

# Tools for seed sourcing decisions in a changing world

3<sup>rd</sup> Southern California Chaparral Symposium:  
Global change and the vulnerability of chaparral  
ecosystems, May 14-16, 2018

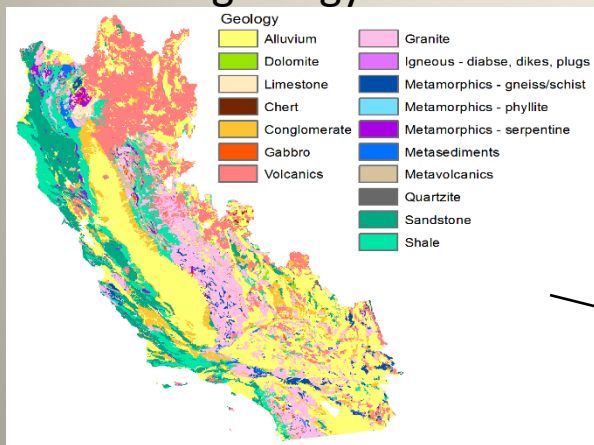
Arlee M. Montalvo, Erin C. Riordan, and Jan L. Beyers



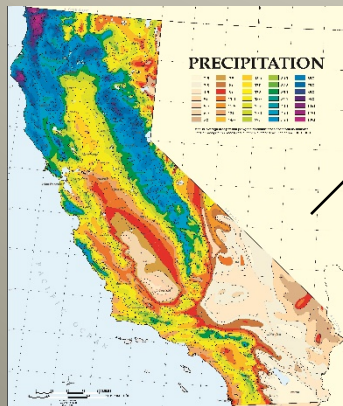
# California shrublands occupy a diverse landscape: Ecological Sections and Subsections

Goudey and Smith (1994) updated with ECOMAP (2007)

## Parent geology



topography



# Careful choice of species, subspecific taxa and seed sources for projects can:

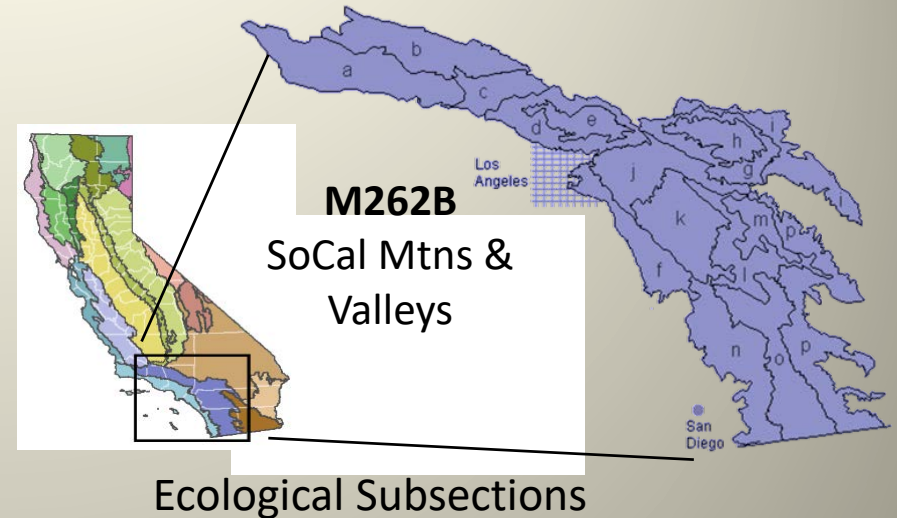
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- Minimize risk of maladaptation
- Reduce risk of inbreeding and outbreeding depression
- Preserve important biological interactions
- Maintain variation and adaptive potential
- Increase long-term success of projects

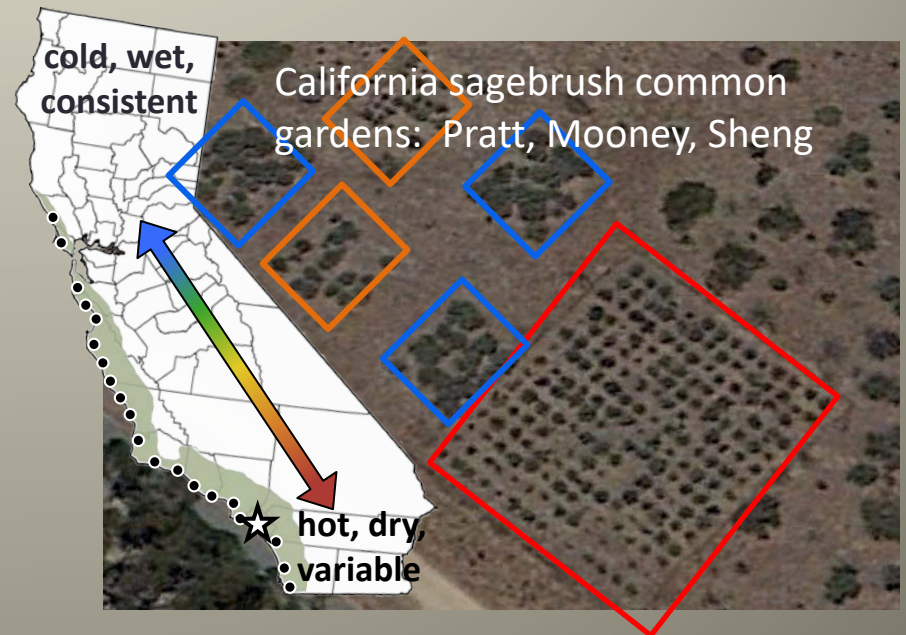
# What information informs seed use?

- Ecoregion maps
  - Species distributions, climate/soil affinities
  - Plant traits associated with maladaptation risk, adaptive capacity
  - Common garden studies revealing adaptation of ecotypes and traits
  - Molecular genetics
    - gene flow, population differentiation
- Taxon-specific seed movement guidelines

**Coarse**



**Fine**

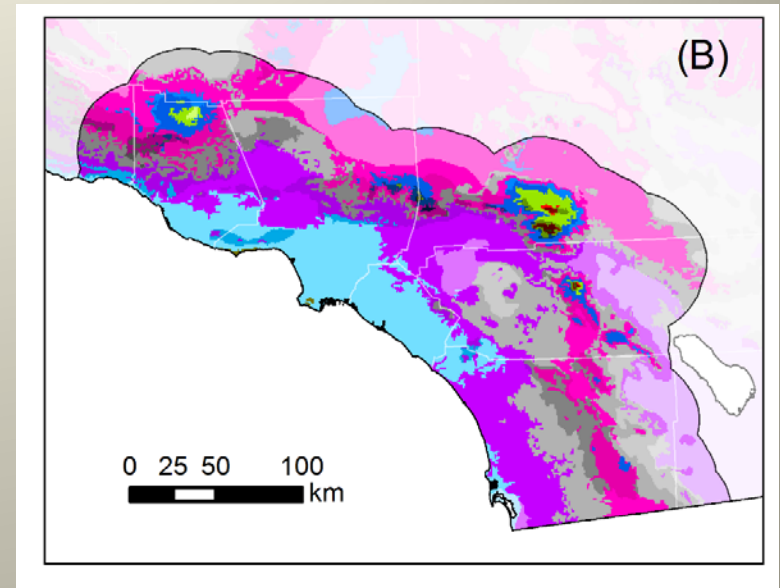
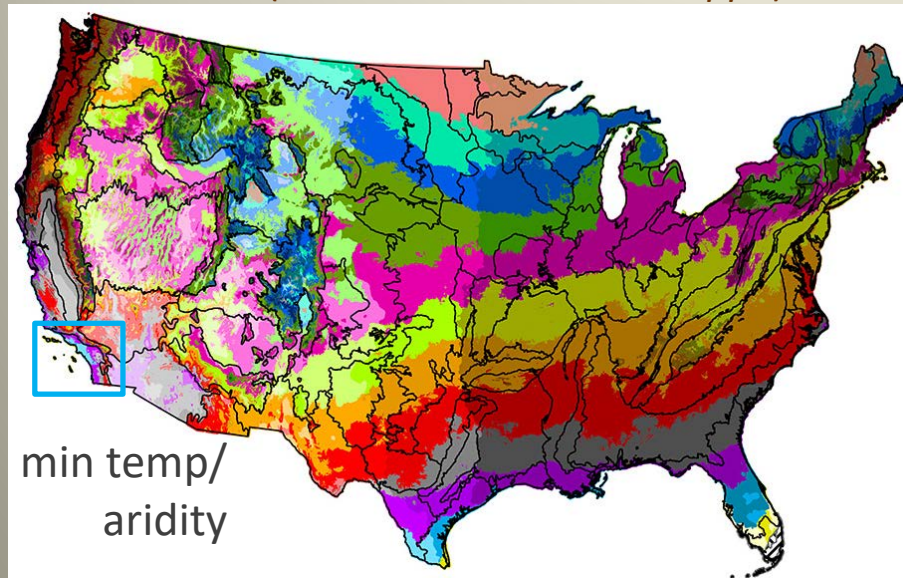


