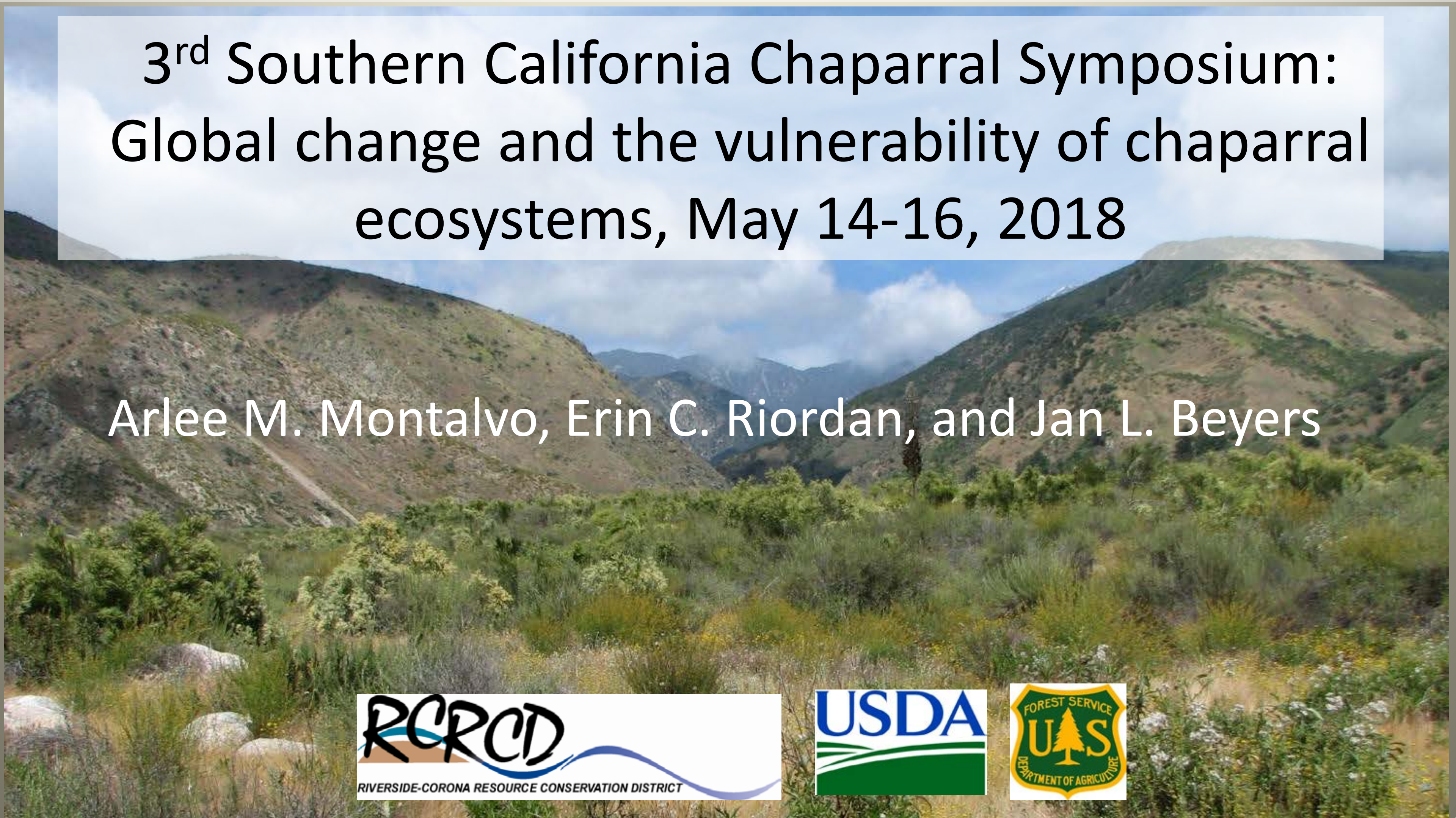
Tools for seed sourcing decisions in a changing world



3rd 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

RCRCD RIVERSIDE-CORONA RESOURCE CONSERVATION DISTRICT

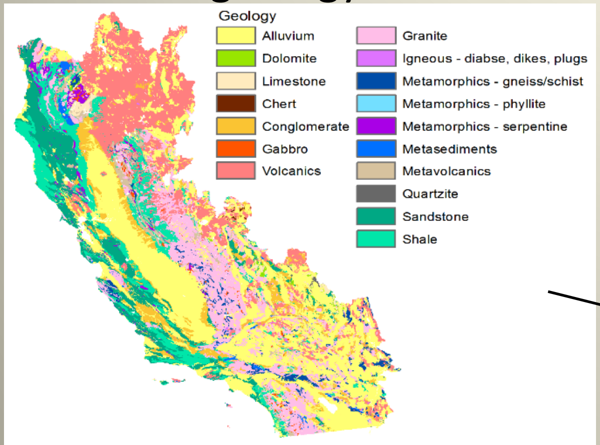
USDA

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

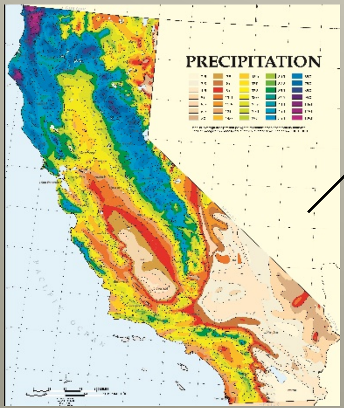
California shrublands occupy a diverse landscape: Ecological Sections and Subsections

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

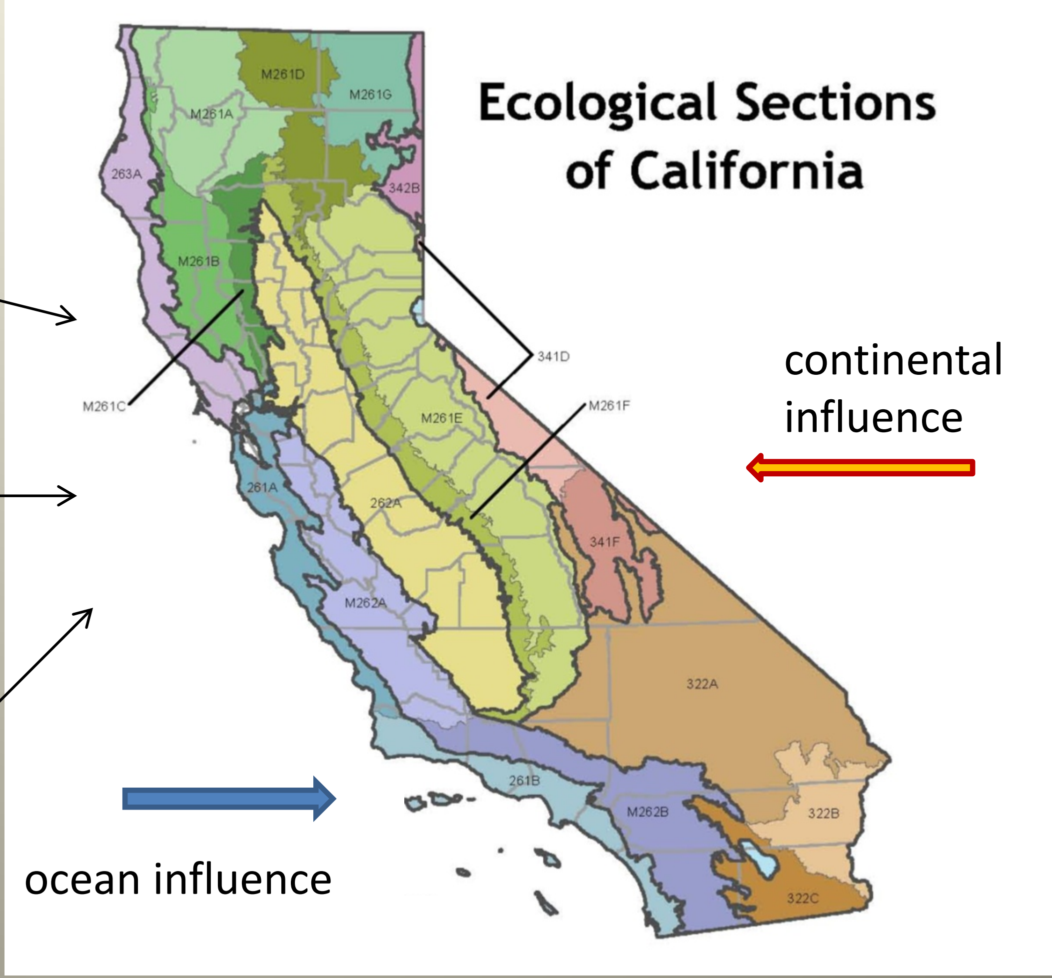
Parent geology



topography



Precipitation and temperature



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

- 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?

