Testing the effects of site selection and artificial shelters on native plant recruitment from seed in a degraded coastal sage scrub restoration




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Barriers to Restoration

- Competition with invasives
- Herbivory
- Lack of suitable habitat for plant establishment (nutrients, moisture, microclimate)
- Limited time and funding

Coastal Sage Scrub Restoration Experiment

Goal:
Improve cost-effectiveness in CSS restoration

Techniques and Emerging technologies:

1. Habitat suitability modeling
2. Tree shelters
3. Seeding of shrubs

Habitat Suitability Modeling

- Remote sensing tools (LiDAR, GIS) help identify topographic microclimates across large landscapes more suitable for critical plant life stages
- Can direct efficient use of resources

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Ecological Applications, 24(2), 2014, pp. 385–395

Mapping habitat suitability for at-risk plant species and its implications for restoration and reintroduction

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Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION

RESEARCH ARTICLE

Cost-effective ecological restoration

Sarah Kimball[1,2], Megan Lulow[1,3], Quinn Sorenson[3], Kathleen Balazs[1,3], Yi-Chin Fang[3], Steven J. Davis[4], Michael O'Connell[3], Travis E. Huxman[1,5]

Ecological restoration is a multibillion dollar industry critical for improving degraded habitat. However, most restoration is conducted without clearly defined success measures or analysis of costs. Outcomes are influenced by environmental conditions that vary across space and time, yet such variation is rarely considered in restoration planning. Here, we present a cost-effectiveness analysis of terrestrial restoration methods to determine how practitioners may restore the highest native

The role of site selection

Moderately steep, Pole-facing slopes:

- Lower incident solar **radiation** and **temperature**

↓

- Reduced **evaporation** and **run-off**

↓

- Increased soil **moisture** and **nutrients**

↓

- **Less stressful** for seedlings, better establishment

Bochet E, Garcia-Fayos P, Poesen J (2009). Topographic thresholds for plant colonization on semi-arid eroded slopes. Earth Surfaces Processes and Landforms 34, 1758-1771.

Limits to habitat suitability models

Photo credit: Cheryl Birker

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Role of shelters

Photo courtesy of Jan Beyers, USFS

Del Campo, Navarro, Aguilella, & González. (2006). Effect of tree shelter design on water condensation and run-off and its potential benefit for reforestation establishment in semiarid climates. Forest Ecology and Management, 235(1), 107-115.