# Generalized tools to guide seed movement

a *starting* tool to be combined with expert knowledge of plants

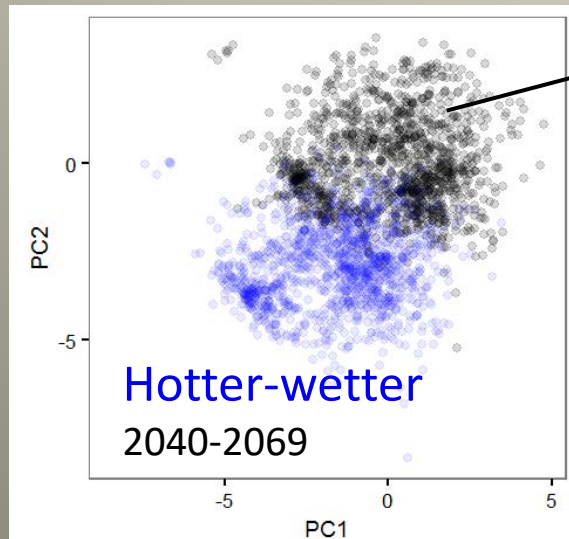
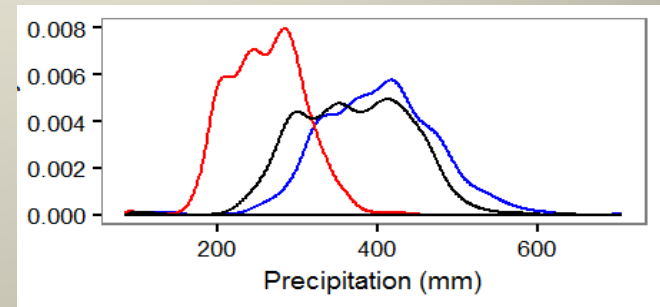
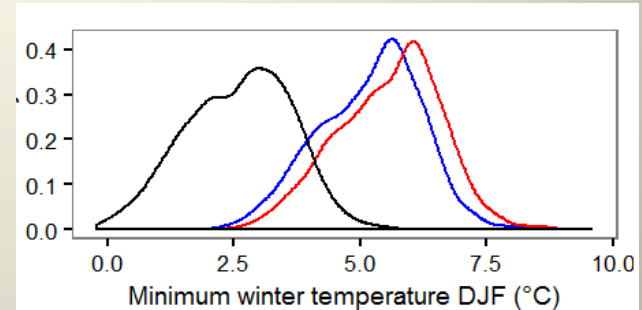
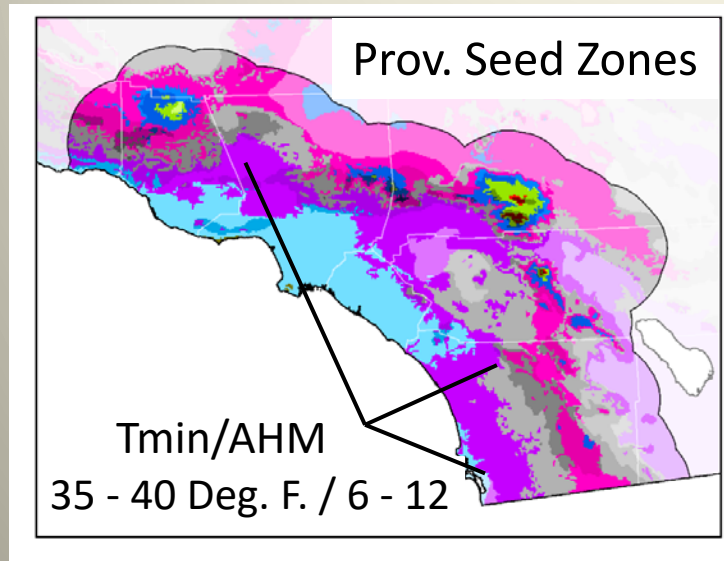
## Provisional Seed Zones

(Bower et al. 2014 *Ecol. Appl.*)

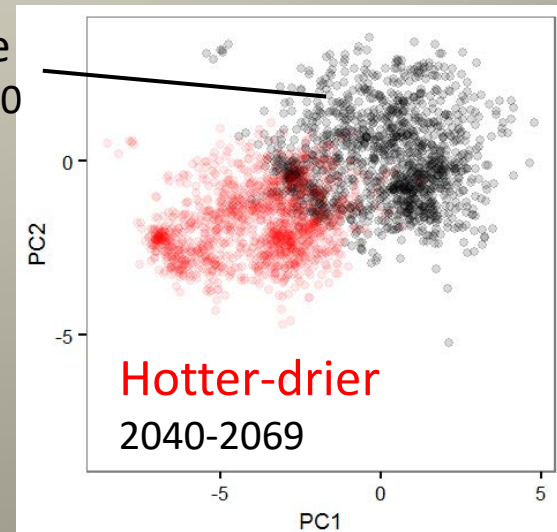


- Identifies areas of relative climatic similarity
- Restrict movement to within zones to minimize maladaptation risk
- Do these zones make sense for California taxa?
- How much are conditions changing in these zones?

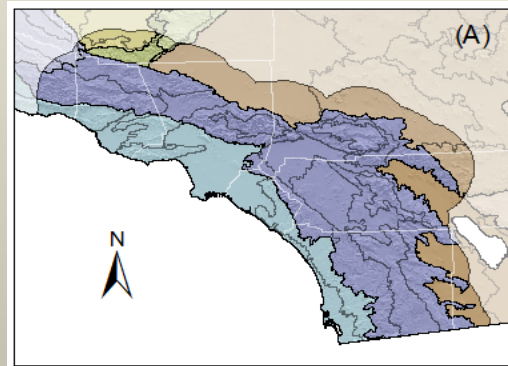
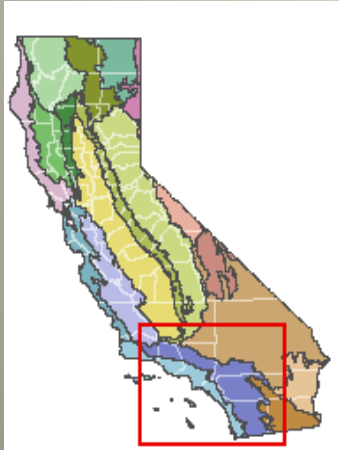
# Climate change: Restoration game changer?