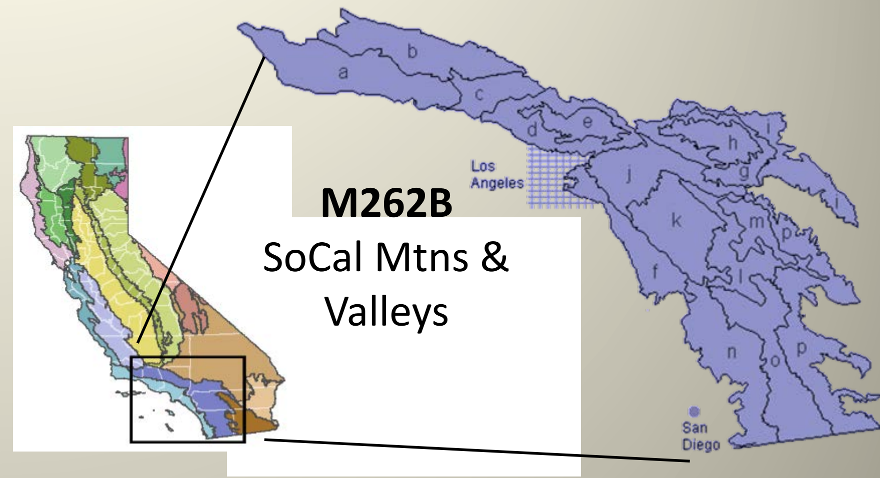
- Ecoregion maps

Coarse

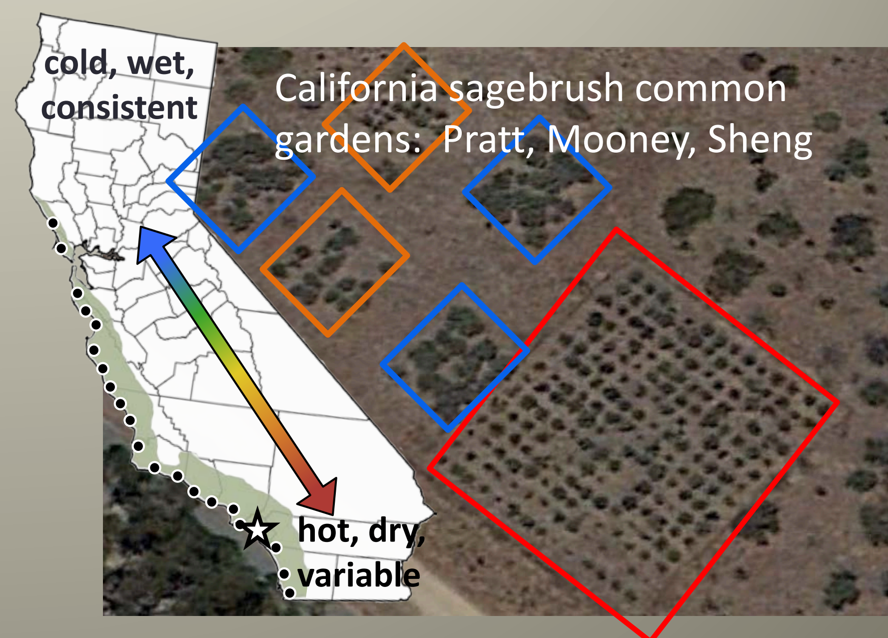
- Species distributions, climate/soil affinities
- Plant traits associated with maladaptation risk, adaptive capacity
- Common garden studies revealing adaptation of ecotypes and traits
- Molecular genetics
  - gene flow, population differentiation

Fine

→ Taxon-specific seed movement guidelines



Ecological Subsections

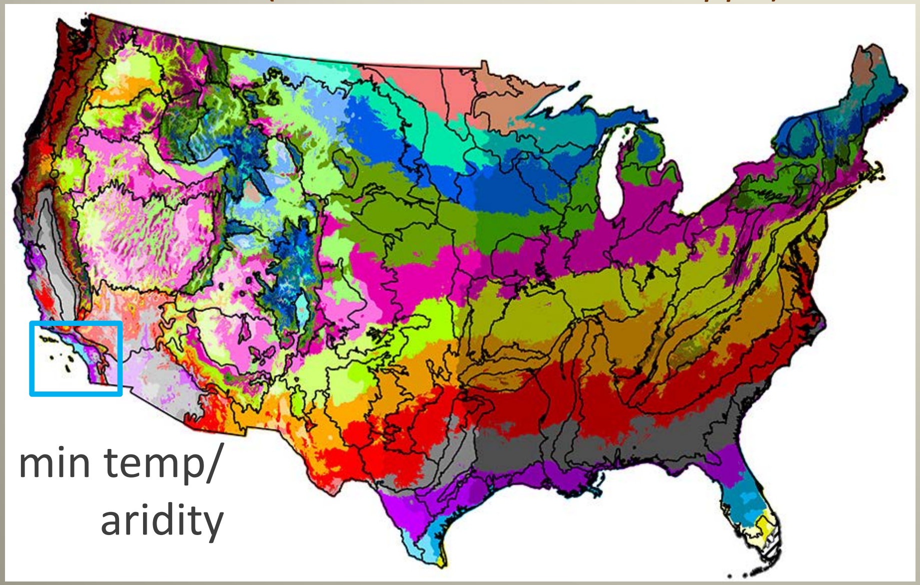


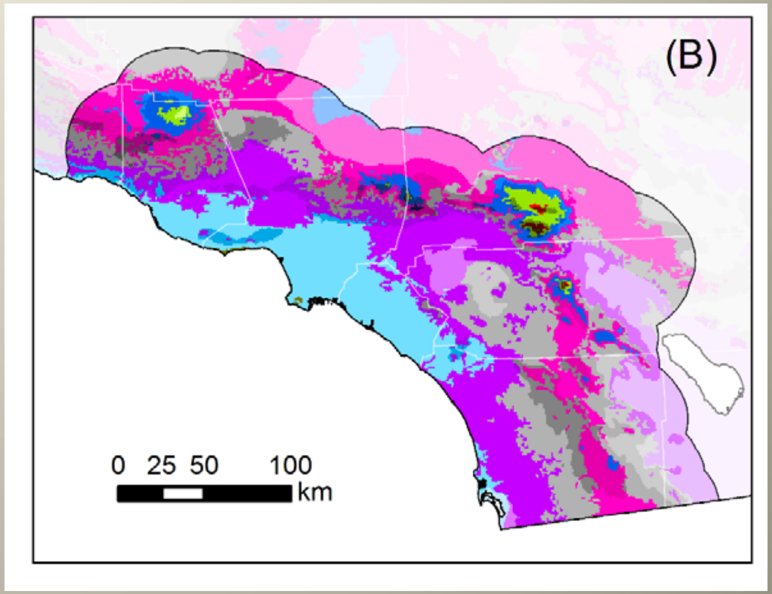
Generalized tools to guide seed movement

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

Provisional Seed Zones

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



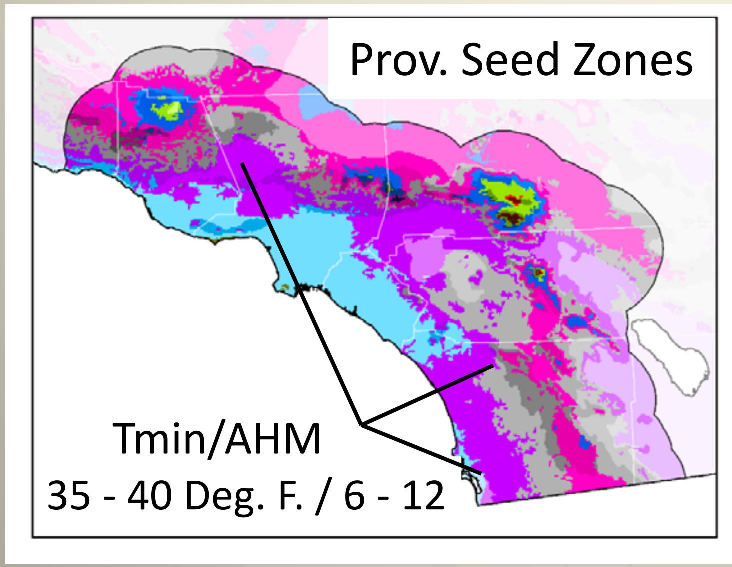


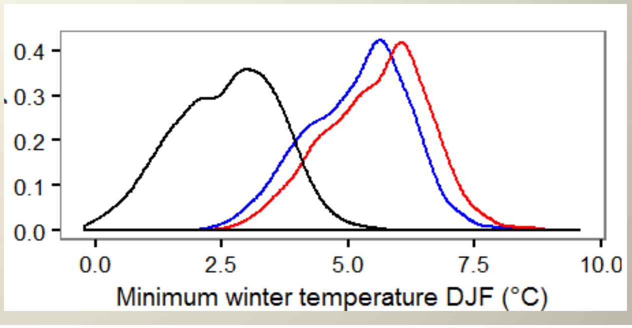
- Identifies areas of relative climatic similarity
- Restrict movement to within zones to minimize maladaptation risk

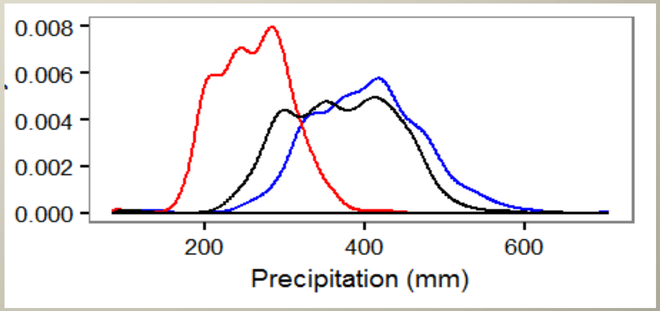
- Do these zones make sense for California taxa?
- How much are conditions changing in these zones?

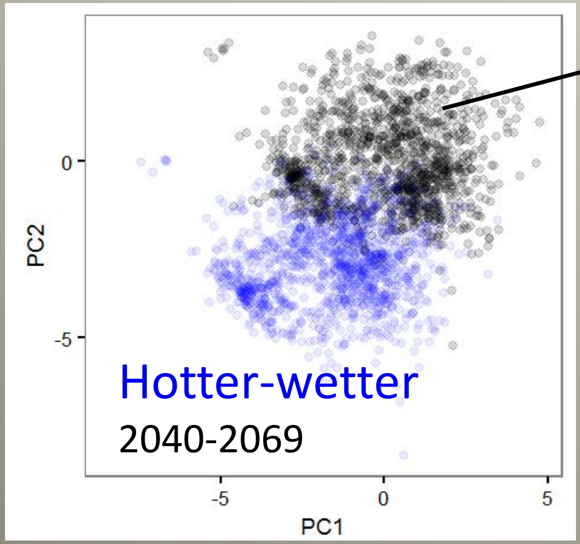
https://www.fs.fed.us/wwetac/threat-map/seedZones/doc/Seed_Zone_Google_Map_Links.pdf

Climate change: Restoration game changer?