Role of shelters

- Anti-herbivory

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Role of shelters

- Anti-herbivory
- Protection from chemical and physical weed management

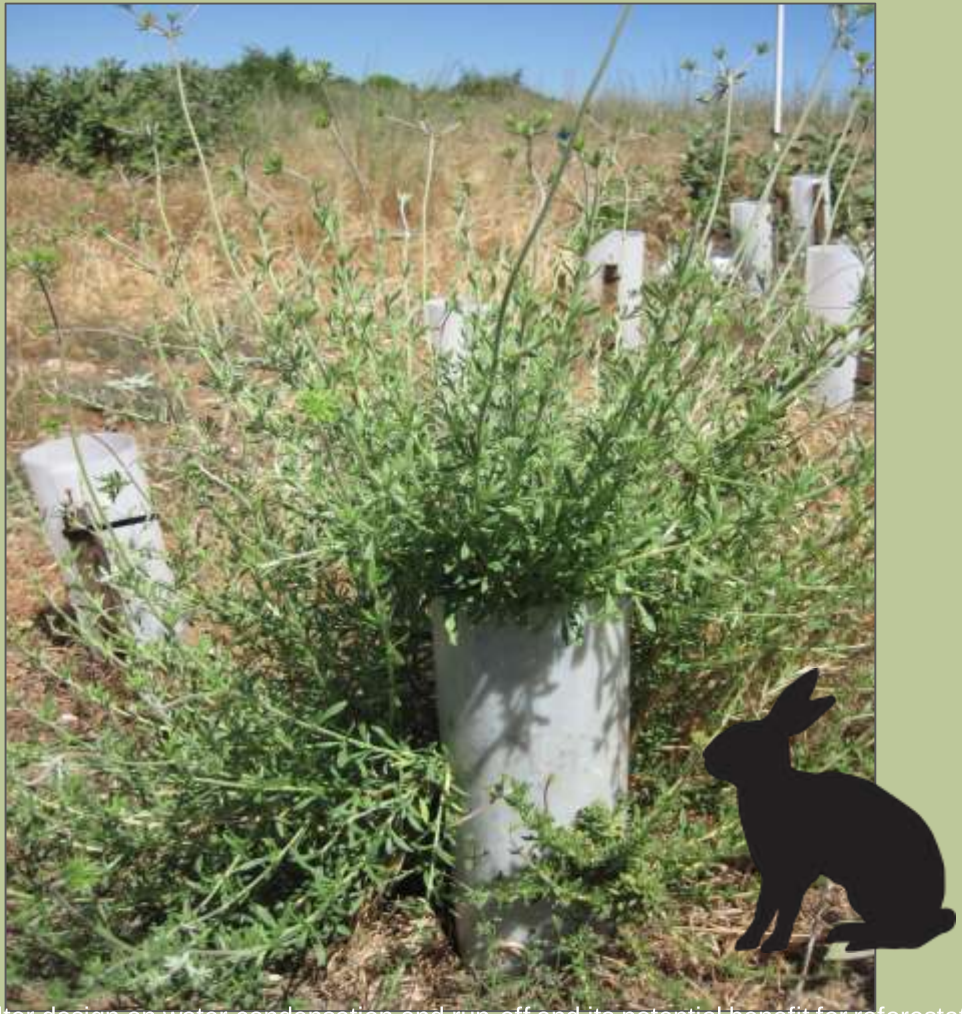
Photo courtesy of Jan Beyers, USFS

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Role of shelters

- Anti-herbivory

- Protection from chemical and physical weed managemen

Beneficial microclimate:

- Solar radiation

- Wind and erosion

- Soil moisture

- Relative humidity

Photo courtesy of Jan Beyers, USFS

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Role of shelters

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Shelter Limitations:

- Lack of non-forestry studies
- Direct-seeding results?
- Varying species interactions

Photo courtesy of Jan Beyers, USFS

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Seeding

Benefits:

- Cost (propagation)
- Labor (transport and transplanting)
- Maintenance (irrigation)
- Nursery-borne pathogens (ex. *Phytophthora* sp.)
- Timing (flexible with seed storage)

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Tradeoffs:

- Lower success rate!!
  - -granivory and herbivory
  - -poor conditions
  - -slow growth/weed competition

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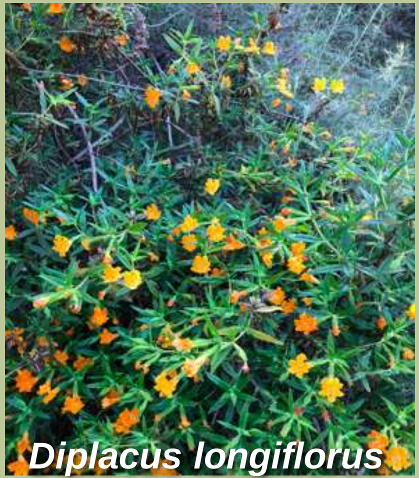
Off-set by shelters?

Different species – different life history traits



Different species – different life history traits

Annual

Perennial

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Perennial

Shade-intolerant

Partial shade

Shade-tolerant

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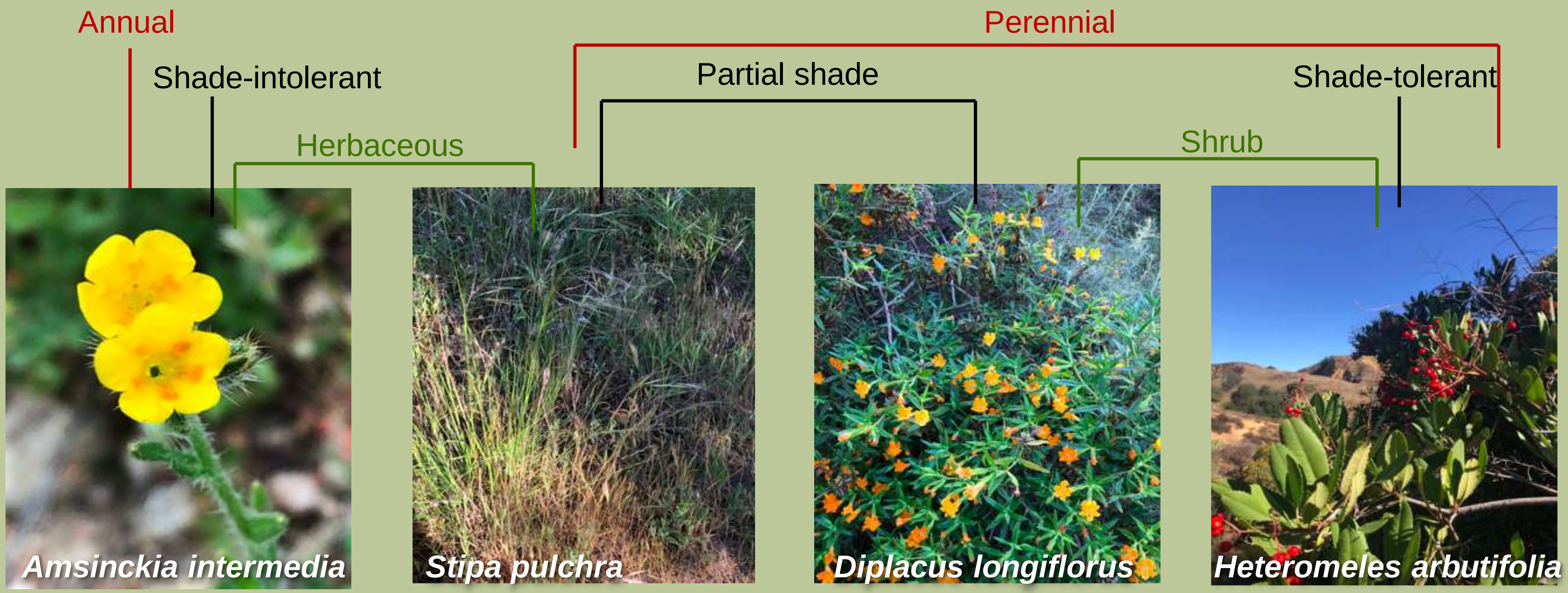