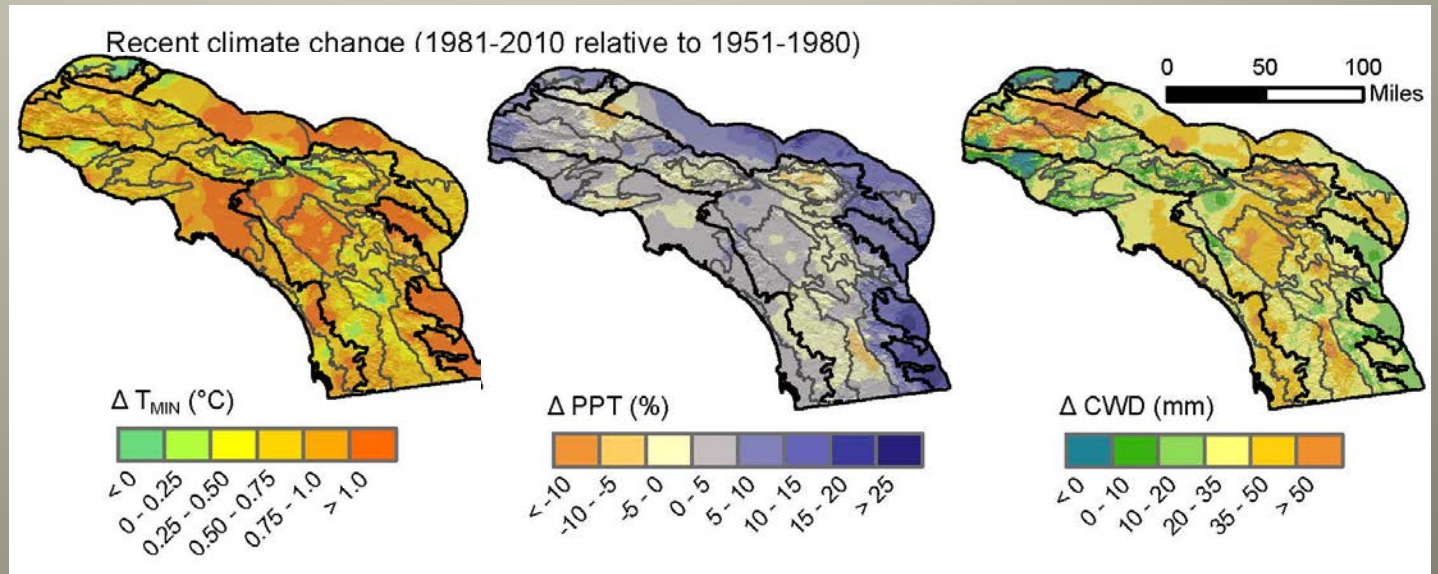
Baseline  
1951-1980



# Observed shifts in climate variables for 1981-2010 relative to 1951-1980

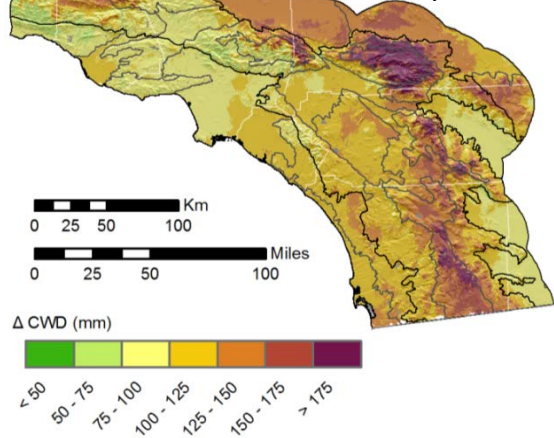


using CA-BCM  
downscaled climate data  
(270 m resolution)

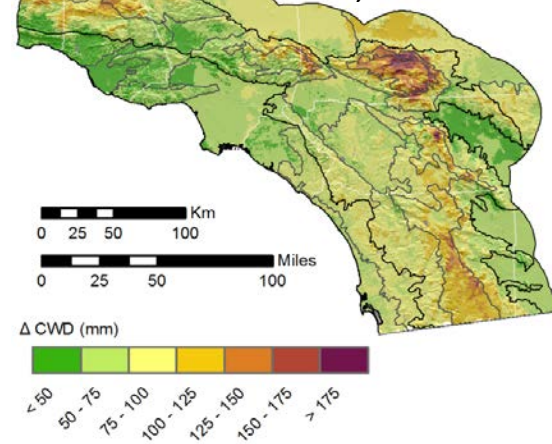


# Climatic Water Deficit is projected to increase midcentury 2040-2069 relative to 1950-2010

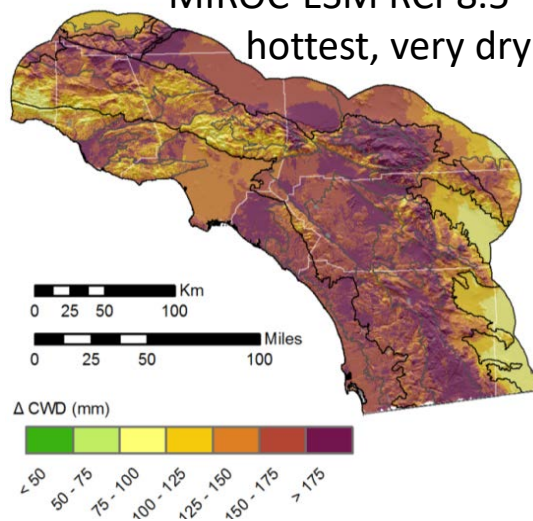
IPSL-CM5A-LR RCP8.5  
hotter, drier



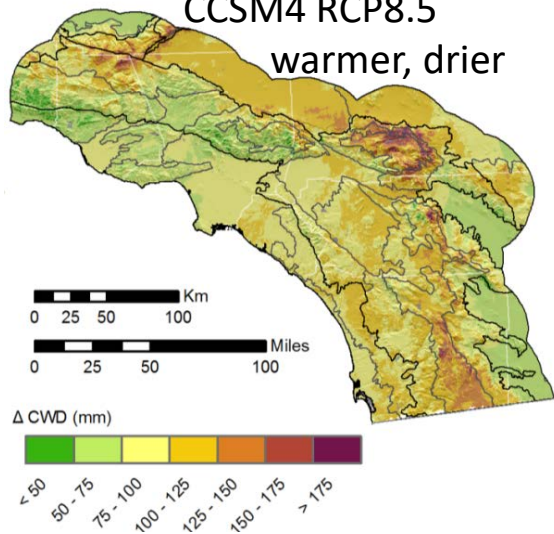
CNRM-CM5 RCP8.5  
hot, wetter



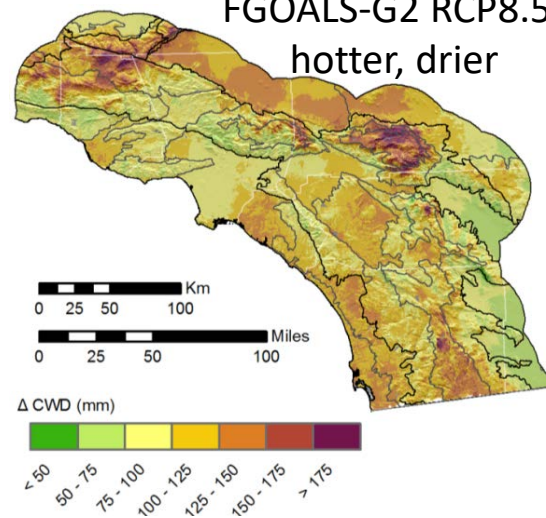
MIROC-ESM RCP8.5  
hottest, very dry



CCSM4 RCP8.5  
warmer, drier



FGOALS-G2 RCP8.5  
hotter, drier



CWD  
Reflects drought stress



# Seeding sourcing for the future?

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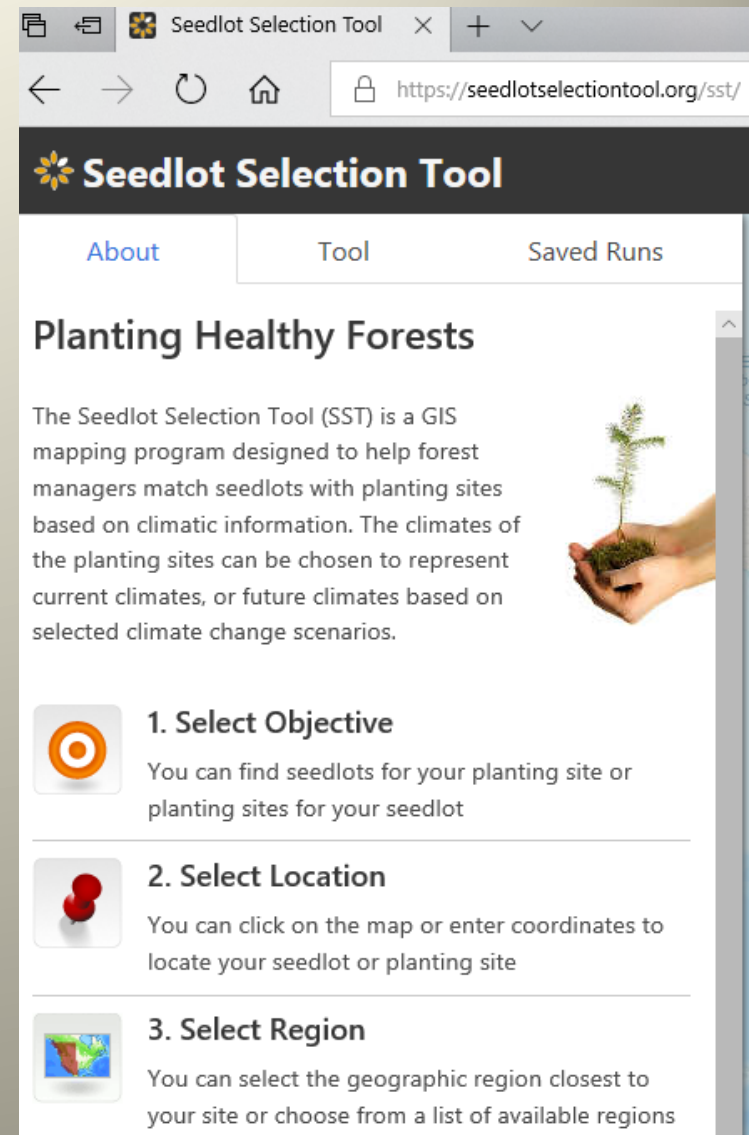
- Identify climate vulnerabilities:
  - What is the projected climate stress (exposure to change)?
  - What do a taxon's traits suggest about its ability to persist in place, adapt, and migrate (adaptive capacity)?
- Consider risks of moving too much or too soon:
  - poor adaptation to current conditions
  - growth phase mismatches with seed/pollen dispersers
  - outbreeding depression
  - unanticipated changes in community interactions
- Are there other, interacting risk factors (land use, fire)?