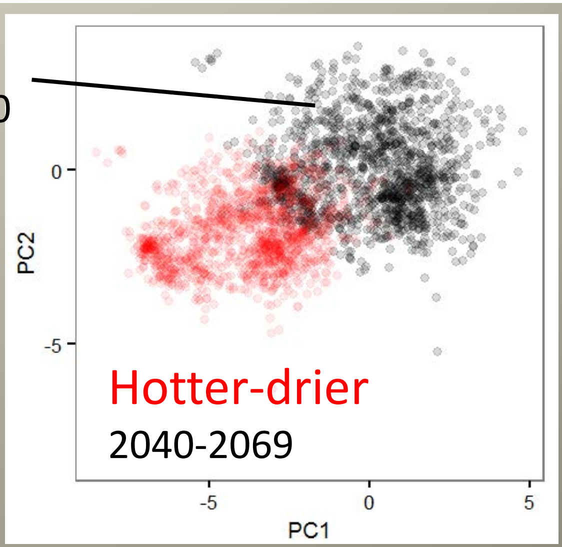




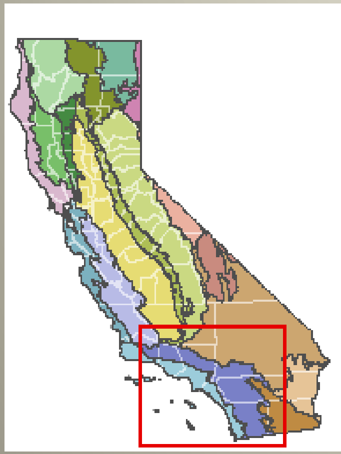


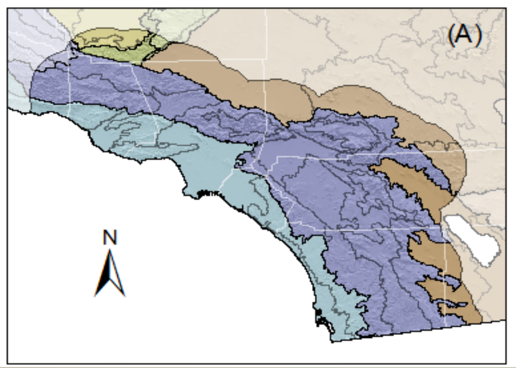


Baseline
1951-1980

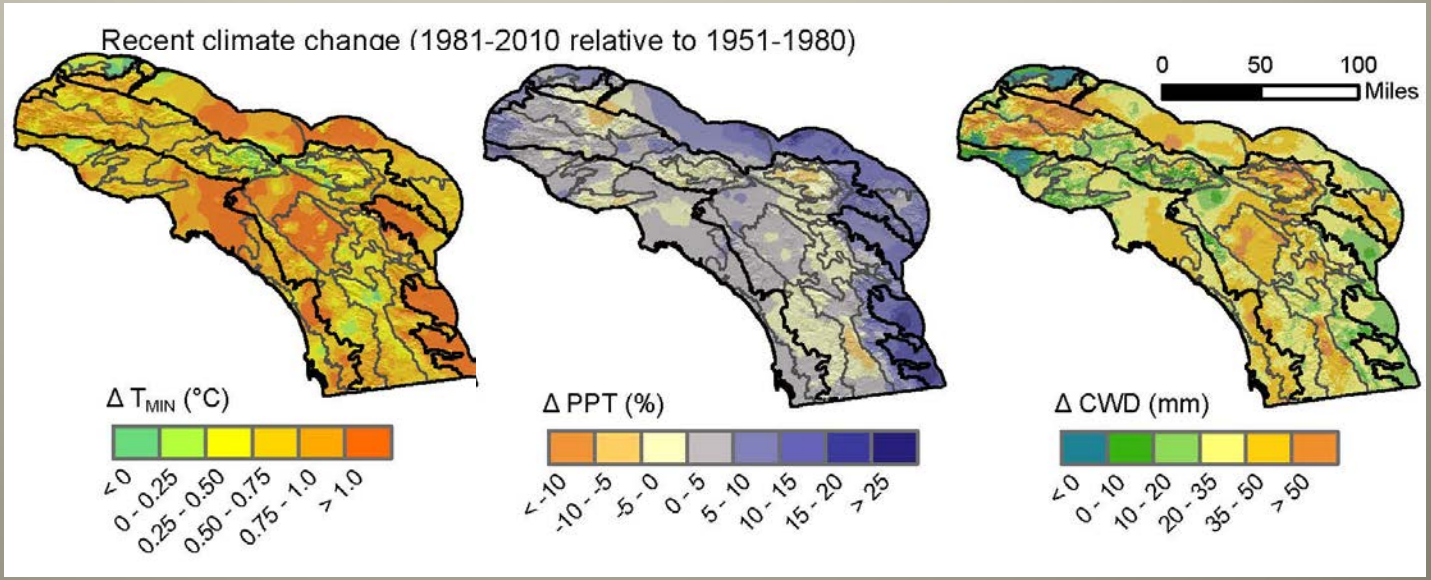


Observed shifts in climate variables for 1981-2010 relative to 1951-1980



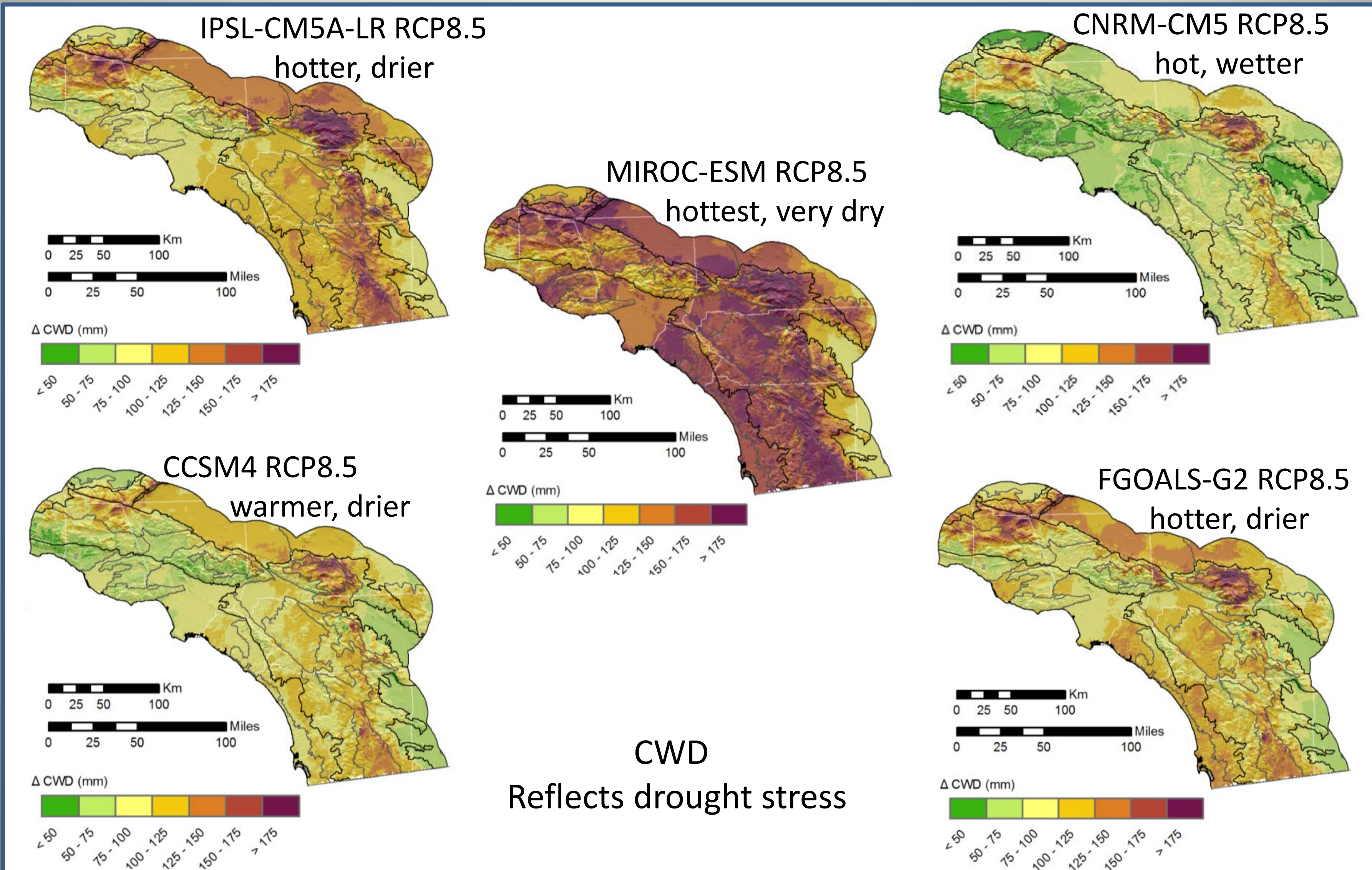


using CA-BCM downscaled climate data (270 m resolution)



Climate data: downscaled to 270m with Basin Characterization Model (BCM; Flint et al. 2013)

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



Seeding sourcing for the future?

- 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)?

