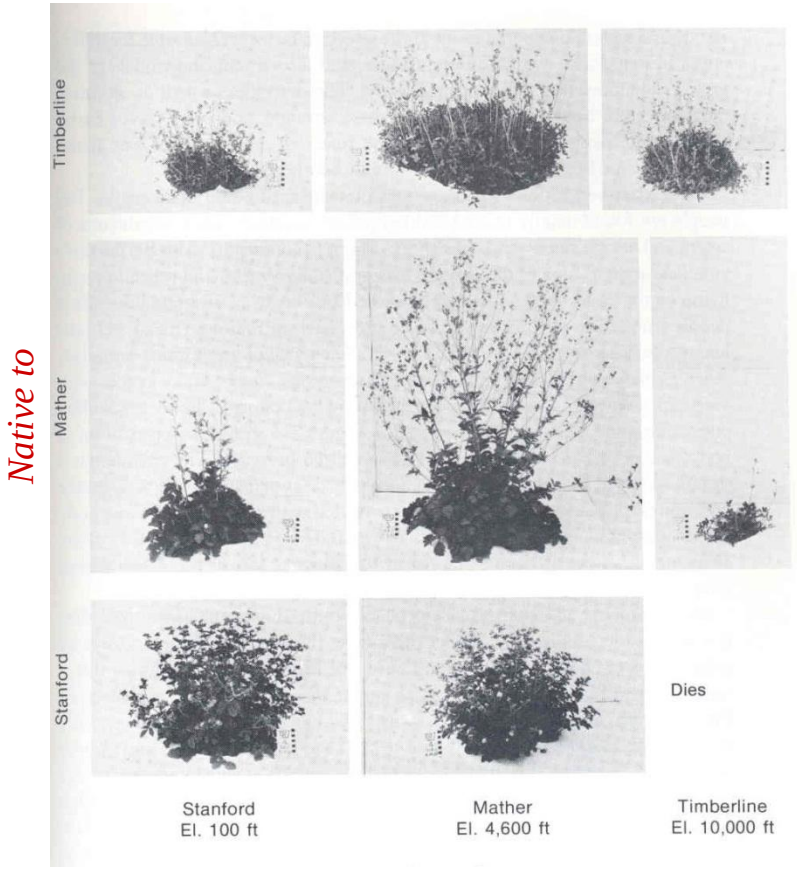
I. Seed are collected from many sources (families)

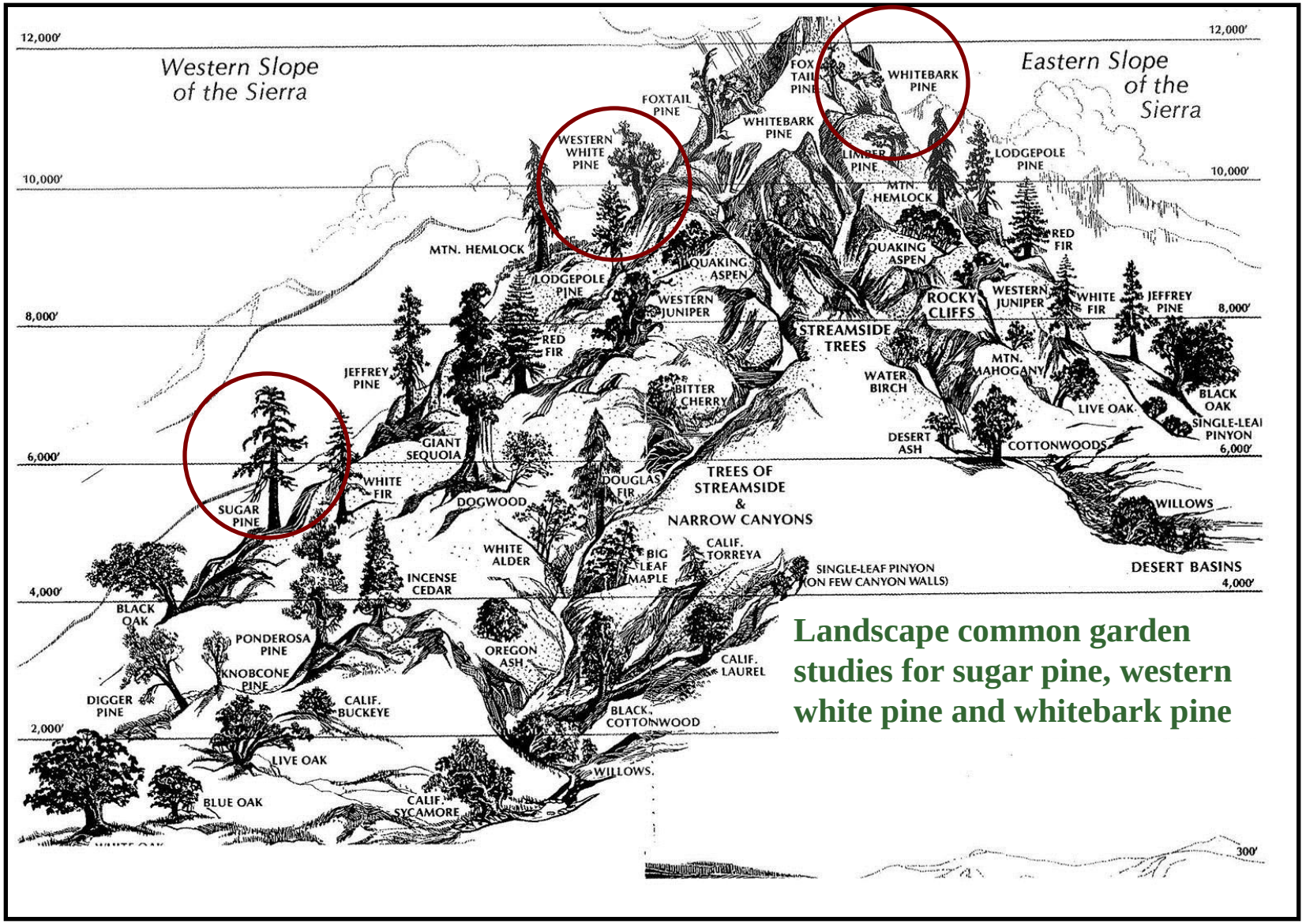
II. Families are grown in a common environment