Different species – different life history traits

Annual

Perennial

Shade-intolerant

Partial shade

Shade-tolerant

Herbaceous

Shrub

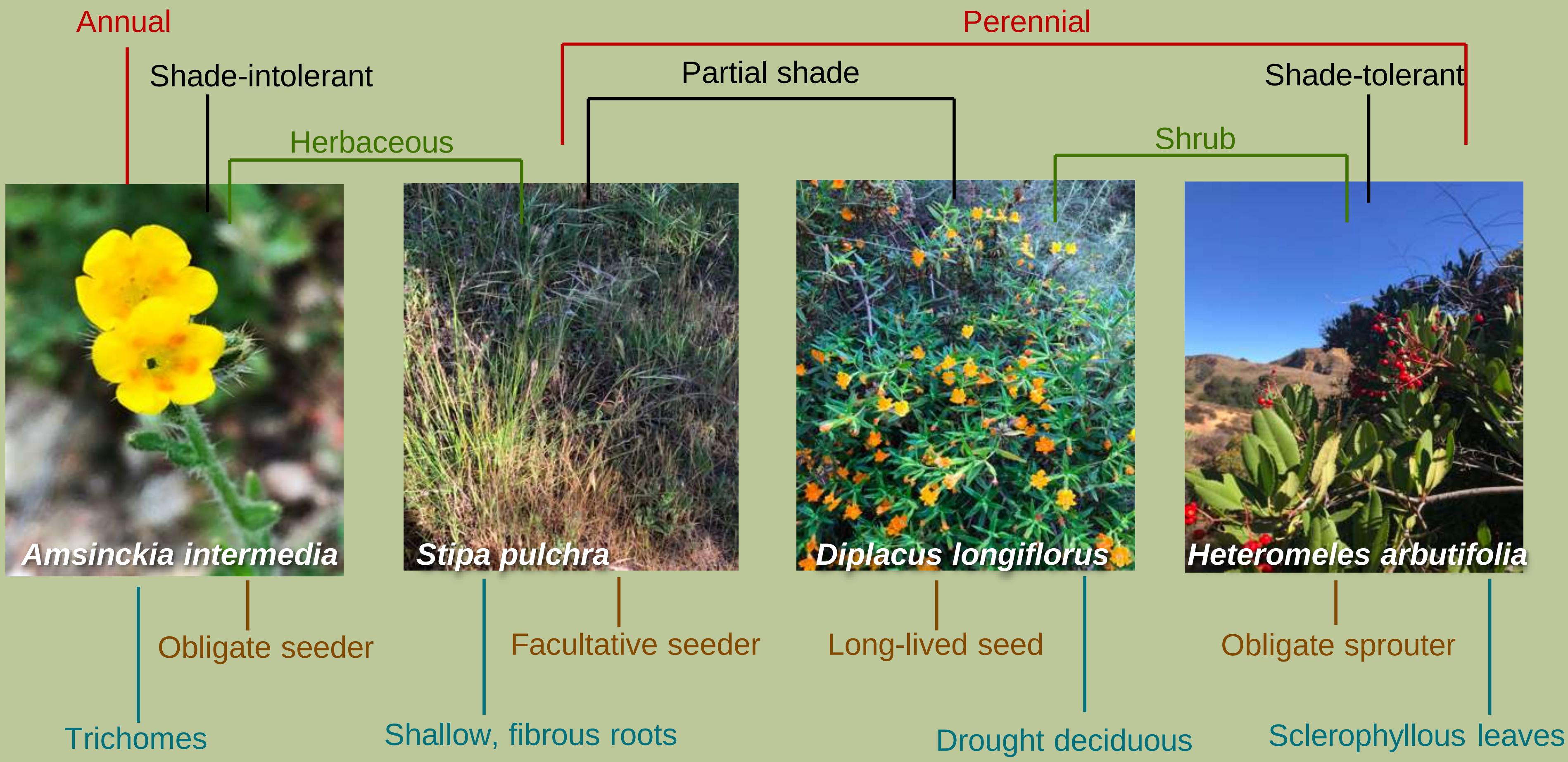
Obligate seeder

Facultative seeder

Long-lived seed

Obligate sprouter

Different species – different life history traits



Question 1

How do site selection and shelters affect abiotic factors important to plant recruitment?