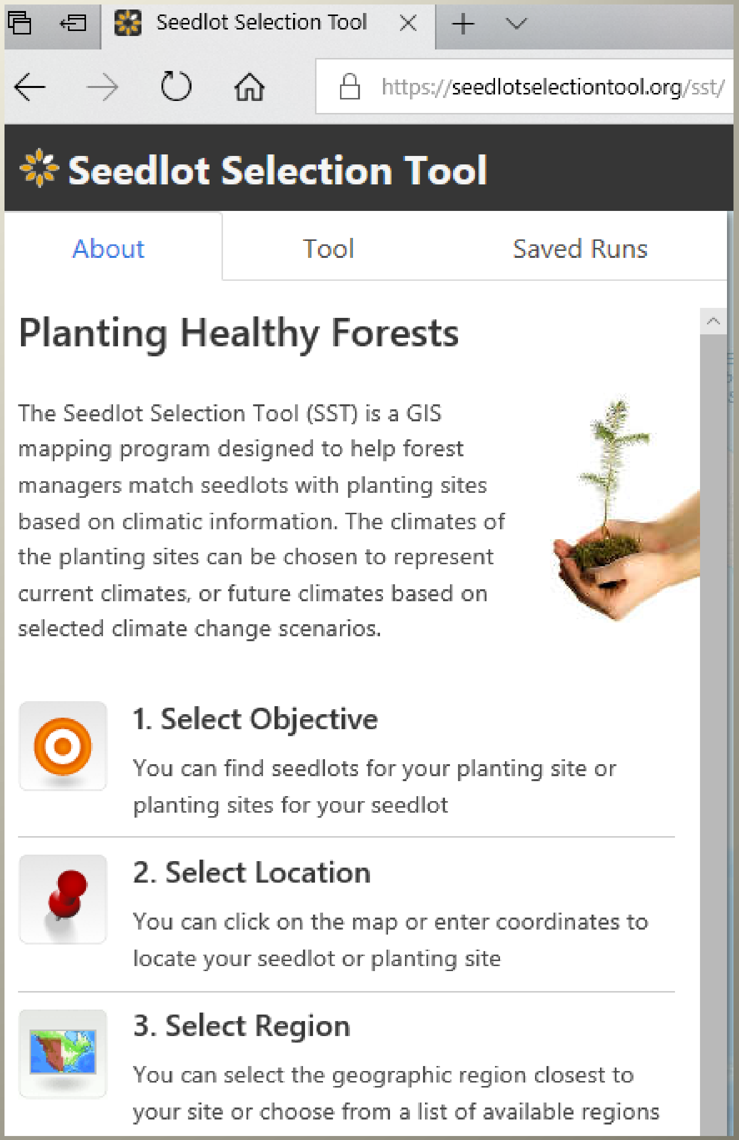
Action should not cause more harm than no action

https://seedlotselectiontool.org/sst

Evolving tools: online seedlot selection tool

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

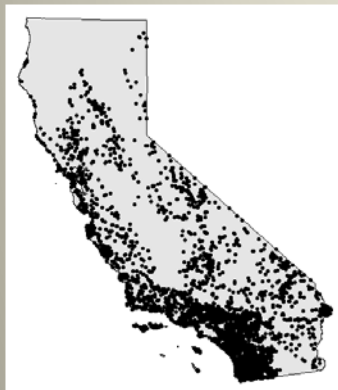
- Web-based, GIS mapping program
- Helps match seedlots of TREES to planting locations
- Uses climate information, including choice of two climate change scenarios
- Flexible designation of climate variables, constraints, distances or tree seed zones
- Expert knowledge about a taxon can improve tool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



5 more steps……

Species distribution modeling approach

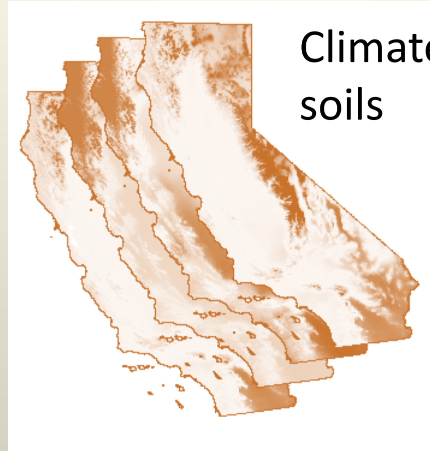
For 36 shrubland taxa:



Species occurrences
Herbarium records (vetted), field surveys

+

Climate variables
soils

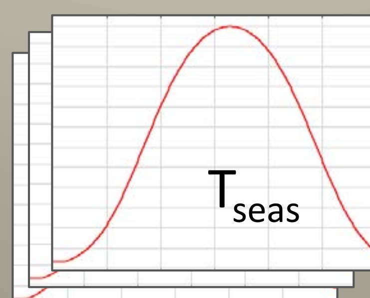


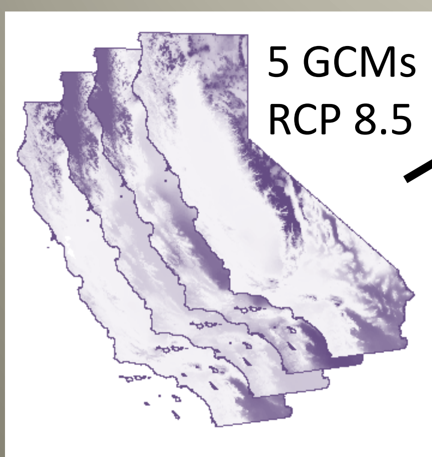
Baseline conditions (1951–1980)

↓

MAXENT

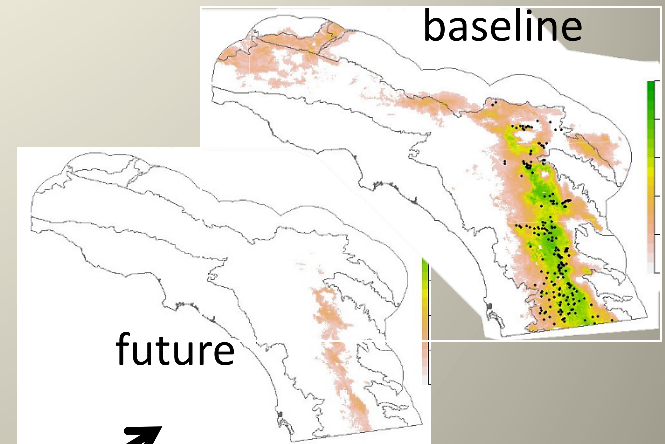
Species Distribution Model (SDM) algorithm



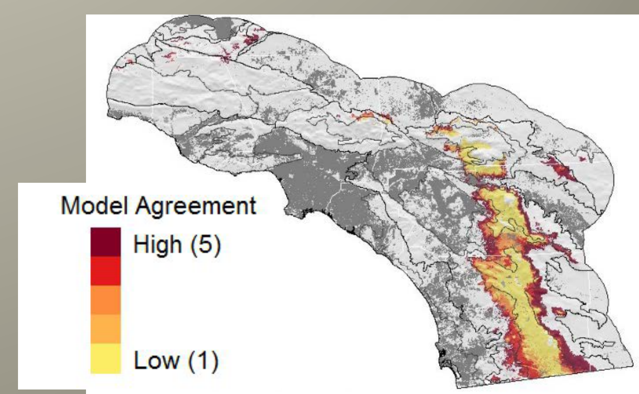


Future conditions (2040–2069)

Habitat suitability

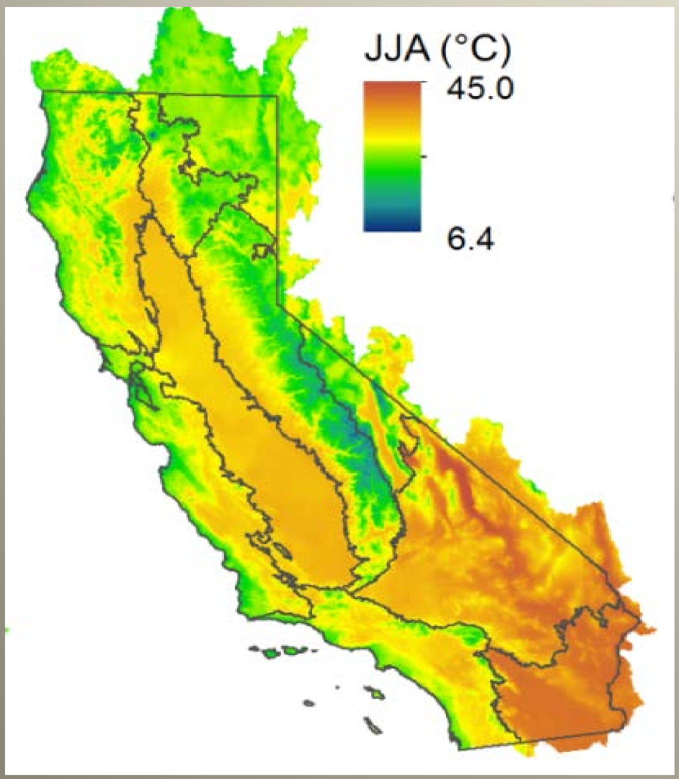


Planning Tools



Downscaled climate data: CA-BCM

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



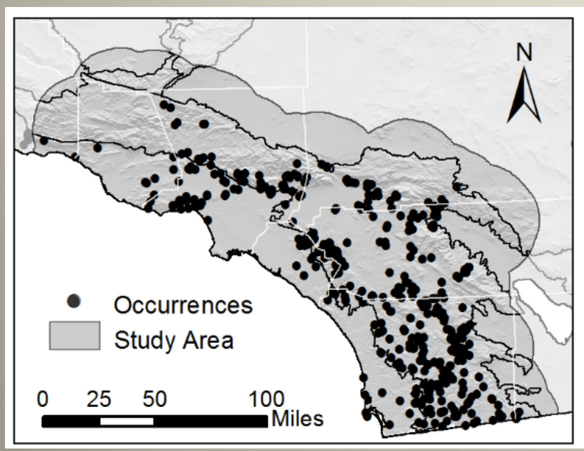
- High resolution (270 m) baseline (1951-1980), current (1981-2010) and projected (2049-2060) climate and hydrologic surfaces
- **Variables used in modeling: strong drivers of plant distribution**
  - Winter T_{min}, Summer T_{max},
  - T seasonality
  - Winter PPT, Summer PPT
  - Climatic Water Deficit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