III. Measure a variety of adaptive traits

IV. Determine relationships between traits and environment of the source locations

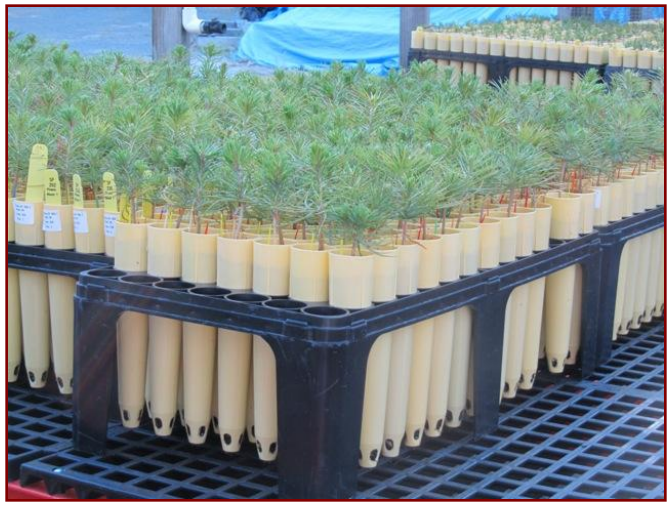
Classic experiment by Clausen, Keck, and Heisy 1940
Potentilla glandulosa - 3 source elevations





Landscape common garden studies for sugar pine, western white pine and whitebark pine

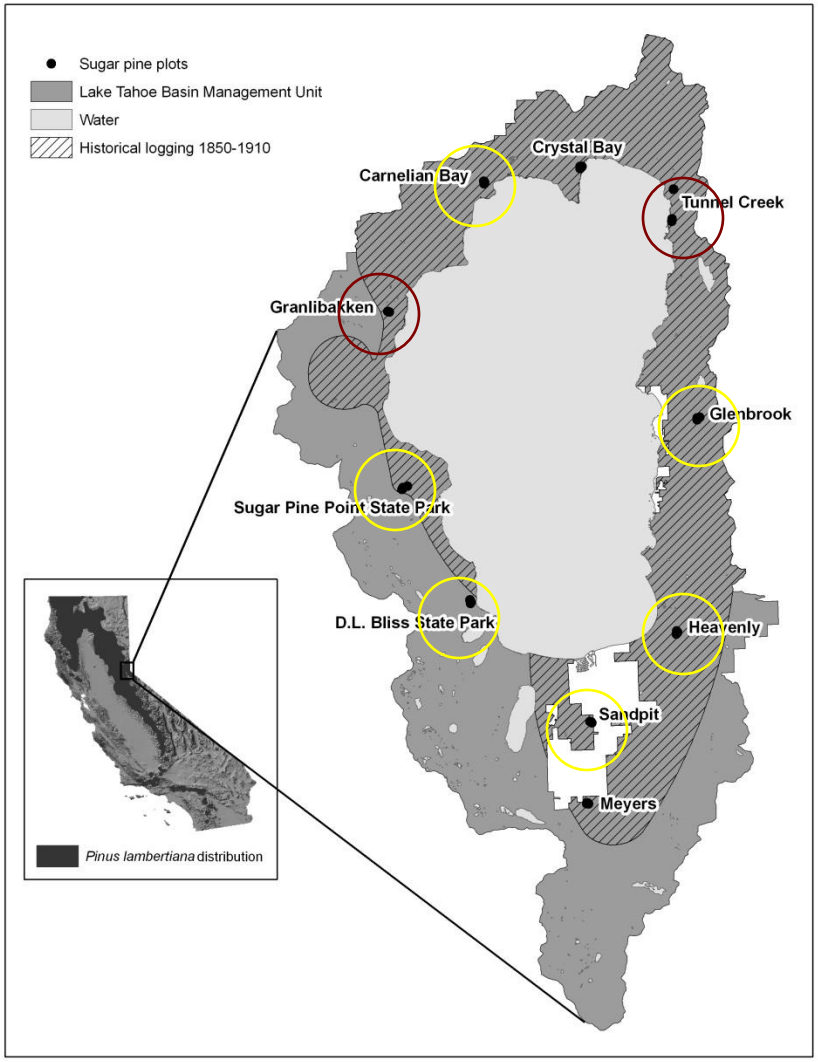
Results of genecological study of Sugar pine, *Pinus lambertiana*, from the Lake Tahoe Basin