- Abiotic conditions will be less severe in High Suitability (HS) plots and Shelter treatments

- Shelters will play a greater role in ameliorating abiotic conditions in harsher Low Suitability (LS) sites than the more moderate HS sites

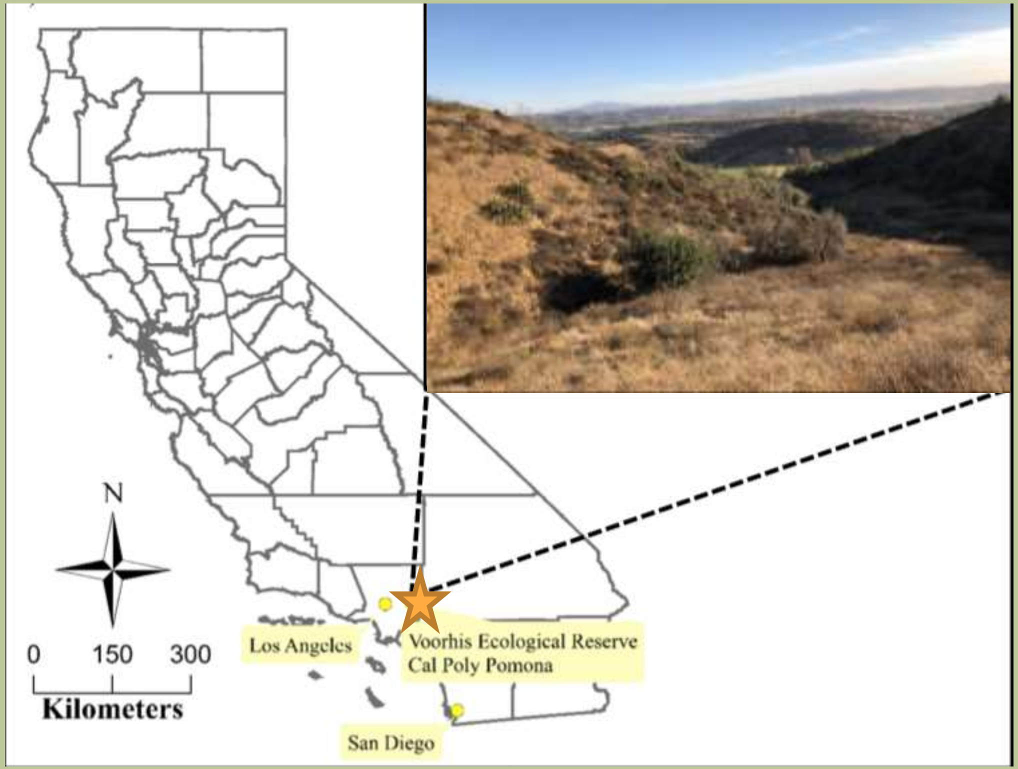
Question 2

How do site selection and shelters affect seed germination and seedling establishment patterns?

- There will be higher germination for all species in shelters and HS sites
- Shelters will play a greater role in seedling survival in LS sites
- Shrub seedlings will show higher association with HS sites and shelters, while herbaceous species will be unaffected or perform better in open treatments

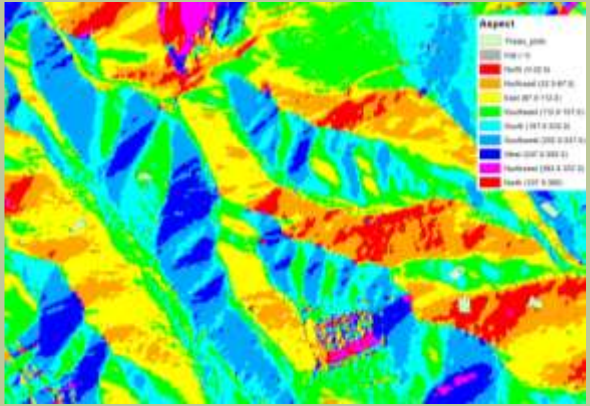
Restoration Experiment

- 2 years (2017-2019)
- Voorhis Ecological Reserve (Cal Poly Pomona)
- Degraded coastal sage scrub habitat
- Increase native cover within experimental plots



Habitat Suitability Model: Voorhis Ecological Reserve

Aspect



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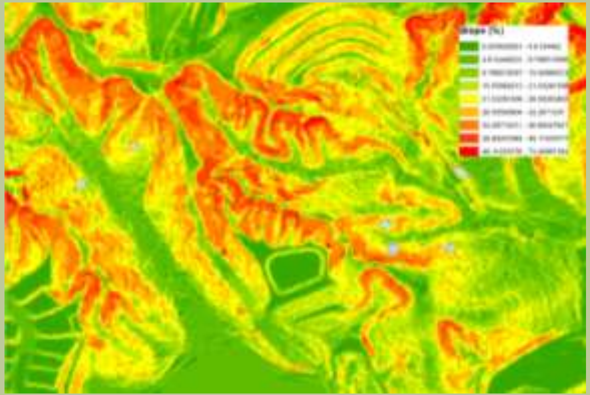
Slope