Flint et al. 2013 Ecological Processes

Projected change in suitable habitat

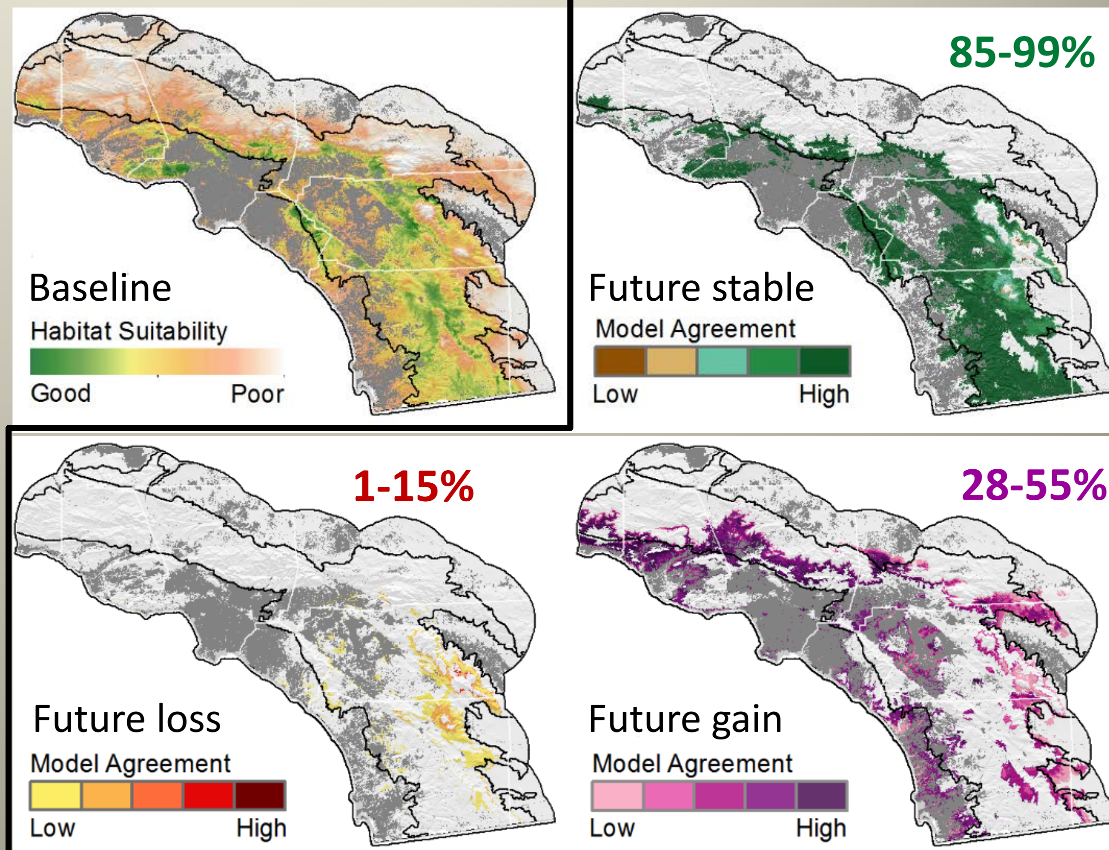
midcentury 2040–2069 relative to 1951–1980