Premise of study

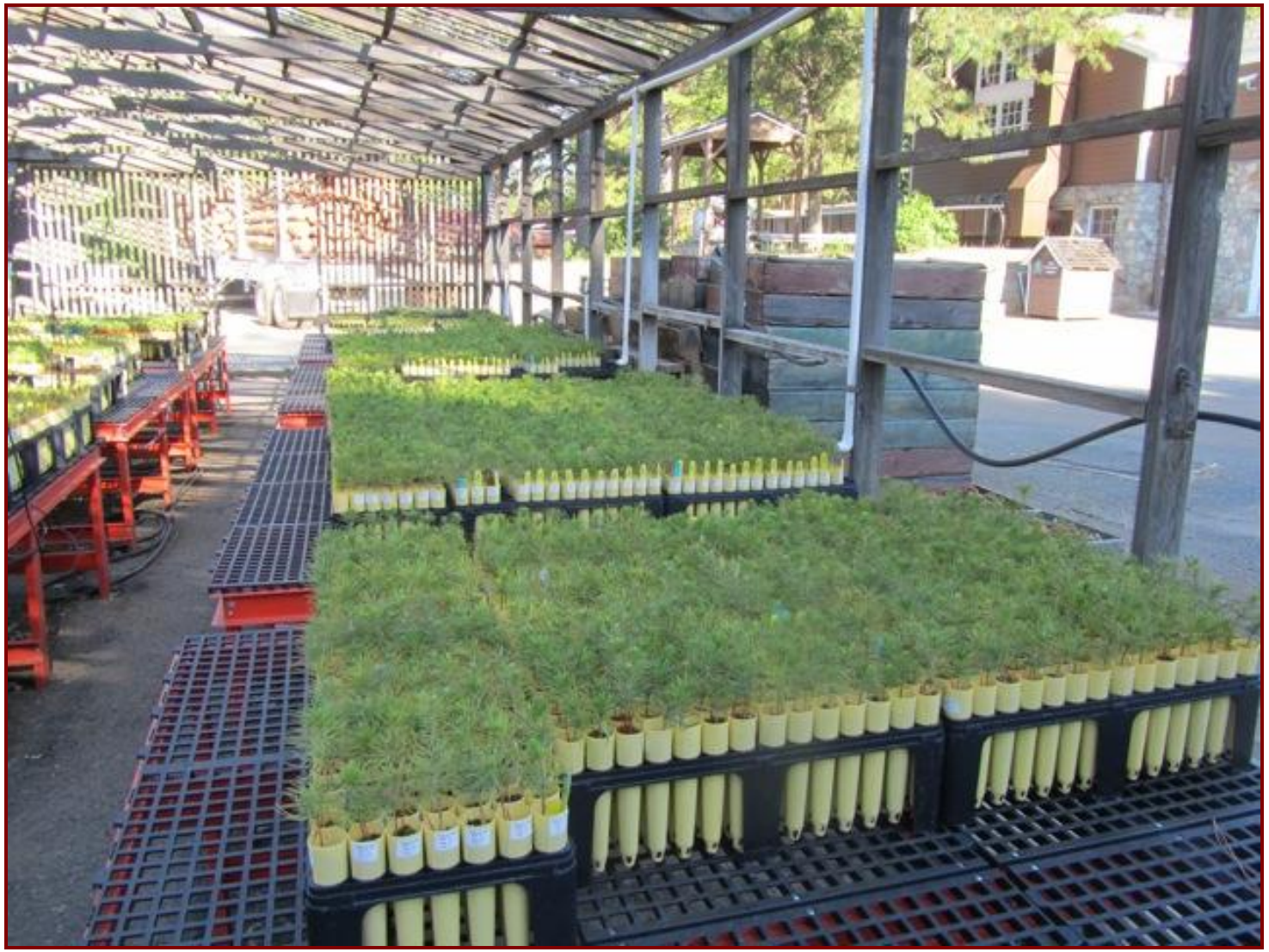
- Examine phenotype by environment interactions
- Determine landscape patterns of phenotypic variation and local adaptation

I. We collected seed from many sources (families) in the Lake Tahoe Basin



- Collected cones/seed from 10 populations
- 111 families from 8 source populations were grown in the common garden