**Action should not cause more harm than no action**

# Evolving tools: online seedlot selection tool

Collaborative project : USDA Forest Service PNW,  
Conservation Biology Institute, Oregon State U

- Web-based, GIS mapping program
- Helps match seedlots of TREES to planting locations
- Uses climate information, including choice of two climate change scenarios
- Flexible designation of climate variables, constraints, distances or tree seed zones
- Expert knowledge about a taxon can improve tool usefulness



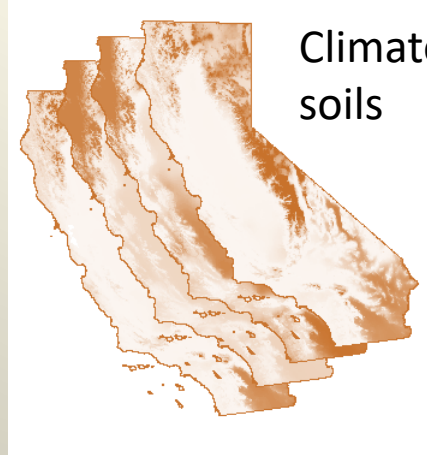
5 more steps.....

# Species distribution modeling approach

For 36 shrubland taxa:



+

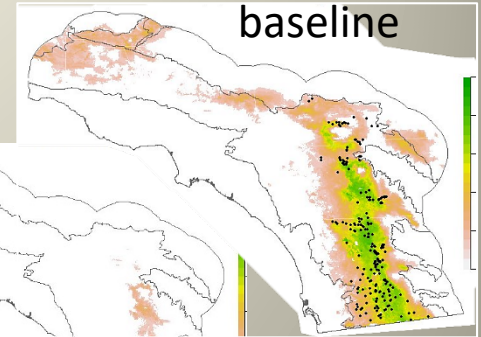


Climate variables  
soils

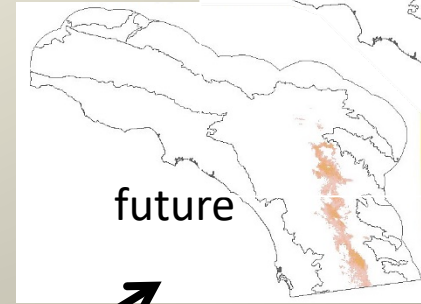
Species occurrences  
Herbarium records (vetted),  
field surveys

Baseline conditions  
(1951–1980)

Habitat suitability



baseline

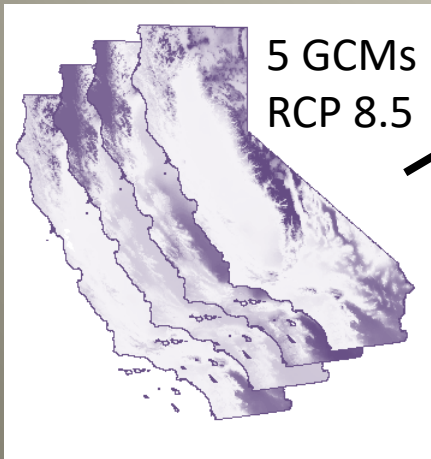
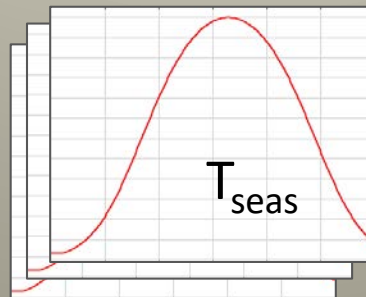


future



**MAXENT**

Species Distribution  
Model (SDM) algorithm

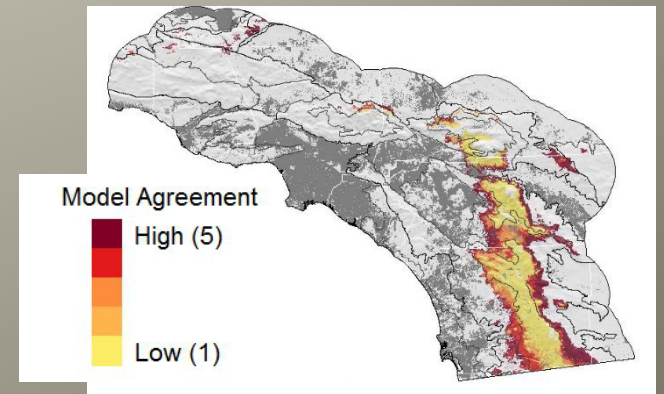


5 GCMs  
RCP 8.5

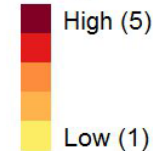
Future conditions  
(2040–2069)



Planning Tools



Model Agreement



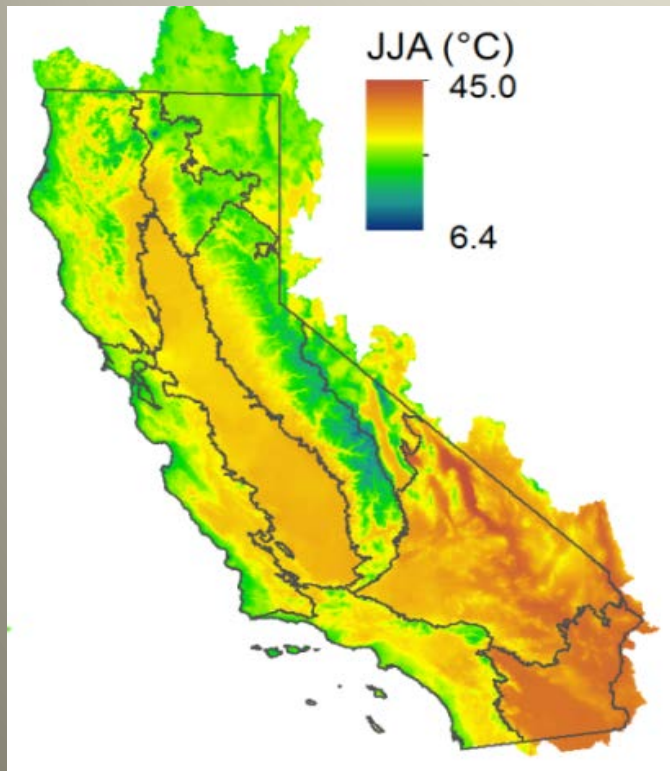
High (5)

Low (1)

# Downscaled climate data: CA-BCM

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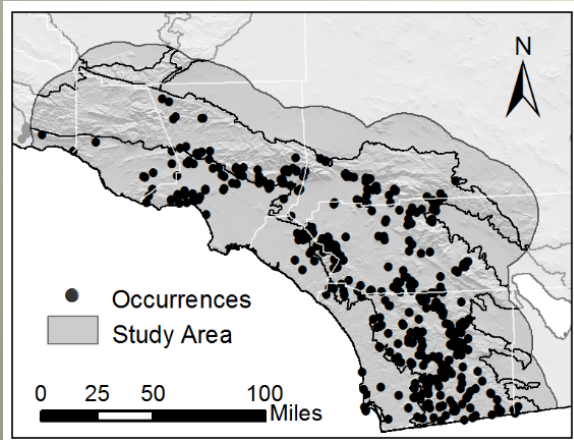
**California Basin Characterization Model (CA-BCM):** applies a monthly regional water-balance model to simulate hydrologic responses to climate at the spatial resolution of a 270 m grid