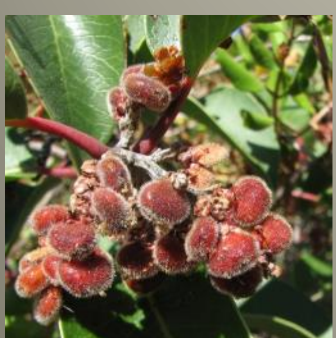
Rhus ovata
sugarbush



Baseline climate:
1951-1980

Future climate:
Mid-century 2040-2069



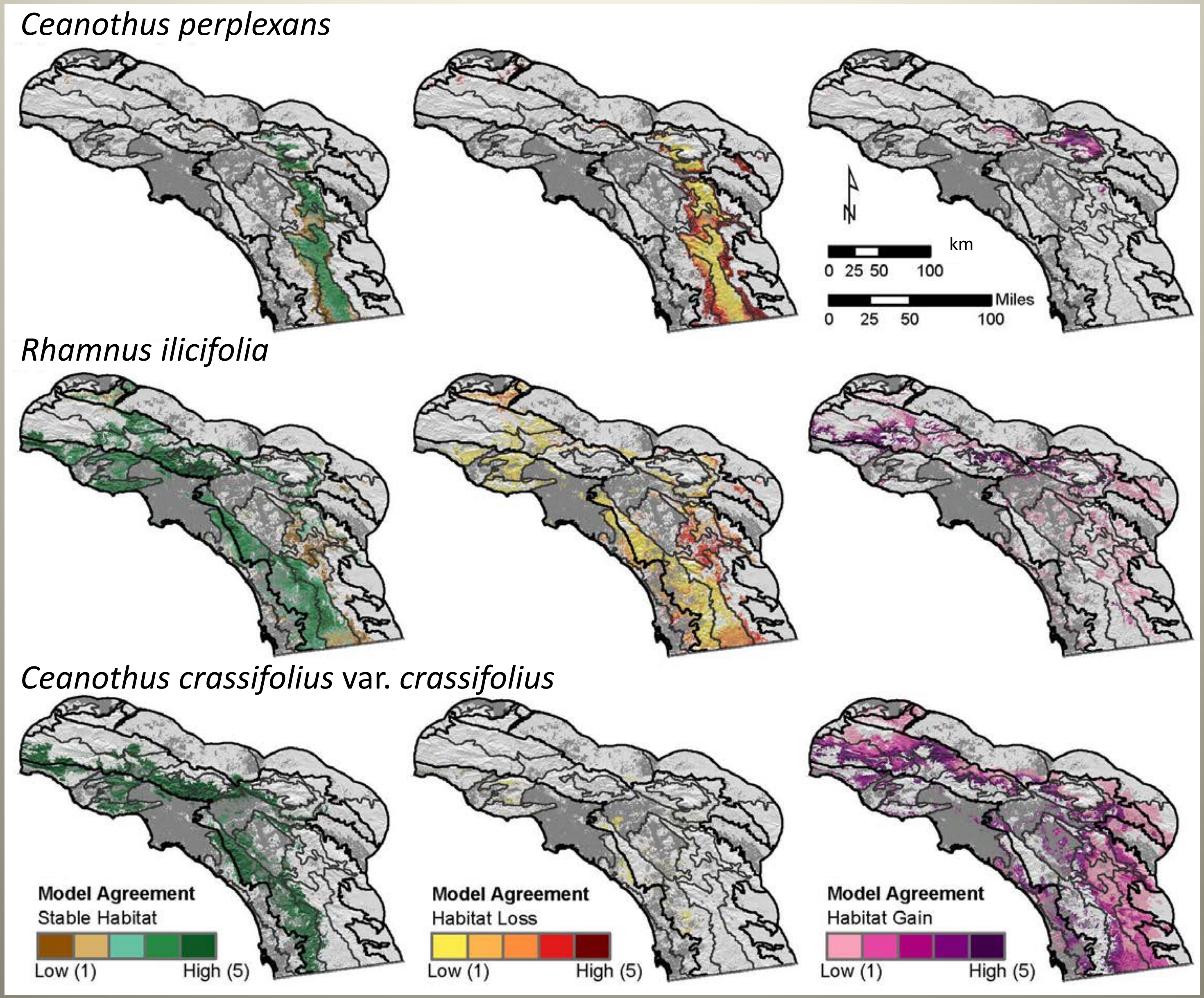


photos: Arlee Montalvo

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

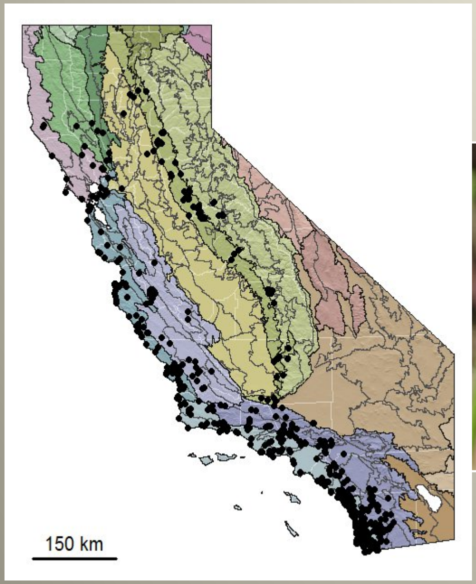
=urban/agriculture

Contrasting patterns of projected suitable habitat

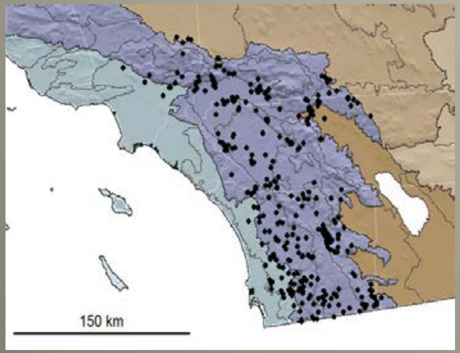


Infraspecific differences in climatic niches

Acmispon glaber



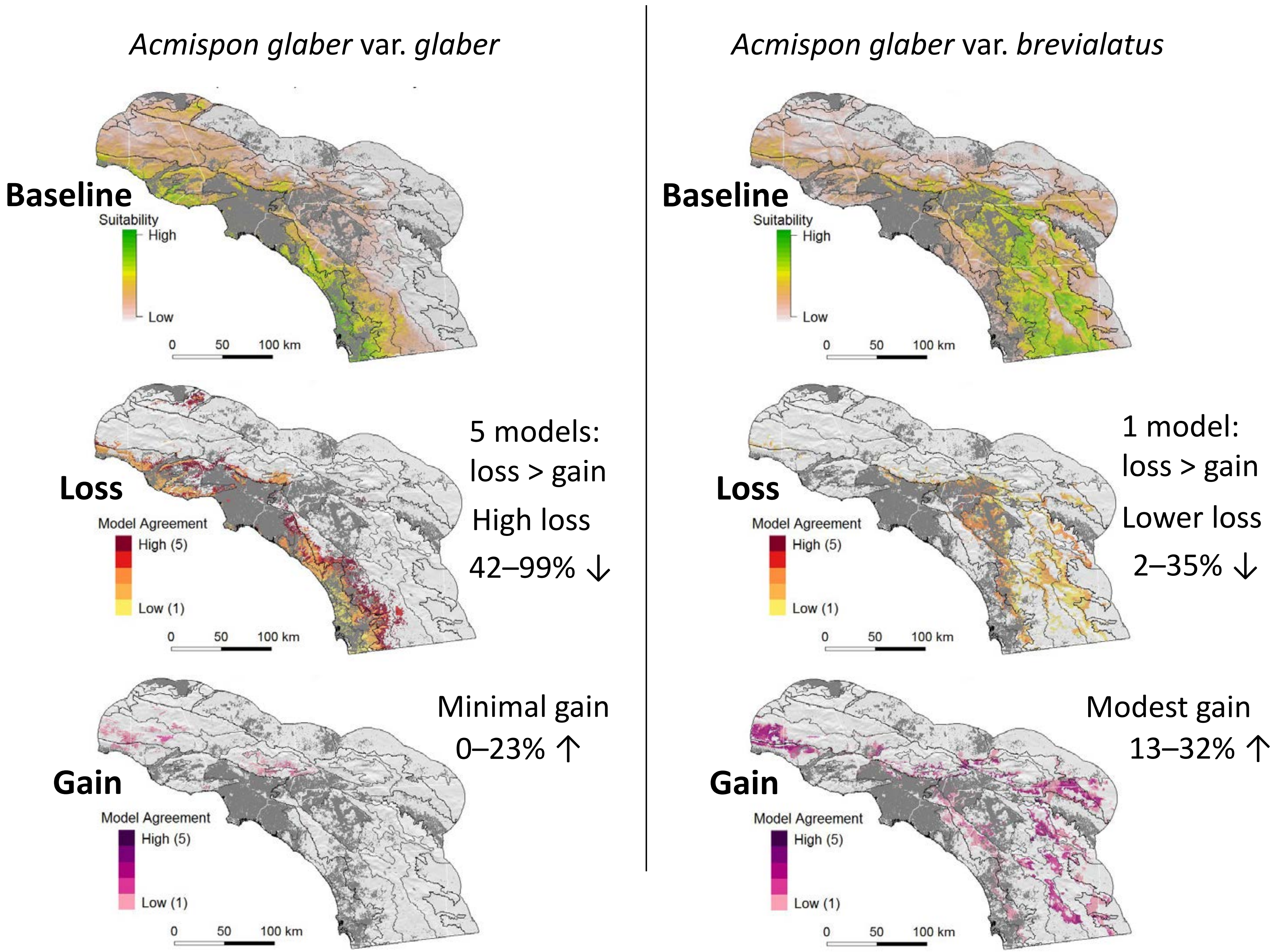
var. *glaber*



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
Suitability
High
Low
0 50 100 km
Loss
Model Agreement
High (5)
Low (1)
5 models: loss > gain
High loss
42–99% ↓
1 model: loss > gain
Lower loss
2–35% ↓
Gain
Minimal gain
0–23% ↑
Modest gain
13–32% ↑

Decision Framework Modified from Shoo, Hoffmann, Garnett, et al. 2013. Climate Change 119:239–46

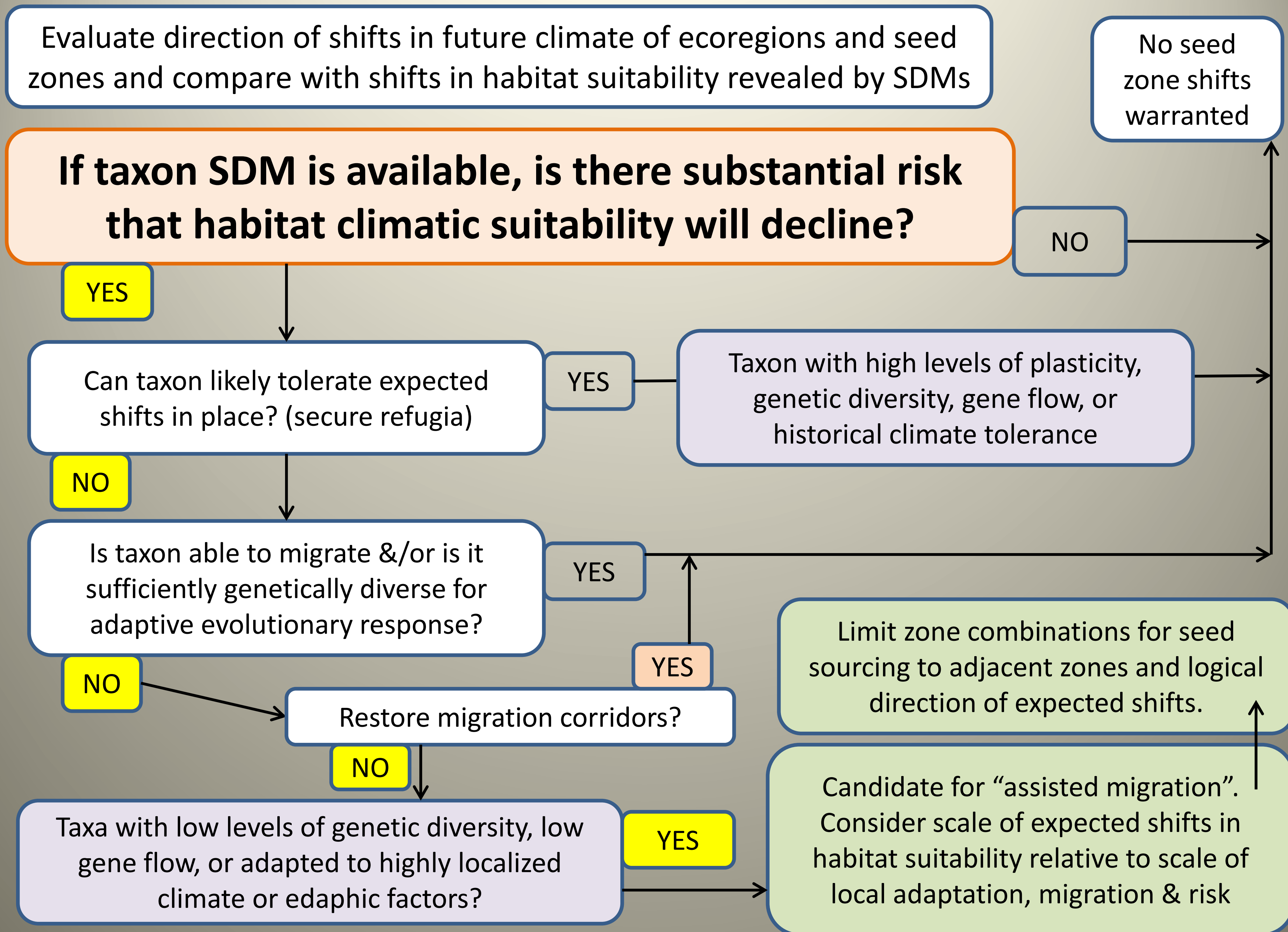
Evaluate direction of shifts in future climate of ecoregions and seed zones and compare with shifts in habitat suitability revealed by SDMs

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

NO → No seed zone shifts warranted

YES ↓

Modified from Shoo, Hoffmann, Garnett, et al. 2013. Climate Change 119:239–46



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

- 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

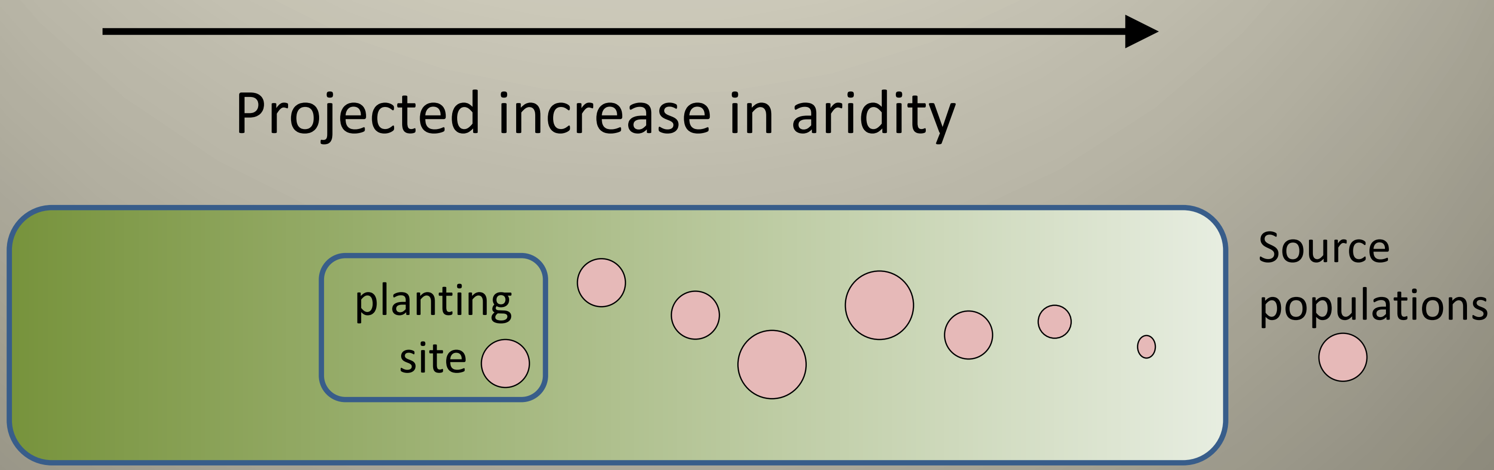
Modified from Havens, Vitt et al. 2015. *Natural Areas Journal*

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?