II. Families are grown in a common environment

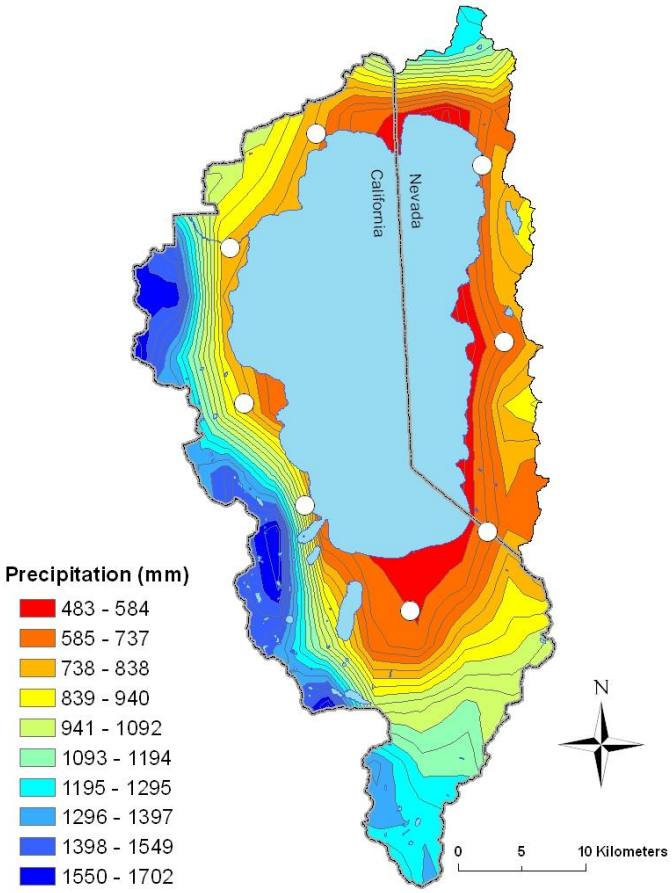


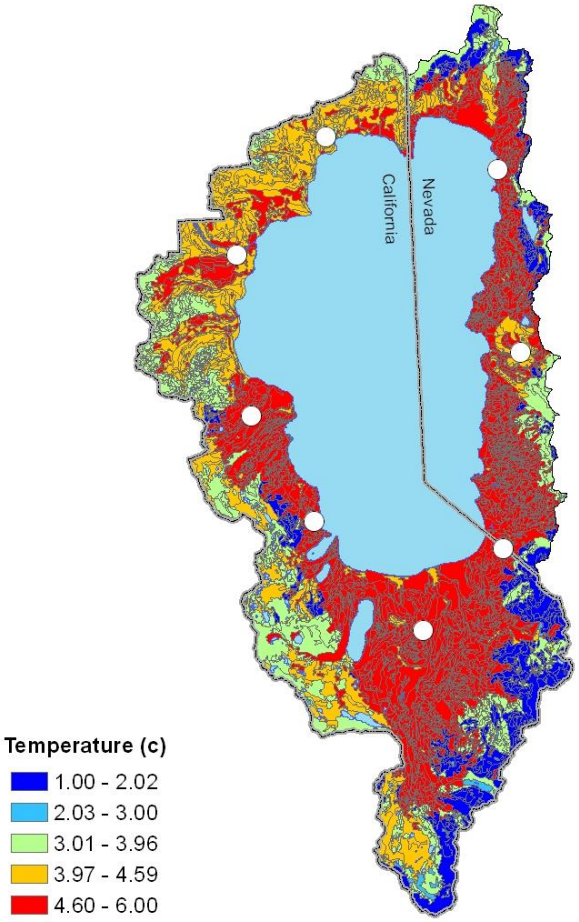
III. Measure a variety of adaptive traits

Trait	Abbreviation	Description	Units
Height increment	HTINC	April 2011 height minus October 2011 height	mm
Bud flush	BF	First visible sign of new flushed needles that were green and emerged from bud scales	julian day
Root : shoot ratio	R:S	Ratio of dry weights after 1.5 years	$g\ g^{-1}$
$\delta^{13}C$	13C	Carbon stable isotope ratio Ğa measure of water-use efficiency	(ä)
$\delta^{15}N$	15N	Foliar nitrogen content	ug

IV. Determine relationships between environment and source locations

a. Climate (annual precipitation, Tmin, Tmax, May GDD, Aug GDD, elevation, % max solar radiation input)