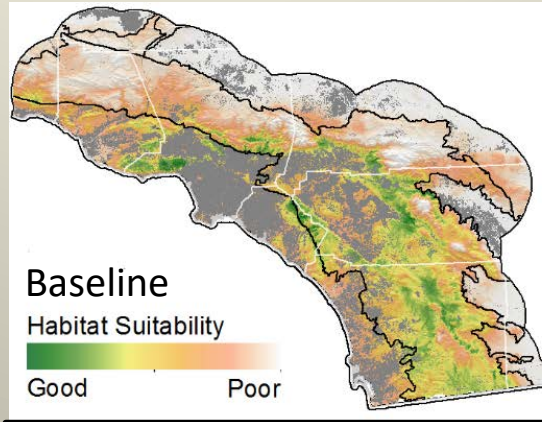
- High resolution (270 m) baseline (1951-1980), current (1981-2010) and projected (2049-2060) climate and hydrologic surfaces
- **Variables used in modeling: strong drivers of plant distribution**
  - Winter  $T_{\min}$ , Summer  $T_{\max}$
  - T seasonality
  - Winter PPT, Summer PPT
  - Climatic Water Deficit (CWD), Actual Evapotranspiration (AET)

# Projected change in suitable habitat midcentury 2040–2069 relative to 1951–1980

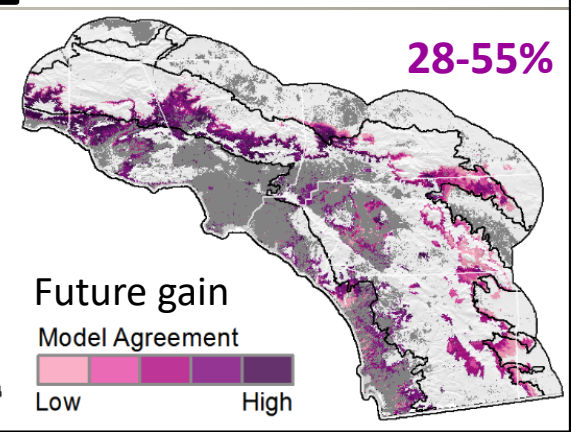
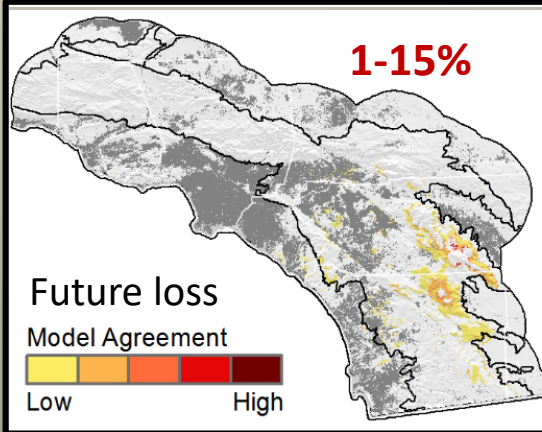
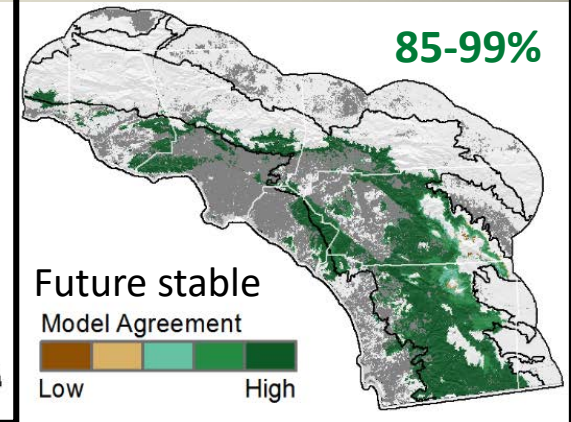
*Rhus ovata*  
sugarbush



Baseline climate:  
1951-1980




Future climate:  
Mid-century 2040-2069



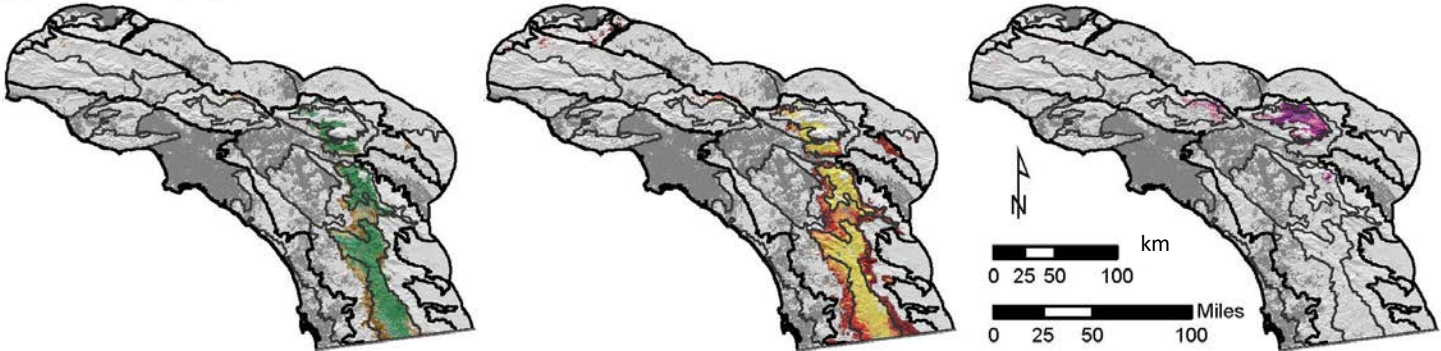
photos: Arlee Montalvo

Five GCMs paired with RCP 8.5: CSSM4, CNRM-CM5, FGOALS-G2, IPSL-CM5A-LR, MIROC-ESM