- 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?

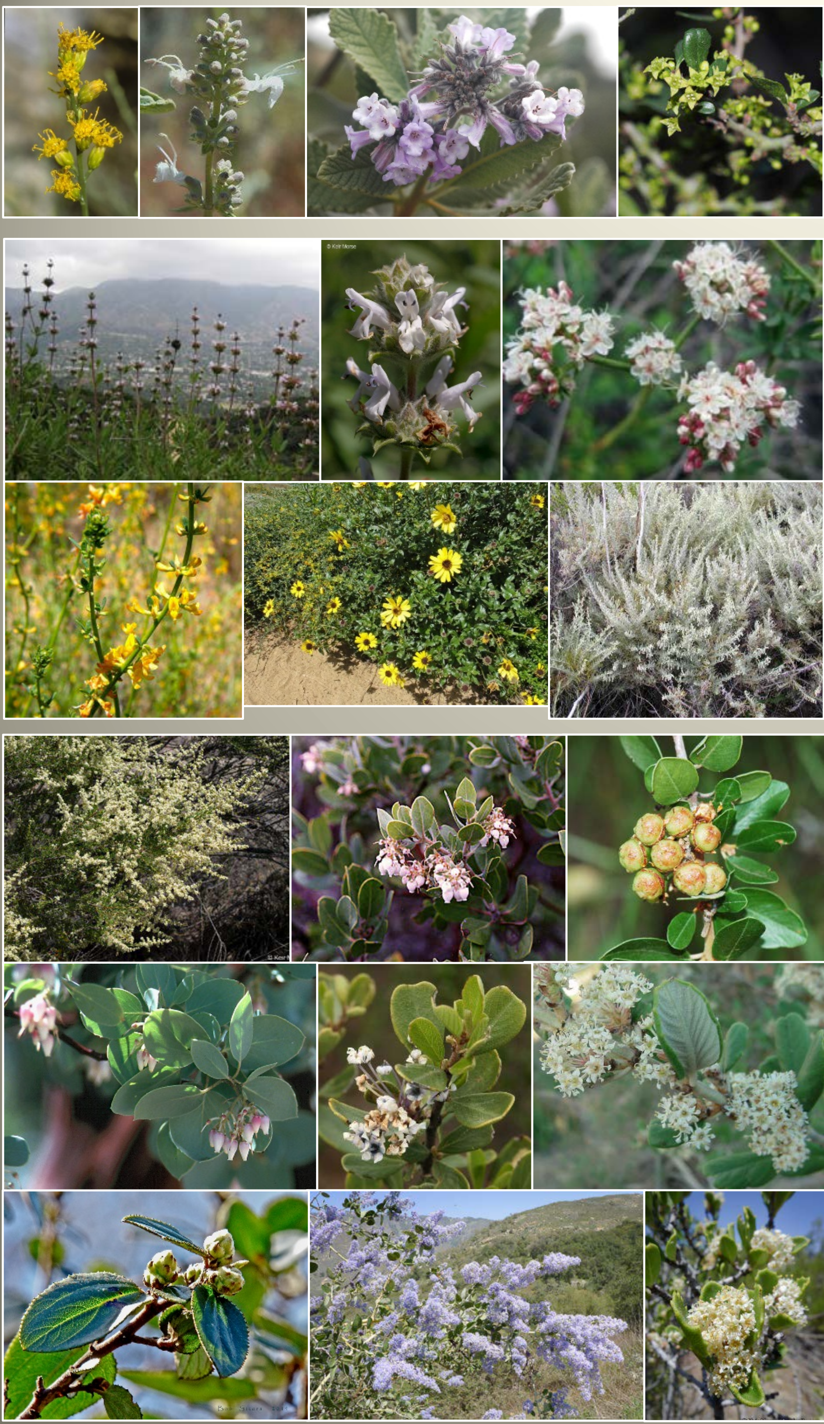


"Climate-adjusted provenancing" (modified from Prober et al. 2015. Frontiers Ecol. Evol.)

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*…



CalPhotos

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 …

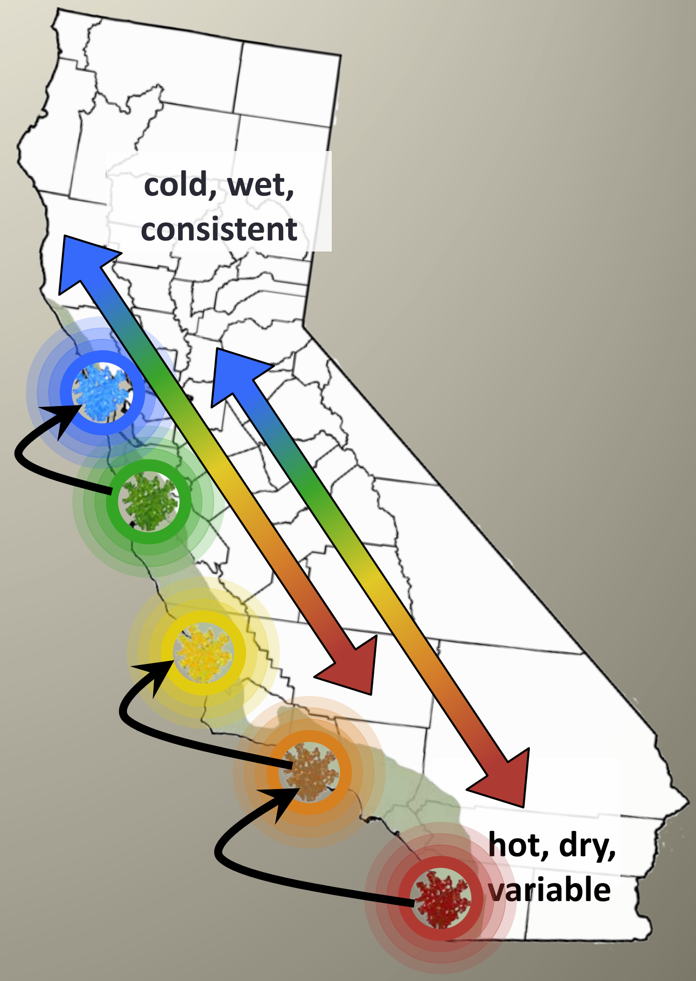
Chaparral

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

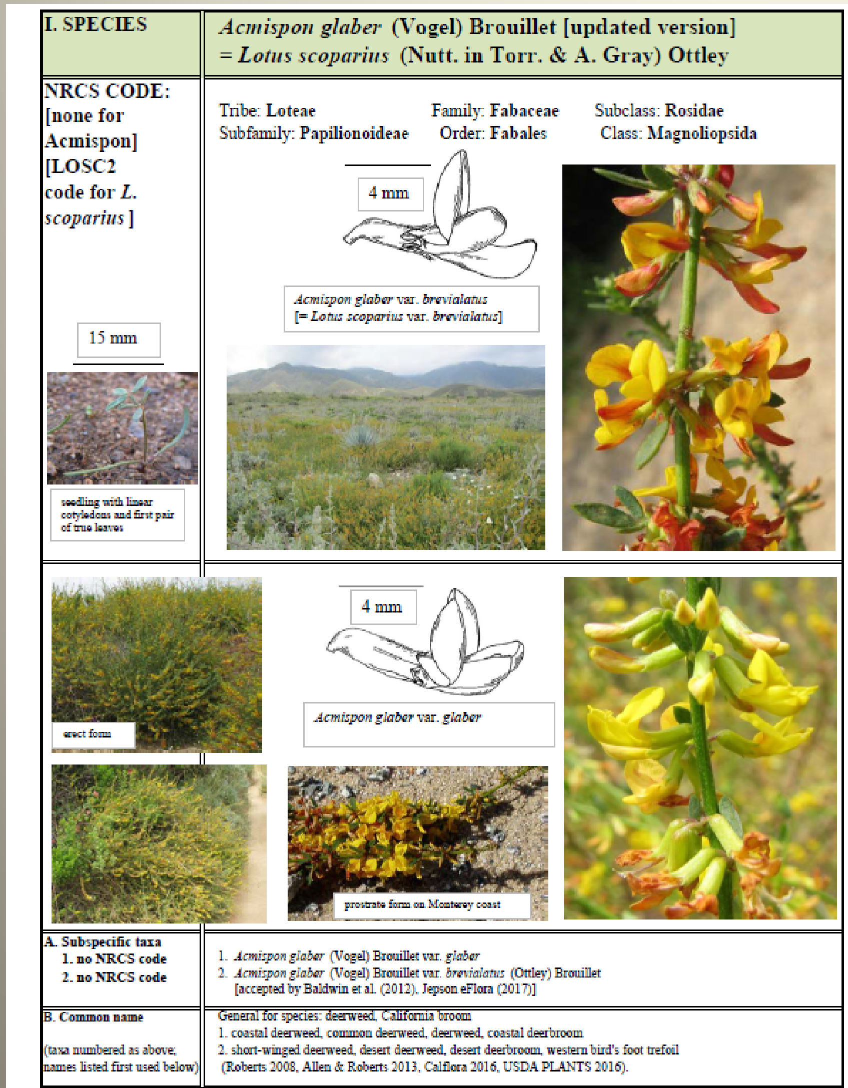
Common gardens with California sagebrush (*Artemisia californica*) revealed patterns that can inform seed sourcing