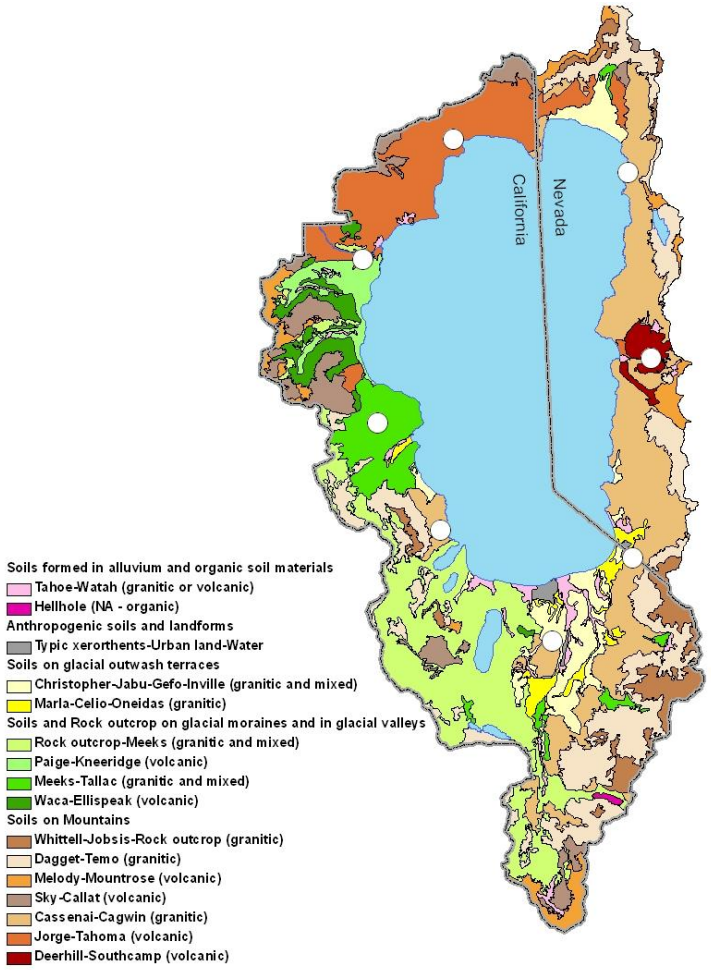


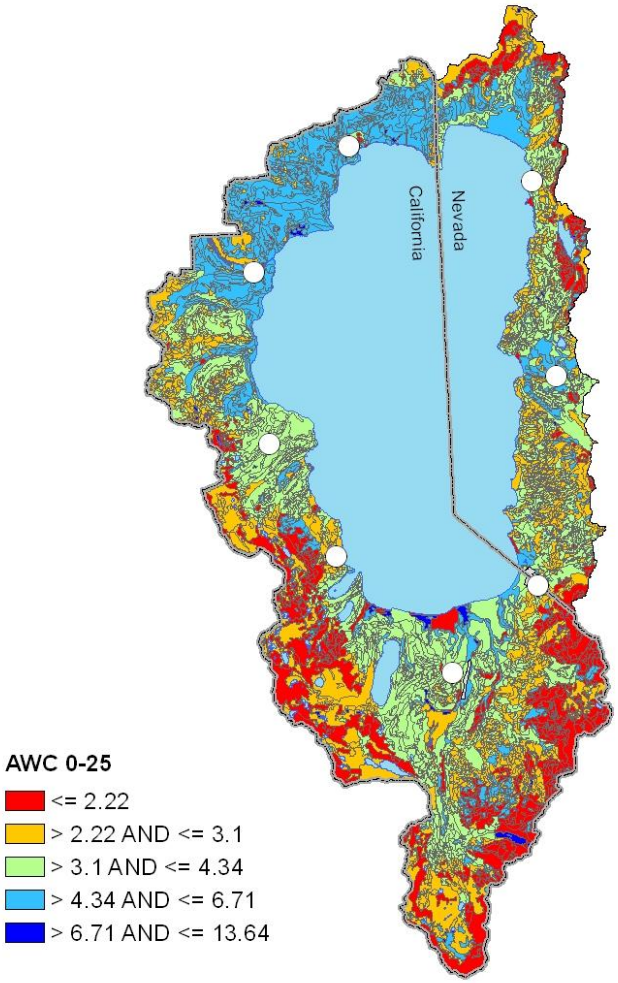


Maps courtesy of Woody Loftis, USDA NRCS

IV. Determine relationships between environment and source locations, cont'd

b. Soil (soil type, soil properties: AWC 0-25, AWC 0-50, % sand, % silt, % clay, CEC, WC -1/3 bar, WC -15 bar)