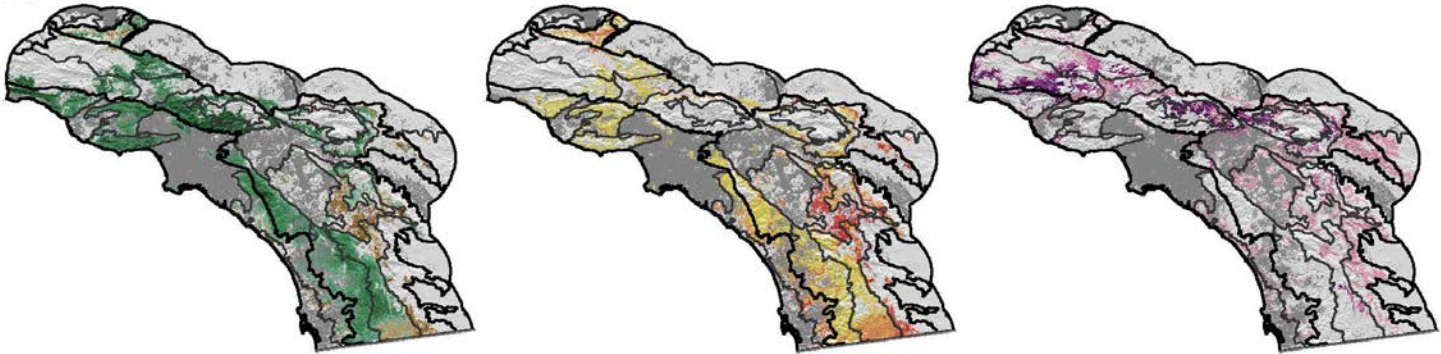
 =urban/agriculture

# Contrasting patterns of projected suitable habitat

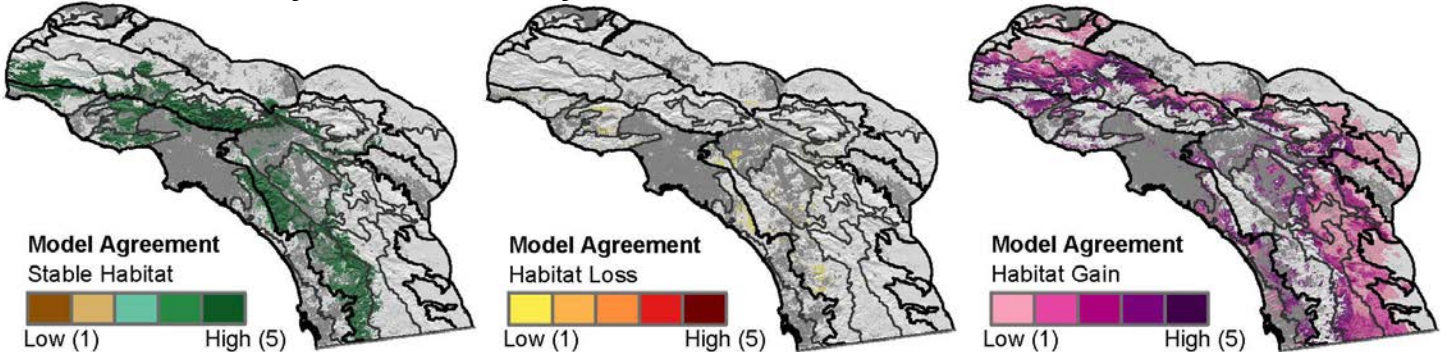
*Ceanothus perplexans*



*Rhamnus ilicifolia*



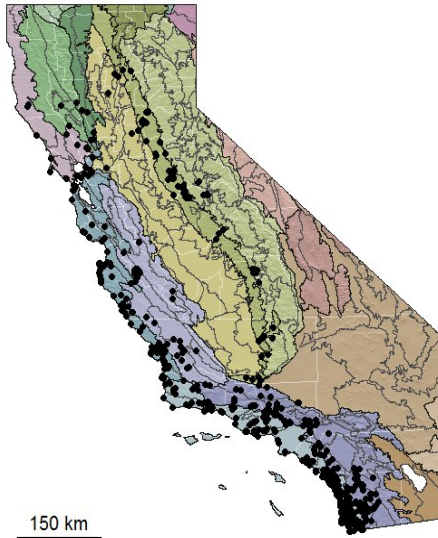
*Ceanothus crassifolius* var. *crassifolius*



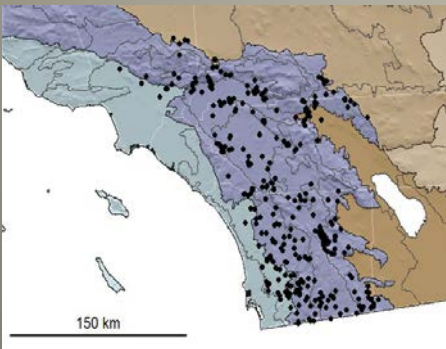
# Intraspecific differences in climatic niches

## *Acmispon glaber*

### var. *glaber*



### var. *brevialatus*



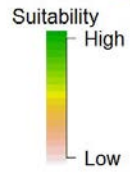
## Deerweed, CA broom

- Subshrub, fire follower
- varieties differ in morphology and habitat affinities
- var. *glaber*: open areas of coastal California; Sierra Nevada foothills
- var. *brevialatus*: southern California; hotter, drier interior
- common garden work showed local adaptation, outbreeding issues

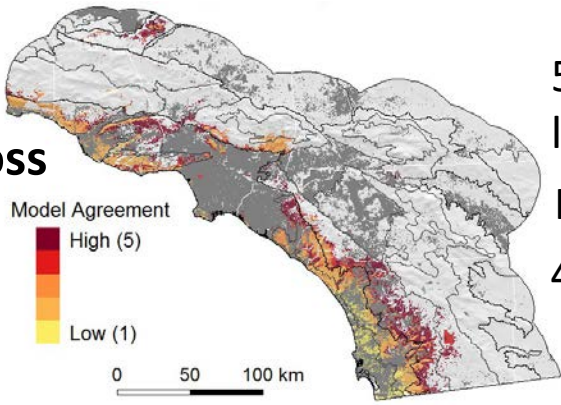
*Acmispon glaber* var. *glaber*

*Acmispon glaber* var. *brevialatus*

**Baseline**

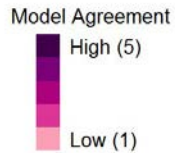


0 50 100 km



5 models:  
loss > gain  
High loss  
42–99% ↓

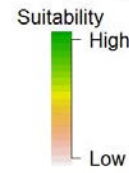
**Gain**



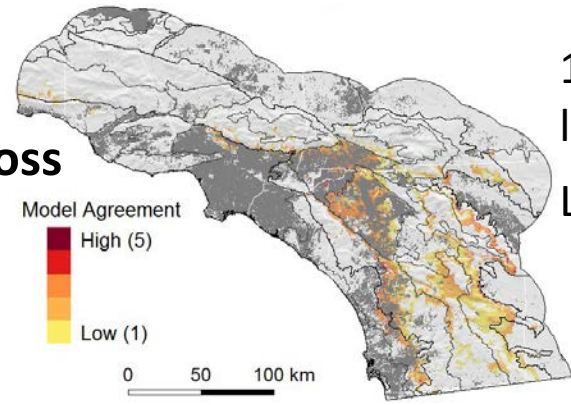
0 50 100 km

Minimal gain  
0–23% ↑

**Baseline**

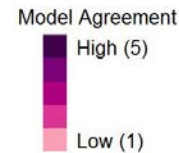


0 50 100 km



1 model:  
loss > gain  
Lower loss  
2–35% ↓

**Gain**



0 50 100 km

Modest gain  
13–32% ↑



Evaluate direction of shifts in future climate of ecoregions and seed zones and compare with shifts in habitat suitability revealed by SDMs

**If taxon SDM is available, is there substantial risk that habitat climatic suitability will decline?**

YES



NO

No seed zone shifts warranted



Evaluate direction of shifts in future climate of ecoregions and seed zones and compare with shifts in habitat suitability revealed by SDMs

**If taxon SDM is available, is there substantial risk that habitat climatic suitability will decline?**

No seed zone shifts warranted

NO

YES

Can taxon likely tolerate expected shifts in place? (secure refugia)

YES

Taxon with high levels of plasticity, genetic diversity, gene flow, or historical climate tolerance

NO

Is taxon able to migrate &/or is it sufficiently genetically diverse for adaptive evolutionary response?

YES

Limit zone combinations for seed sourcing to adjacent zones and logical direction of expected shifts.

NO

Restore migration corridors?

YES

NO

Taxa with low levels of genetic diversity, low gene flow, or adapted to highly localized climate or edaphic factors?

YES

Candidate for “assisted migration”. Consider scale of expected shifts in habitat suitability relative to scale of local adaptation, migration & risk

# Species vary in their exposure, resilience, and vulnerability to climate change and translocation

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- What traits capture differences in species' ability to persist in place, adapt, and migrate?
- What traits are associated with different levels of risk of maladaptation or outbreeding depression?

# Plant traits influence migration (gene flow)

Fruit type x primary / secondary dispersers

near (meters)  far (km)



Gravity / ants,  
rodents, water



Wind / ants



Birds,  
squirrels /  
rodents



Birds, mammals /  
rodents

# Habitat and species traits can guide “distance” decisions

Modified from Havens, Vitt et al. 2015. *Natural Areas Journal*

## Conservative/local sourcing

## Relaxed/longer distance sourcing

### Species traits

Narrow and/or habitat specialist



Widely distributed/or generalist

Little long-distance gene flow



Extensive long-distance gene flow

Low phenotypic plasticity



High phenotypic plasticity

Narrow environmental tolerance



Wide environmental tolerance

### Habitat traits

Historically fragmented



Recently fragmented\*

High quality



Low quality/degraded

Ancient/stable landscape



Younger/dynamic landscape

### Taxonomic understanding

Taxonomic uncertainty/cryptic species



Well known/stable taxonomy

High hybridization potential



Low hybridization potential

Low rates of evolution (conserved)