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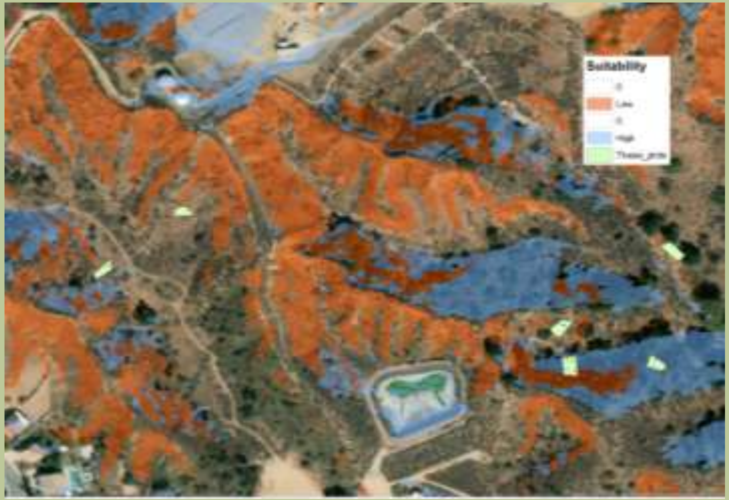

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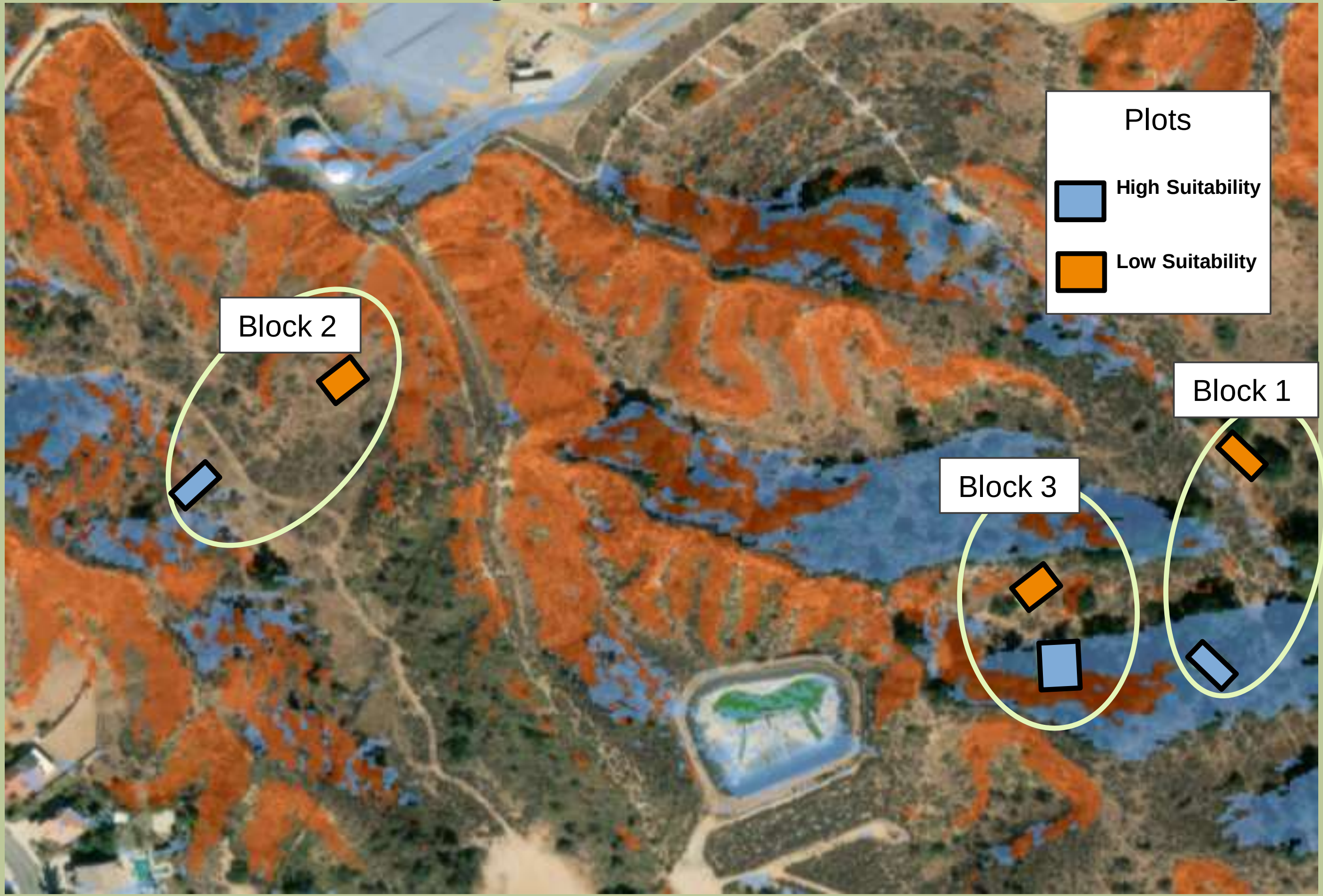