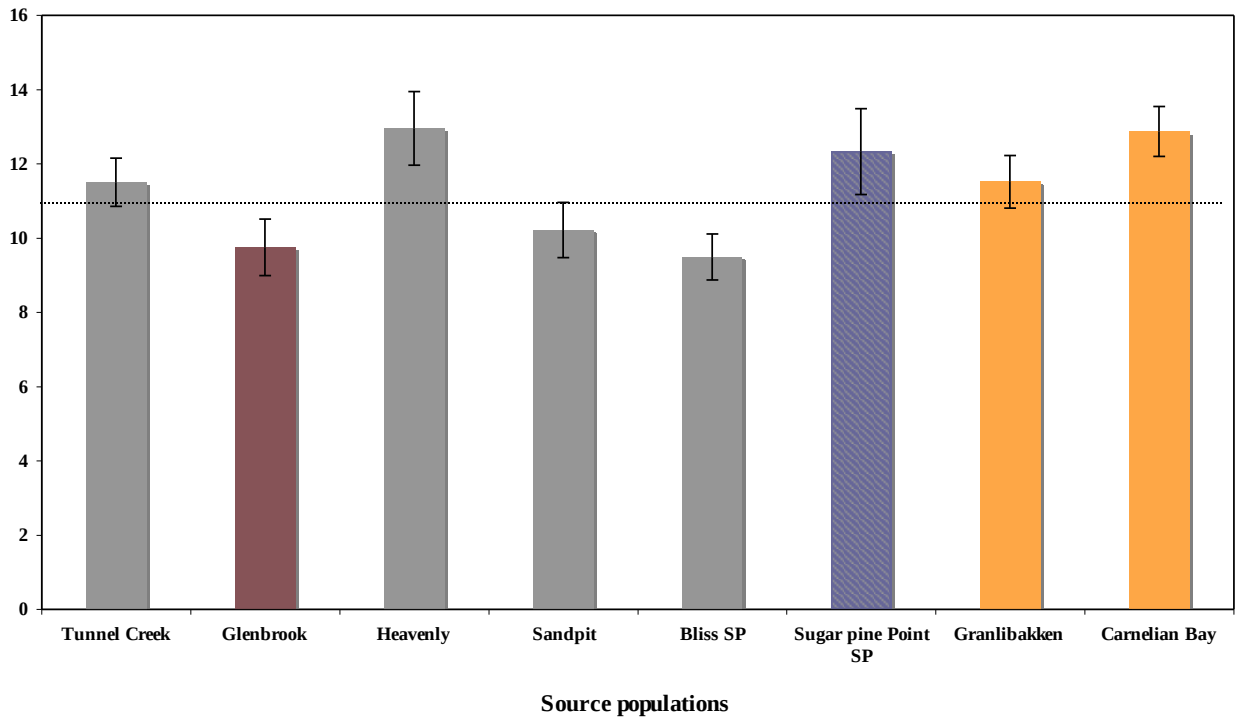




Maps courtesy of Woody Loftis, USDA NRCS

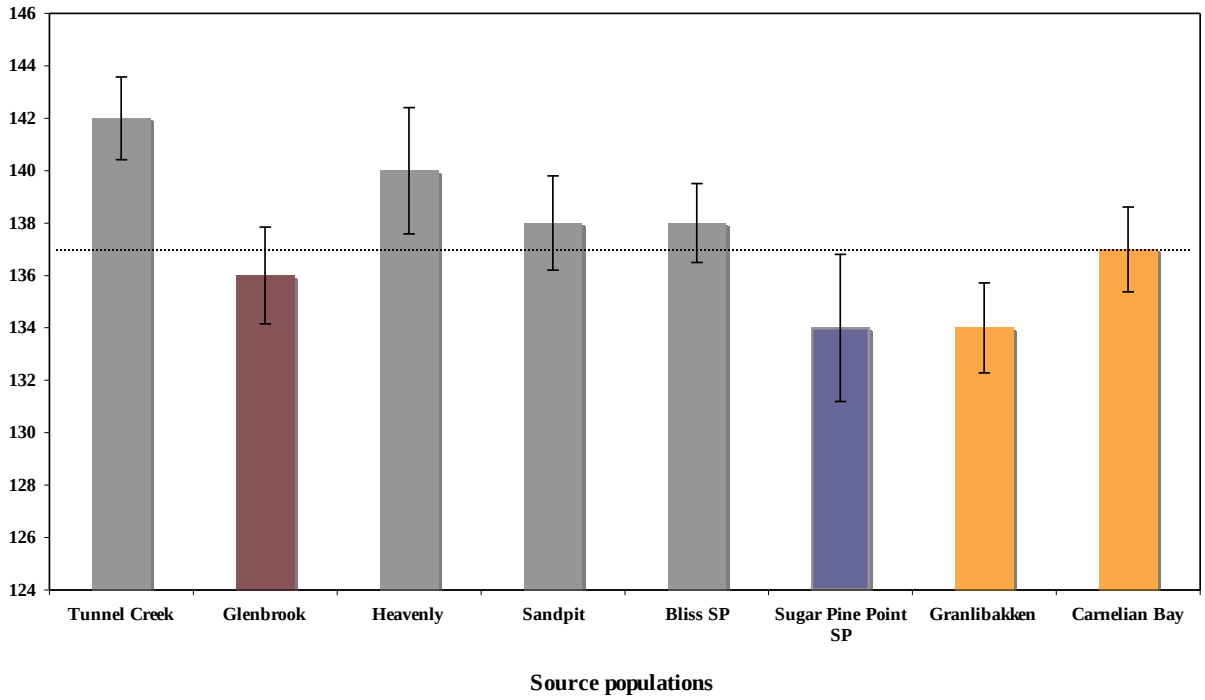
Trait – Height growth

Variable	HTINC
Elevation (m)	**-0.35**
% max. rad. input	-0.03
Ann. ppt. (mm)	-0.01
Tmin (^{o}C)	**-0.36**
Tmax (^{o}C)	-0.05
May GDD	-0.08
Aug GDD	**-0.26**
AWC 0-25	0.13
AWC 0-50	0.18
% sand	-0.11
% silt	-0.08
% clay	-0.14
CEC	0.07
WC -1/3 bar	**0.19**
WC -15 bar	0.16



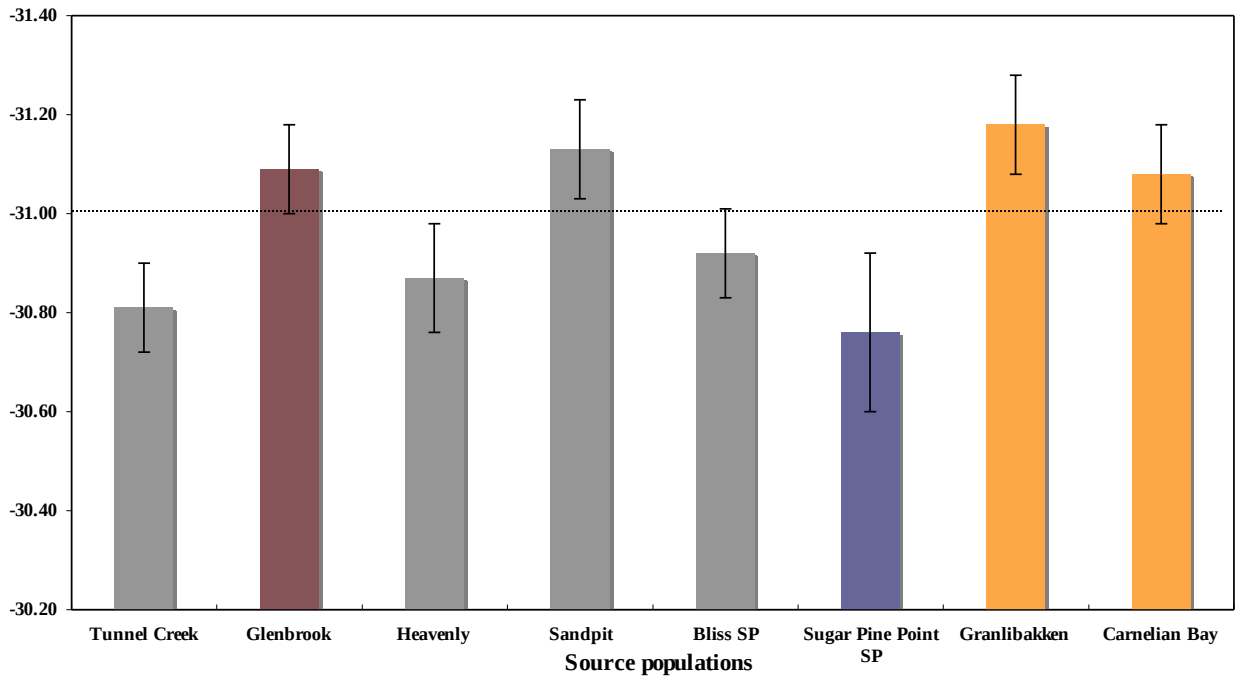
Trait – Bud flush (growth initiation)