High rates of evolution

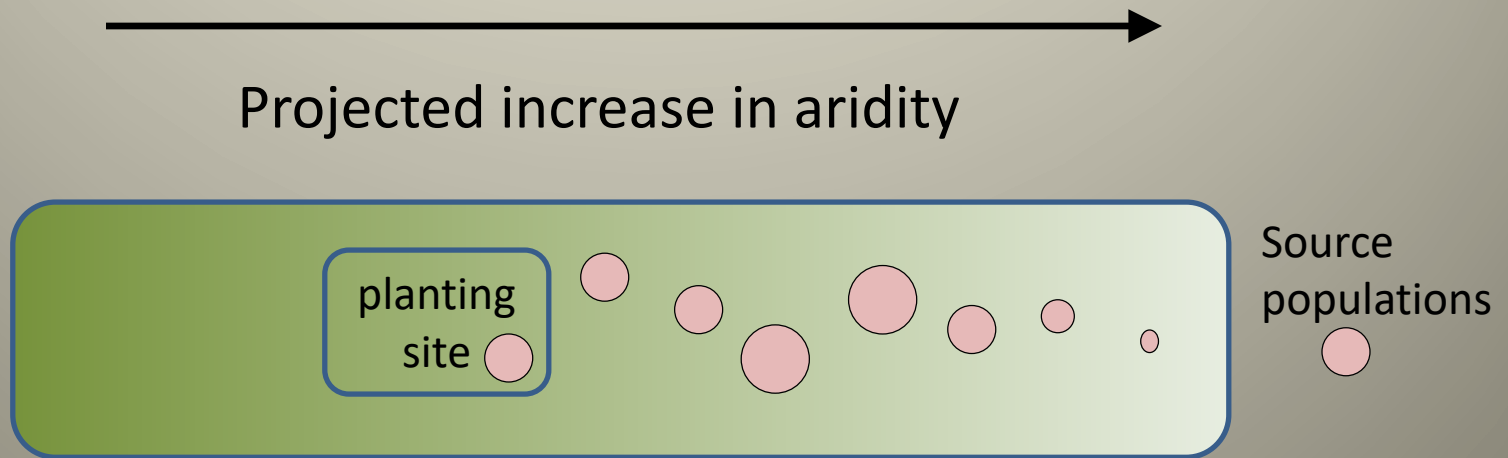
Distance ecological/genetic/geographic

# Choice of provenancing model?

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- For a particular taxon, how can we minimize risk of maladaptation and genetic mismatches?
- What type of seed sourcing (provenancing) model should we use within seed zones or among seed zones?



“Climate-adjusted provenancing” (modified from Prober et al. 2015. *Frontiers Ecol. Evol.*)

Species vary in their exposure to climate change  
and in attributes that affect how they cope



Information needed to navigate  
decision formats can be found...

*... all over the place...*

# For easy shopping....

Providing easy access to information:  
36 foundational shrubs/subshrubs

## Alluvial scrub

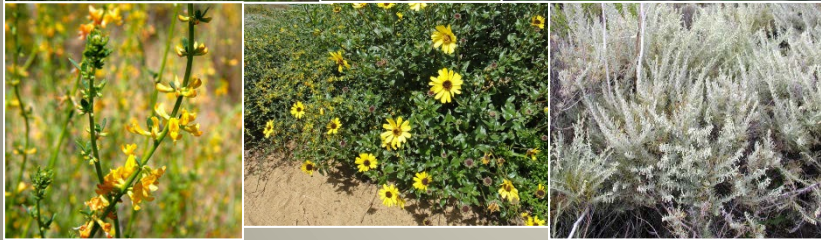
*Lepidospartum squamatum*, *Salvia apiana*,  
*Eriodictyon crassifolium*, *Rhamnus crocea* ...

## Coastal sage scrub

*Salvia mellifera*, *Eriogonum fasciculatum*,  
*Acmispon glaber*, *Encelia californica*,  
*Artemisia californica*, *Malosma laurina* ...

## Chaparral

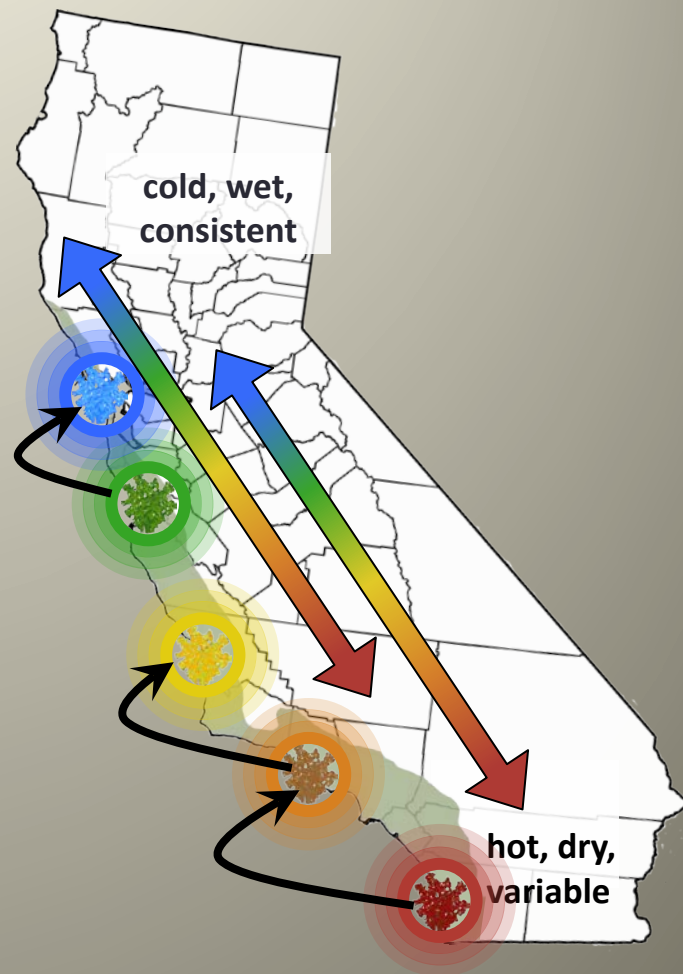
*Adenostoma fasciculatum*, *Arctostaphylos glandulosa*, *A. glauca*, *Ceanothus crassifolius*,  
*C. cuneatus*, *C. leucodermis*, *C. perplexans*,  
*Cercocarpus betuloides*, *Prunus ilicifolia*,  
*Rhamnus ilicifolia*, *Rhus ovata*...




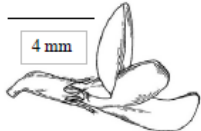





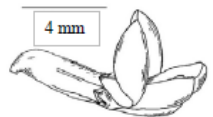






Common gardens with California sagebrush (*Artemisia californica*) revealed patterns that can inform seed sourcing  
(figure courtesy: J. Pratt, K. Mooney, & D. Sheng- UCI)

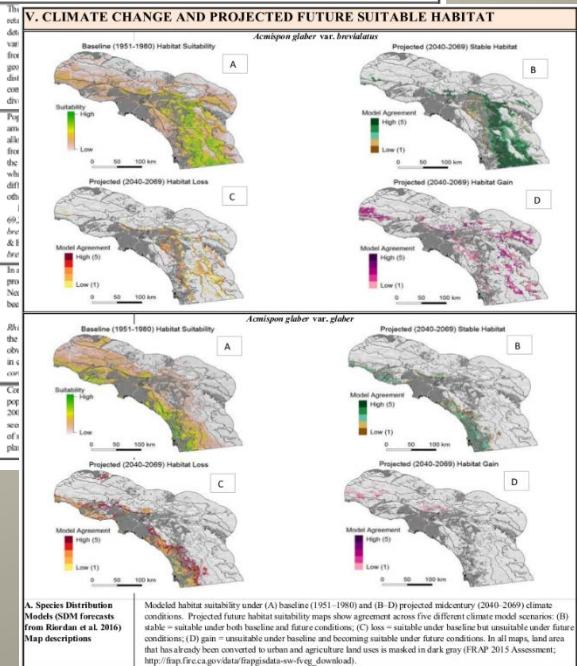
- Climate, genetic variation in plant traits, and arthropod community structure all covary across environmental gradients.
- Experimental response to water addition varies among populations.
- Greater plasticity of southern populations may make them more resilient to climate change.