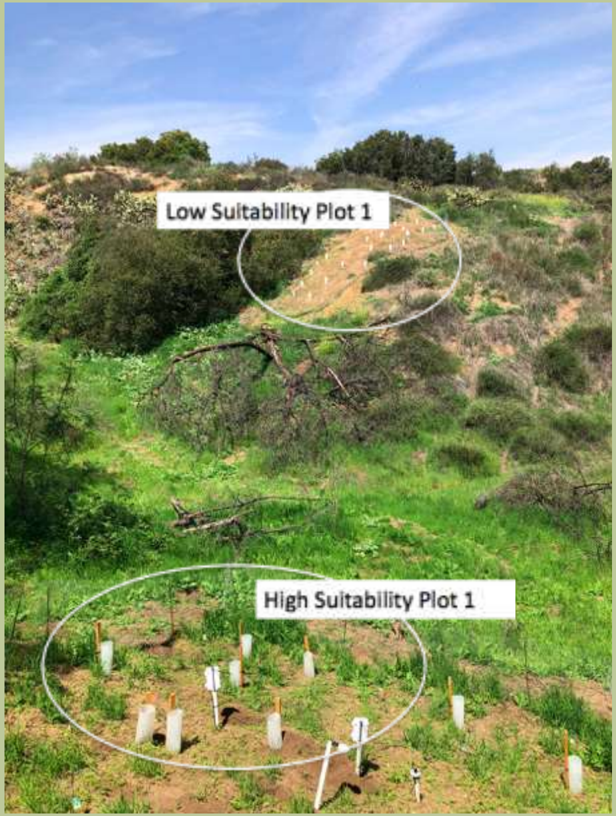
High Suitability:

- North-facing aspect
- 10-30% slope

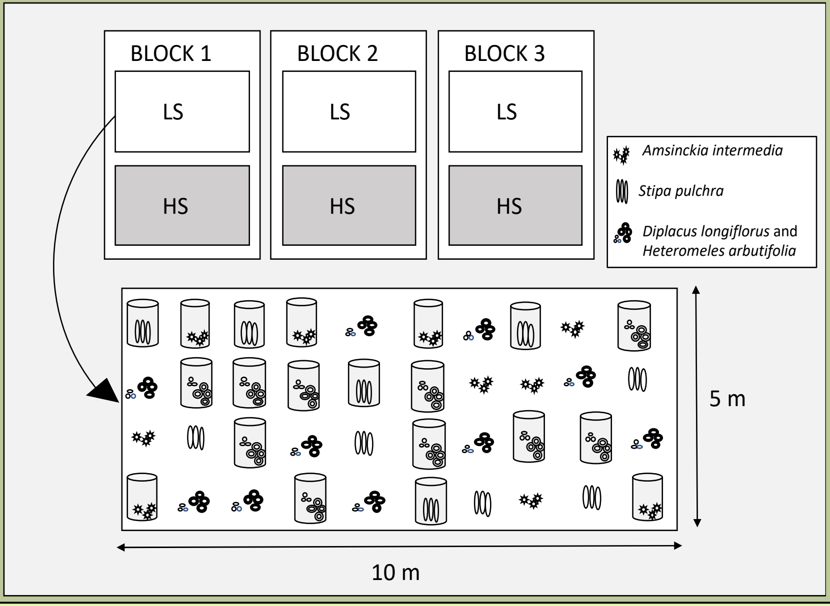
Low Suitability:

- South-facing aspect
- >30% slope

Experimental Design



Two 10x5 m plots per block



Three-factors:

- **Suitability (**2 levels) [whole-plot]
- **Species** (4 levels)
- **Shelter** (2 levels) [factorial]

X 3 blocks

Replication:

n=30 per Species, Suitability and Shelter treatment

N=240 total subplots over 6 plots

Site Preparation

All non-natives hand-cleared before and throughout experiment





Site Preparation

All non-natives hand-cleared before and throughout experiment

Sensors measured hourly:
- Solar radiation
- Air and soil temperature
- Soil moisture
- Leaf wetness

+ Sediment erosion traps

Shelters

- Shelter experiment modeled after trial in Angeles National Forest (Beyers and VinZant, 2016)
- TreePro Tree Tubes (Lafayette, IN)
- 30cm tall by 10cm diameter
- Single-walled, translucent plastic
- Ventilation holes (halfway up to allow herbicide treatment at base)