Variable	BF
Elevation (m)	-0.15
% max. rad. input	-0.05
Ann. ppt. (mm)	0.03
Tmin (^{o}C)	-0.15
Tmax (^{o}C)	-0.12
May GDD	-0.13
Aug GDD	0.09
AWC 0-25	**-0.21**
AWC 0-50	**-0.21**
% sand	0.16
% silt	-0.16
% clay	-0.15
CEC	-0.14
WC -1/3 bar	0.05
WC -15 bar	-0.08

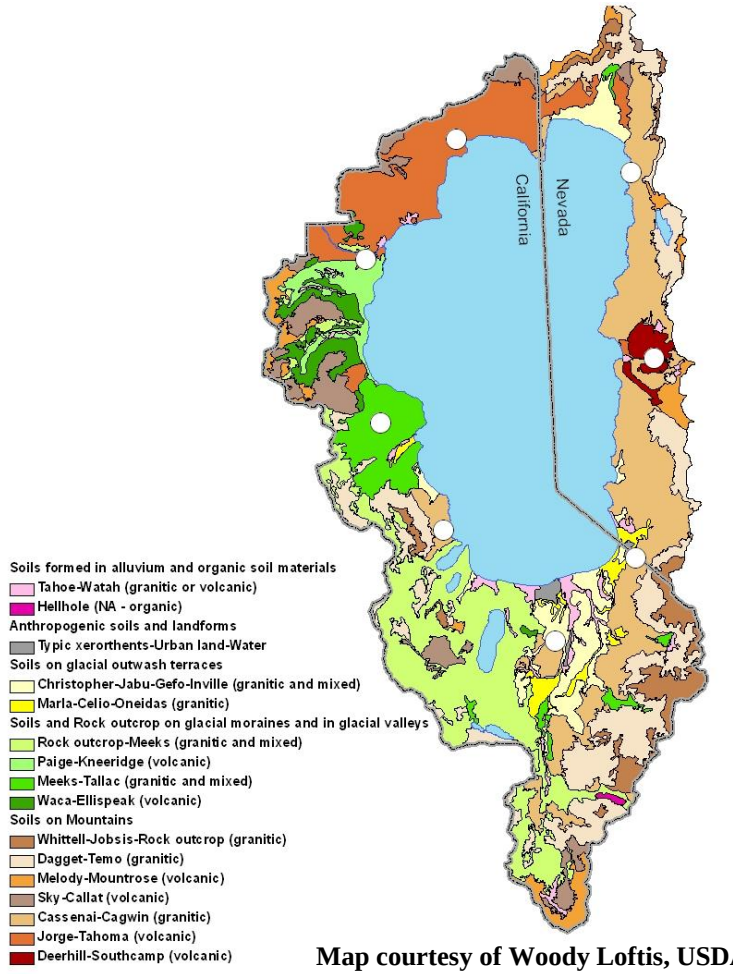


Trait – $\delta^{13}C$ (water-use efficiency)

Variable	$\delta^{13}C$
Elevation (m)	**-0.20**
% max. rad. input	-0.07
Ann. ppt. (mm)	0.14
Tmin (°C)	-0.18
Tmax (°C)	**-0.26**
May GDD	**-0.26**
Aug GDD	0.01
AWC 0-25	**-0.21**
AWC 0-50	-0.19
% sand	0.14
% silt	-0.12
% clay	-0.16
CEC	-0.18
WC -1/3 bar	0.17
WC -15 bar	-0.01