# Plant profiles for southern CA shrublands

<b>I. SPECIES</b>		<i>Acmispion glaber</i> (Vogel) Brouillet [updated version] = <i>Lotus scoparius</i> (Nutt. in Torr. & A. Gray) Ottley	
<b>NRCS CODE:</b> [none for <i>Acmispion</i> ] [LOSC2 code for <i>L. scoparius</i> ]	Tribe: Loteae Subfamily: Papilionoideae	Family: Fabaceae Order: Fabales	Subclass: Rosidae Class: Magnoliopsida
			
	<i>Acmispion glaber</i> var. <i>brevialatus</i> [= <i>Lotus scoparius</i> var. <i>brevialatus</i> ]		
			
	<i>Acmispion glaber</i> var. <i>glaber</i>		
			
<b>A. Subspecific taxa</b> 1. no NRCS code 2. no NRCS code	1. <i>Acmispion glaber</i> (Vogel) Brouillet var. <i>glaber</i> 2. <i>Acmispion glaber</i> (Vogel) Brouillet var. <i>brevialatus</i> (Ottley) Brouillet [accepted by Baldwin et al. (2012), Jepson eFlora (2017)]		
<b>B. Common name</b>  (taxa numbered as above, names listed first used below)	General for species: deerweed, California broom 1. coastal deerweed, common deerweed, deerweed, coastal deerbroom 2. short-winged deerweed, desert deerweed, desert deerbroom, western bird's foot trefoil (Roberts 2008, Allen & Roberts 2013, Calflora 2016, USDA PLANTS 2016).		

<b>IV. HABITAT</b>	
<b>A. Vegetation alliances, associations</b>	The Manual of California Vegetation (Sawyer et al. 2009) uses the name <i>Lotus scoparius</i> and treats the two varieties as a single taxon for the purposes of vegetation classification. The taxon is considered co-dominant to other shrubs in 30 different coastal sage scrub, upland sage scrub, chaparral, and desert scrub alliances. Within many areas, <i>L. scoparius</i> may become dominant for several years following fire, forming the <i>Lotus scoparius</i> shrubland alliance until other, longer-lived taxa dominate. Also listed as codominant in the <i>Carex panicea</i> herbaceous alliance in coastal sand dune vegetation and the <i>Arenaria dracunculoides</i> alliance in annual or perennial grassland. California broom occurs as a codominant in alliances dominated by <i>Arenaria californica</i> , <i>Adenostoma fasciculatum</i> , <i>A. aureoides</i> and several different
<b>B. Herbivory, seed predation, disease</b>	Plants develop flower galls. Larvae of 27 species of butterflies in the Lycaenidae were successfully reared on the leaves and flowers of <i>L. scoparius</i> collected in Riverside, California (Pratt & Balfour 1991). Genera included <i>Lycaena</i> , <i>Abades</i> , <i>Calliphrys</i> , <i>Chlorostomox</i> , <i>Eronia</i> , <i>Mintistrymon</i> , and <i>Strymon</i> . Larval Nepticulidae butterflies in the species <i>Microglypta kneriella</i> (name the same (Wagner 1987)). Seed predation after seed dispersal in shrubland can be high (70%) but can be much lower in grassland and the shrub/grassland ecotone (DeSimone & Zeller 2001).
<b>B. Habitat affinity and breadth of habitat</b> (taxa numbered as above)	In w Hut 1. P Lac 2. P
<b>C. Elevation range</b>	Sea
<b>D. Soil: texture, chemical, depth</b>	Pre "oh mch
<b>E. Precipitation</b>	Both sum Su Vall glo in w -1: (26) the -40 Sub S pre.
<b>F. Drought tolerance</b>	Dro rath are 1 vige drou Schl
<b>G. Flooding or high water tolerance</b>	Upe tolerance
<b>H. Wetland indicator status for California</b>	Non
<b>I. Shade tolerance</b>	Shu
<b>C. Palatability, attractiveness to animals, response to grazing</b>	The plants provide valuable forage for deer, especially in drought years or after fire when growth of herbaceous vegetation is sparse (Conrad 1987, Dale 2000). Plants tend to branch after light grazing (Montalvo pers. obs.).
<b>D. Mycorrhizae or nitrogen fixing nodules</b>	Roots form symbiotic associations with nitrogen fixing bacteria within root nodules and with arbuscular mycorrhizal fungi (Montalvo 2004, A. Montalvo pers. obs.). <i>Acmispion glaber</i> and related species of <i>Acmispion</i> possess a gene (NSP1) that regulates nodulation and the formation of the symbiosis between their roots and <i>Rhizobium</i> , and allelic variation was found within species for the NSP1 gene (Derrien et al. 2014).
<b>VIII. ECOLOGICAL GENETICS</b>	
<b>A. Hardy</b>	Both varieties have 2n = 14 chromosomes (Munz & Keck 1968, Grant 1995). Ploidy levels in the related <i>Acmispion araphalense</i> , <i>A. dracunculoides</i> , and <i>A. nevadensis</i> are also 2n = 14 (Brouillet 2009).
<b>B. Plasticity</b>	Most plasticity is in vegetative traits rather than in traits of the flowers (A. Montalvo pers. obs.).
<b>C. Geographic variation (morphological and physiological traits)</b>	



Montalvo, A. M., E. C. Riordan, and J. L. Beyers. 2017. Plant Profile for *Lotus scoparius*, 2nd edition. Native Plant Recommendations for Southern California Ecoregions. Riverside-Corona Resource Conservation District and U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Riverside, CA.

# Plant profiles for southern CA shrublands

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- Referenced taxonomic, ecological, and genetic information to help guide seed collection and transfer of foundation species
  - Taxonomy, distribution, habitat affinity, life-history traits, reproduction, fire response, dispersal capacity, biological interactions, geographic/genetic variation, common gardens, ...
- Predictive models of habitat suitability and projected mid-century climate change to create maps of future climate stress (e.g., loss of climatic suitability)
- Summary of ecological and evolutionary considerations for restoration and seed transfer

**Balance risk of creating maladapted populations with the risk of local extinction (extirpation)**

# Summary

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- SDM can be used with detailed information about plants to inform seed sourcing decisions.
- Decision frameworks are available to guide decisions regarding seed movement.
- Candidates for assisted migration: high climate exposure, low gene flow/adaptive capacity, or highly compromised dispersal capacity from fragmentation
- **Other risk factors may be more important or may interact with climate change**

SDM results available soon:

Find plant profiles at:  
[http://rcrcd.org/#Plant\\_Materials](http://rcrcd.org/#Plant_Materials)

## Using Species Distribution Models With Climate Change Scenarios to Aid Ecological Restoration Decisionmaking for Southern California Shrublands

Erin C. Riordan, Arlee M. Montalvo, and Jan L. Beyers



Forest Service

Pacific Southwest  
Research Station

Research Paper  
PSW-RP-270

April  
2018

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  - > Chaparral
  - > Oak Woodland
- > Landscaping
- > Nurseries

## PLANT MATERIALS

### Native Plant Profiles

#### Tools for Providing Genetically Appropriate Plant Materials for Southern California Ecoregions:

More and more, land managers are striving to place the right plants in the right place at the right time to ensure sustainability of our natural resources. RCRCD has partnered with local and federal agencies, restoration companies, universities, land conservancies, non-profit groups, and seed companies to develop lists of native plants of primary importance to seeding and revegetation projects in southern California. Partners identified a critical need for information to help guide them in the selection of species and to identify where to collect genetically appropriate seeds for particular planting sites. The RCRCD is creating plant profiles to fill this need. The profiles include information that will help guide choices of species and seed sources for restoration and other native planting projects within sensitive habitats and conservation lands, with a focus on species that form the backbone of coastal sage scrub, low-elevation chaparral, and alluvial scrub plant communities.

#### Download Native Plant Profiles:

The following species were prioritized for profiles. The letters "PDF" show up in blue font in the last column when a profile is complete and ready for download. Click on the blue PDF to obtain the desired file. More profiles will be added as they are completed, pending funding for continued work. Check regularly for updates: several profiles were recently revised, including those for California sagebrush, deerweed, black sage, and white sage, to reflect new information.

#### Lists of Plant Profiles

# National Native Seed Strategy for Rehabilitation and Restoration/ 2015-2020

- **The vision: the right seed in the right place at the right time**
- The Mission: To ensure the availability of genetically appropriate seed to restore viable and productive plant communities and sustainable ecosystems.



A public-private partnership of organizations that share the goal: to protect native plants by ensuring that native plant populations and their communities are maintained, enhanced, and restored.

Protecting/supporting/managing biodiversity