Photo courtesy of Jan Beyers, USFS

Seeding

Seeds collected and cleaned

Seeds counted and sorted

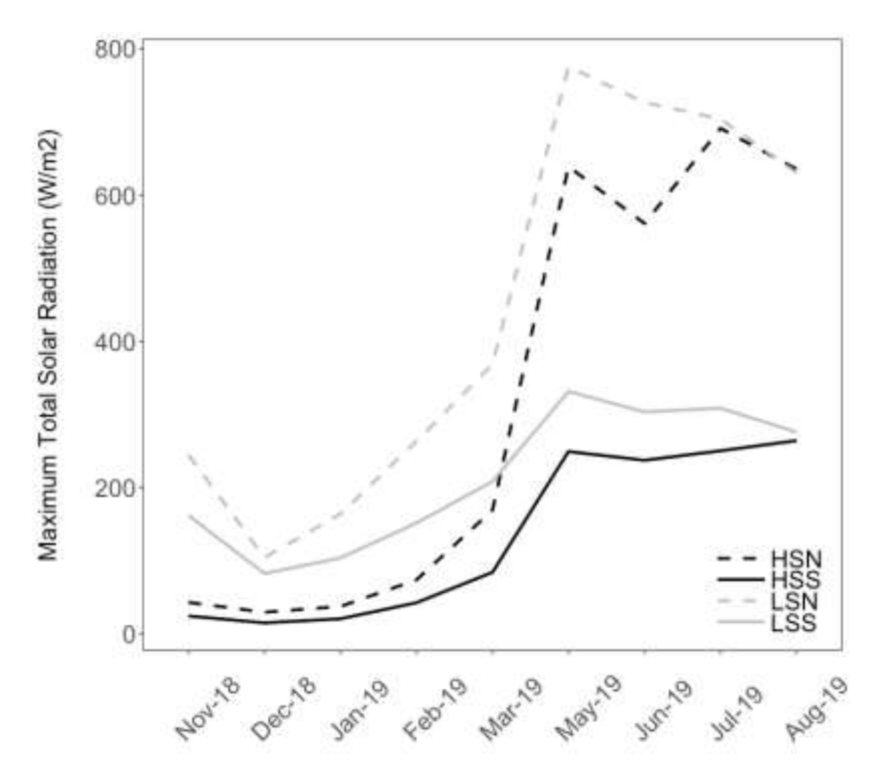
Greenhouse trials

Seeds surface sown at a rate >100 seeds/m^2 and hand-tamped

Results: Abiotic

Results: Solar Radiation

Maximum Total Solar Radiation, Year 2



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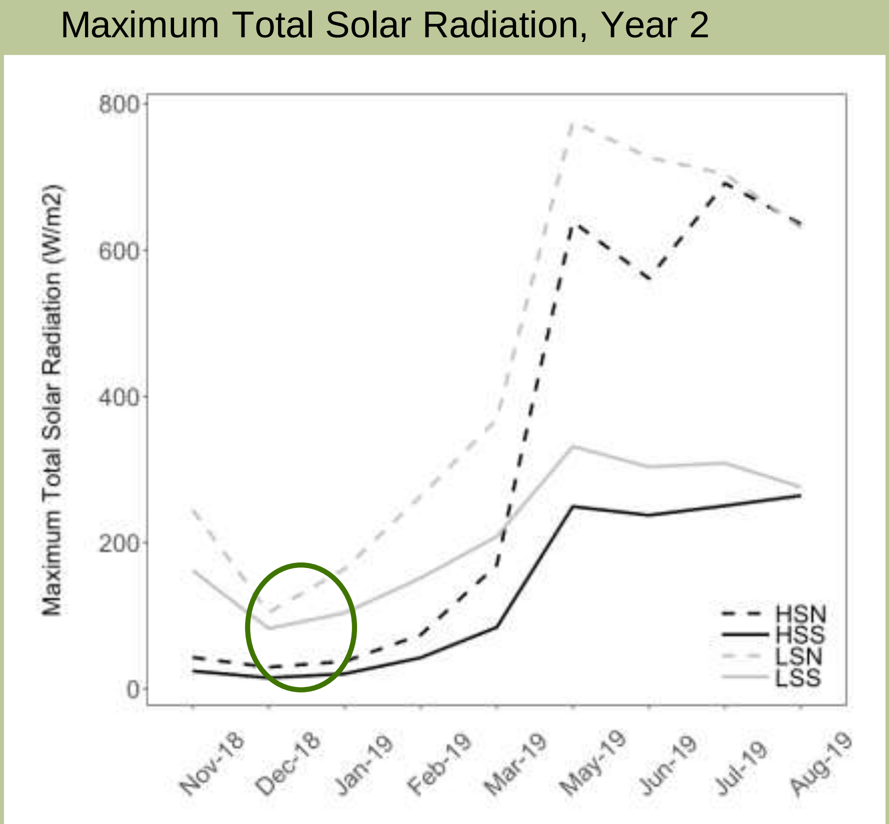