Influence of soil type on plant traits in the Lake Tahoe Basin



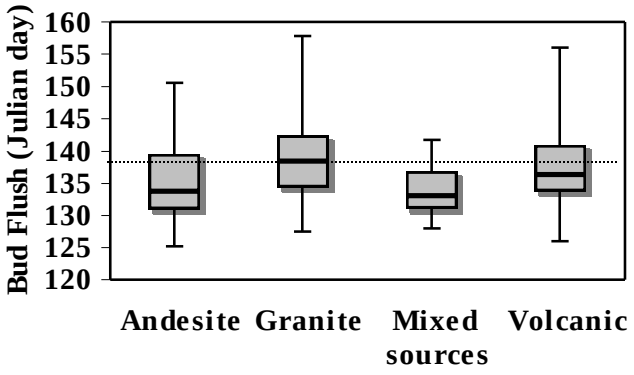
Map courtesy of Woody Loftis, USDA NRCS

	Soil type						
Trait	Andesite	Granitic	Mixed sources	Volcanic	Overall mean	*F*-ratio	*P*-value
HTINC	12.65	11.03	12.20	9.79	11.25	4.35	**0.006**
BF	134.79	139.52	134.60	137.18	137.77	3.41	**0.020**
R:S	1.18	1.21	1.30	1.19	1.20	0.78	0.504
13C	-31.13	-30.93	-30.79	-31.11	-31.00	5.23	**0.001**
15N	22.61	22.68	22.43	22.30	22.58	0.17	0.919

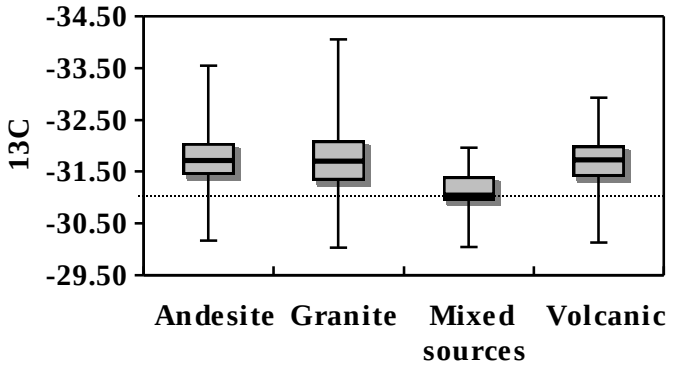
Plant adaptation to drought involves both phenological and physiological traits

Strategies include late bud flushing and less negative $\delta^{13}C$

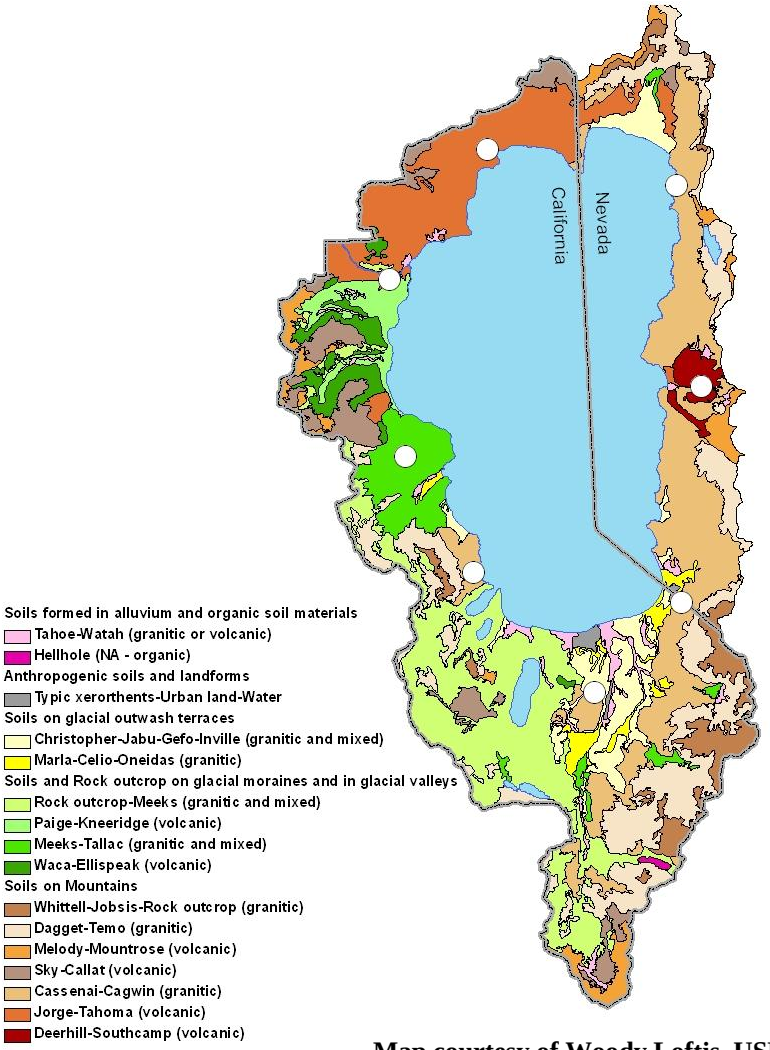
Phenology – Bud flush



Physiology – Water-use efficiency



Drought adapted phenotypes and within–Basin seed transfer



Map courtesy of Woody Loftis, USDA NRCS

- Deploy drought adapted phenotypes (in some populations/stands) to mitigate the effects of a warming climate.
- White pine restoration plantings will included a diversity of seedlings including WPBR-resistant and drought tolerant phenotypes.

- Tom Burt for cone collections
- Woody Loftis (USDA NRCS) for invaluable soil survey data and maps
- Anne Liston
- Jim Pollock
- UCD – stable isotope facility
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