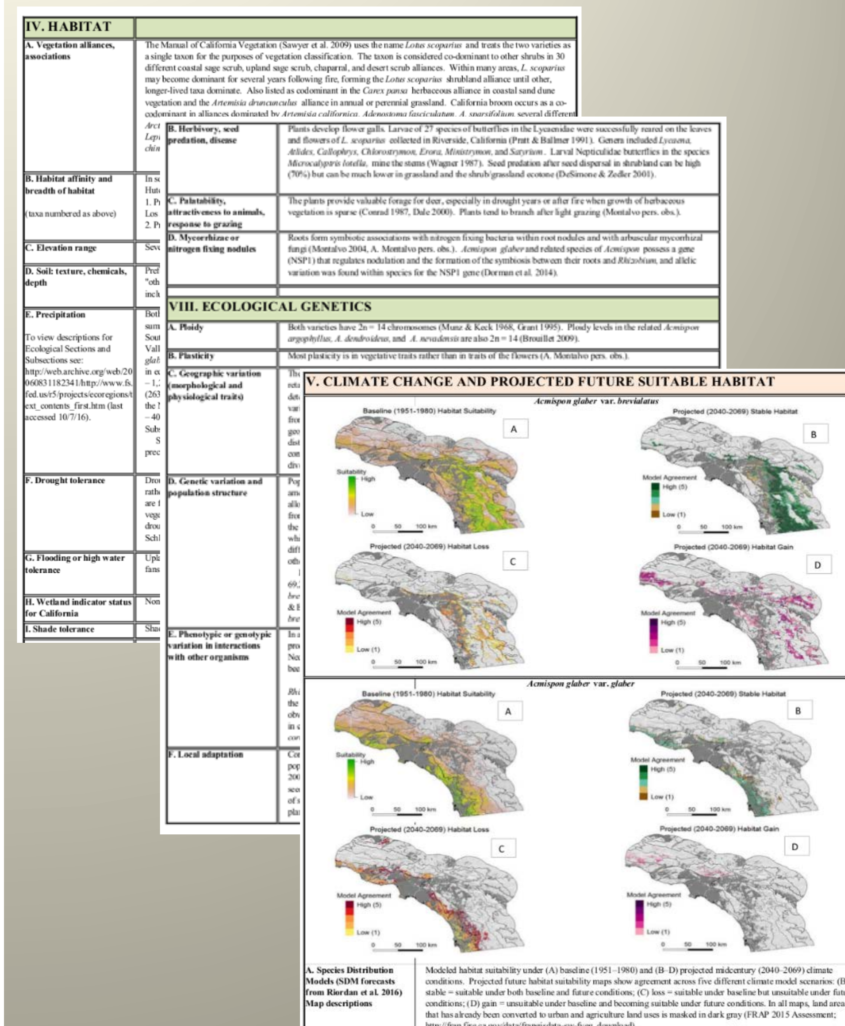
(figure courtesy: J. Pratt, K. Mooney, & D. Sheng- UCI)

- Climate, genetic variation in plant traits, and arthropod community structure all co-vary 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





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

- 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

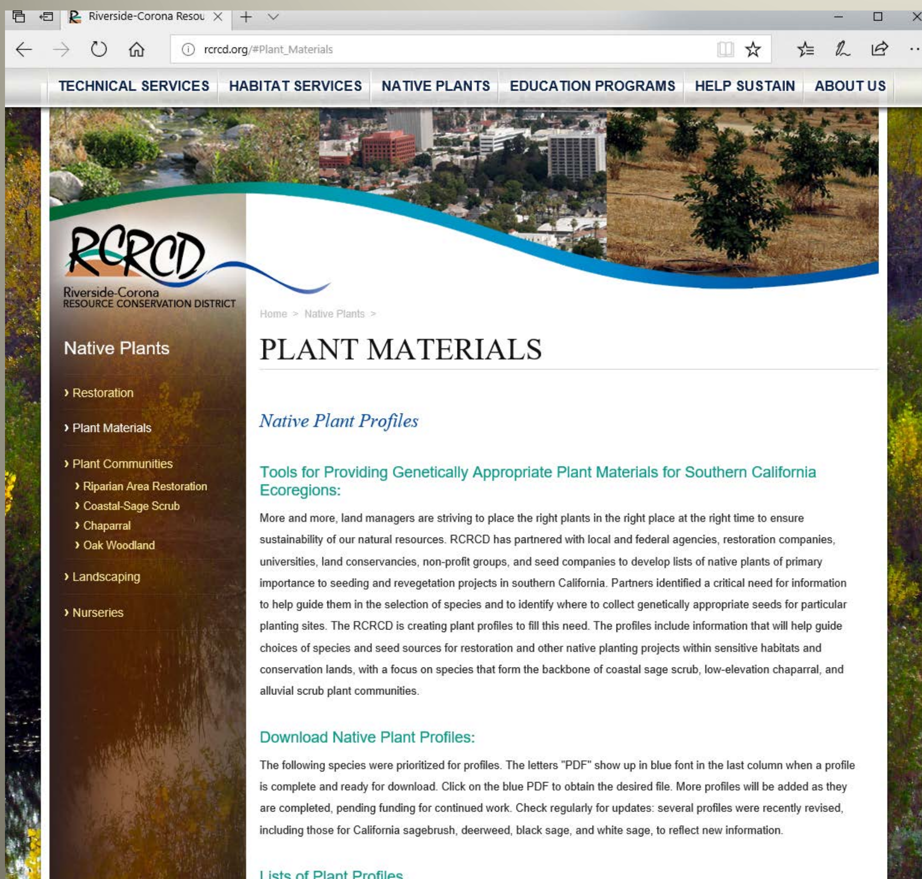
Balance risk of creating maladapted populations with the risk of local extinction (extirpation)

Posting at http://rcrcd.org/#Plant_Materials

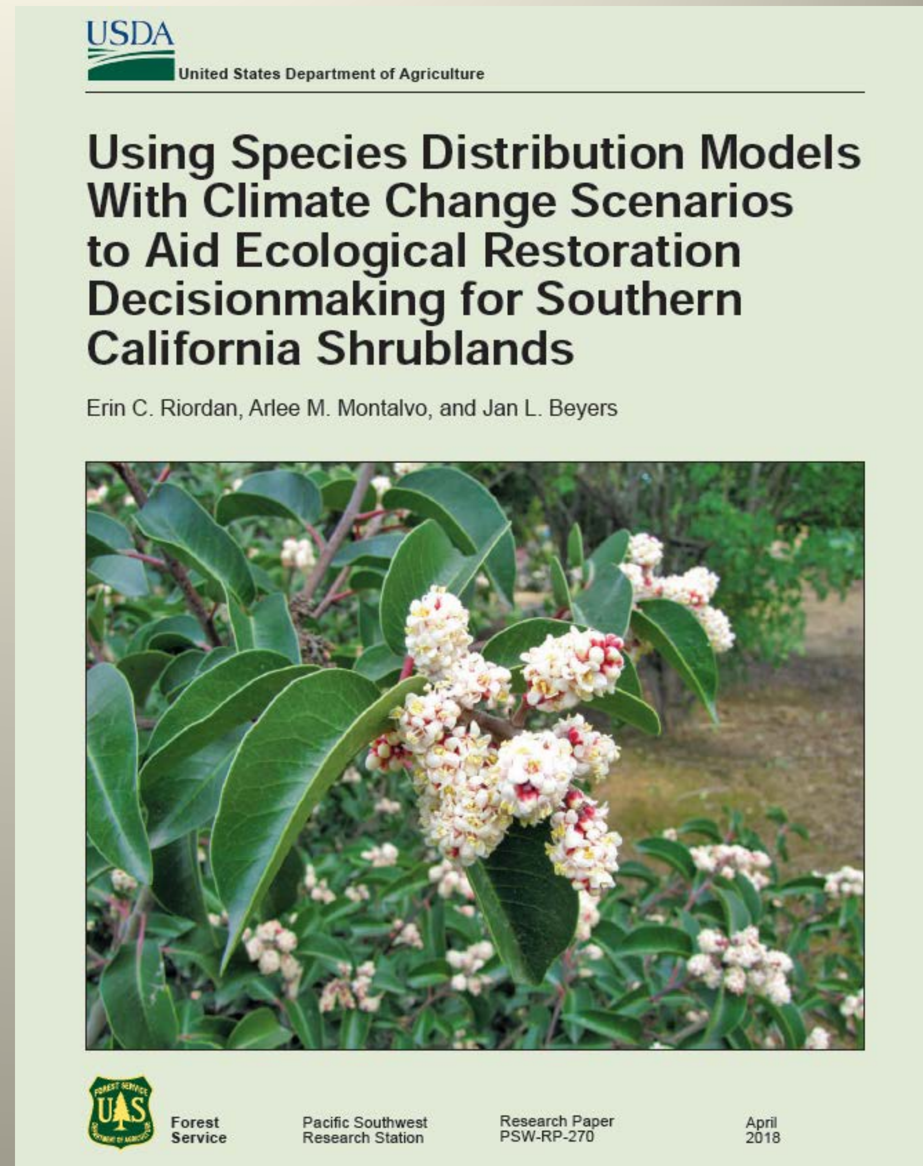
Summary

- 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**

Find plant profiles at:
http://rcrcd.org/#Plant_Materials



SDM results available soon:



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.

pca
Plant Conservation Alliance

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