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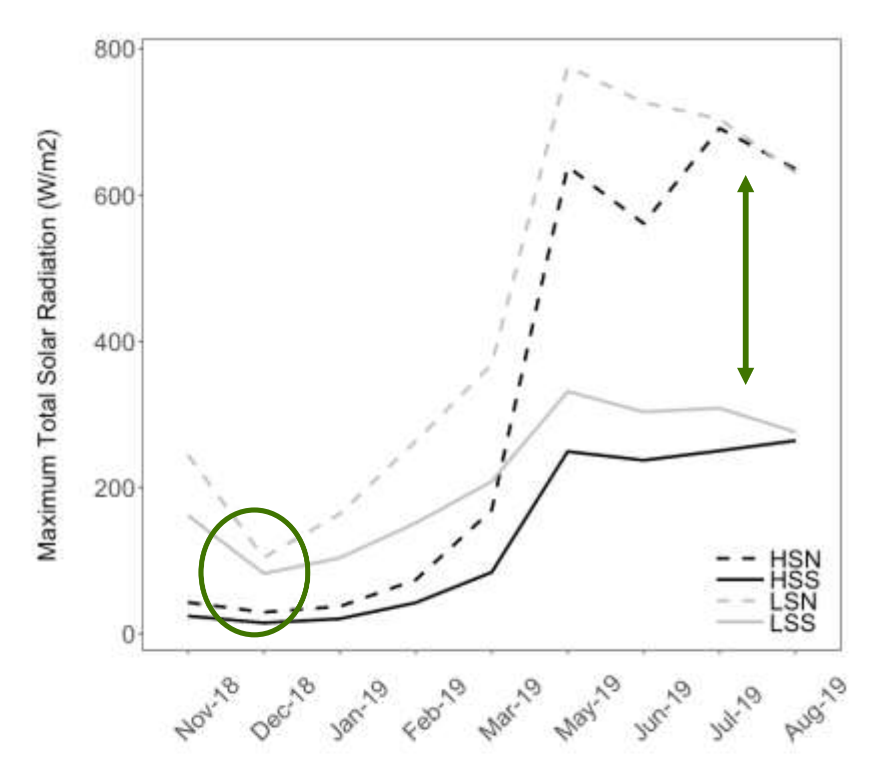
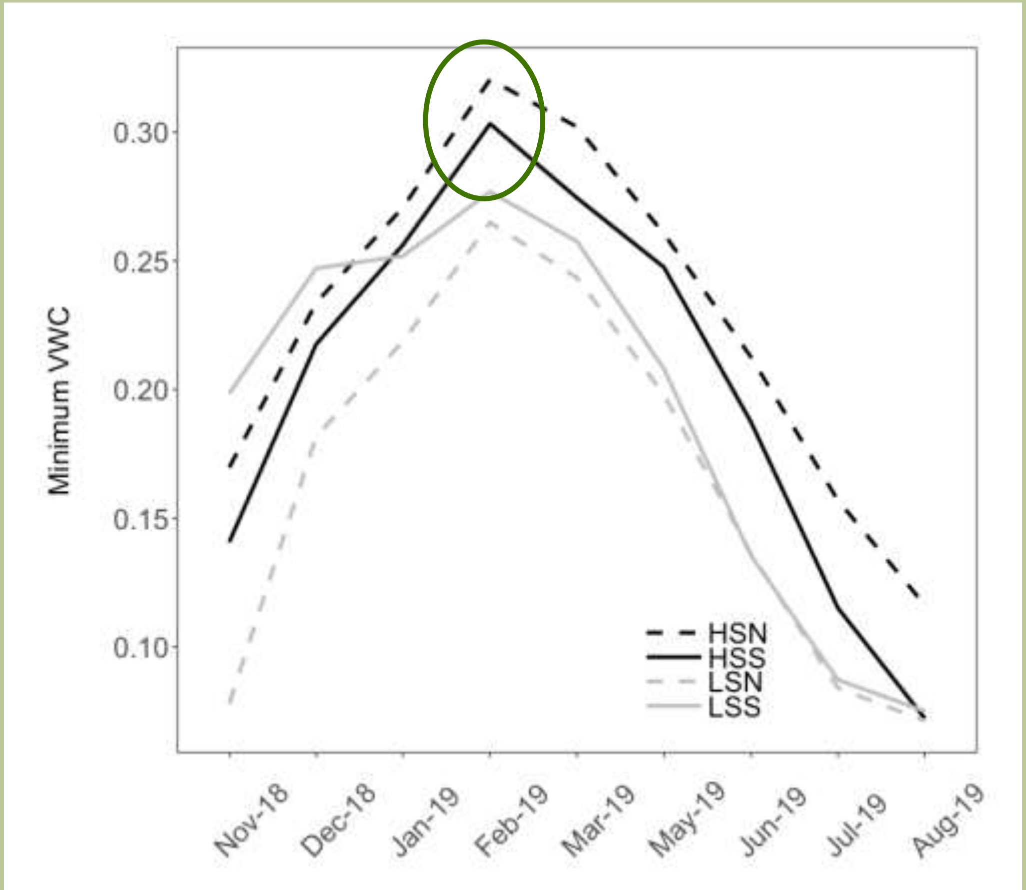


Results: Soil Moisture

Volumetric Water Content, Year 2



Results: Sediment erosion

Block	Collection Date	Sediment Erosion (g)	
		High	Low
1	Dec'18-Jan'19	13.42 ± 1.84	2,449 ± 1,875
	Feb-Mar'19	32.24 ± 10.92	2,740 ± 1,941
2	Dec'18-Jan'19	5.17 ± 3.31	858 ± 538
	Feb-Mar'19	2.39 ± 0.94	285 ± 133
3	Dec'18-Jan'19	50.99 ± 32.80	592 ± 285
	Feb-Mar'19	56.20 ± 42.66	411 ± 199

Results: Seedlings

Results: Germination

- **Shelters** increased germination for all species

Results: Germination

- **Shelters** were more important for germination than Suitability

Shelters: +23%
Suitability: +3%

Shelters: +12%
Suitability: +2%

Shelters: +5%
Suitability: +2%

Shelters: +5%
Suitability: -4%

Results: Germination

- **Shelters** were more important for germination than Suitability
- **High Suitability** shelters had higher germination than Low Suitability shelters.

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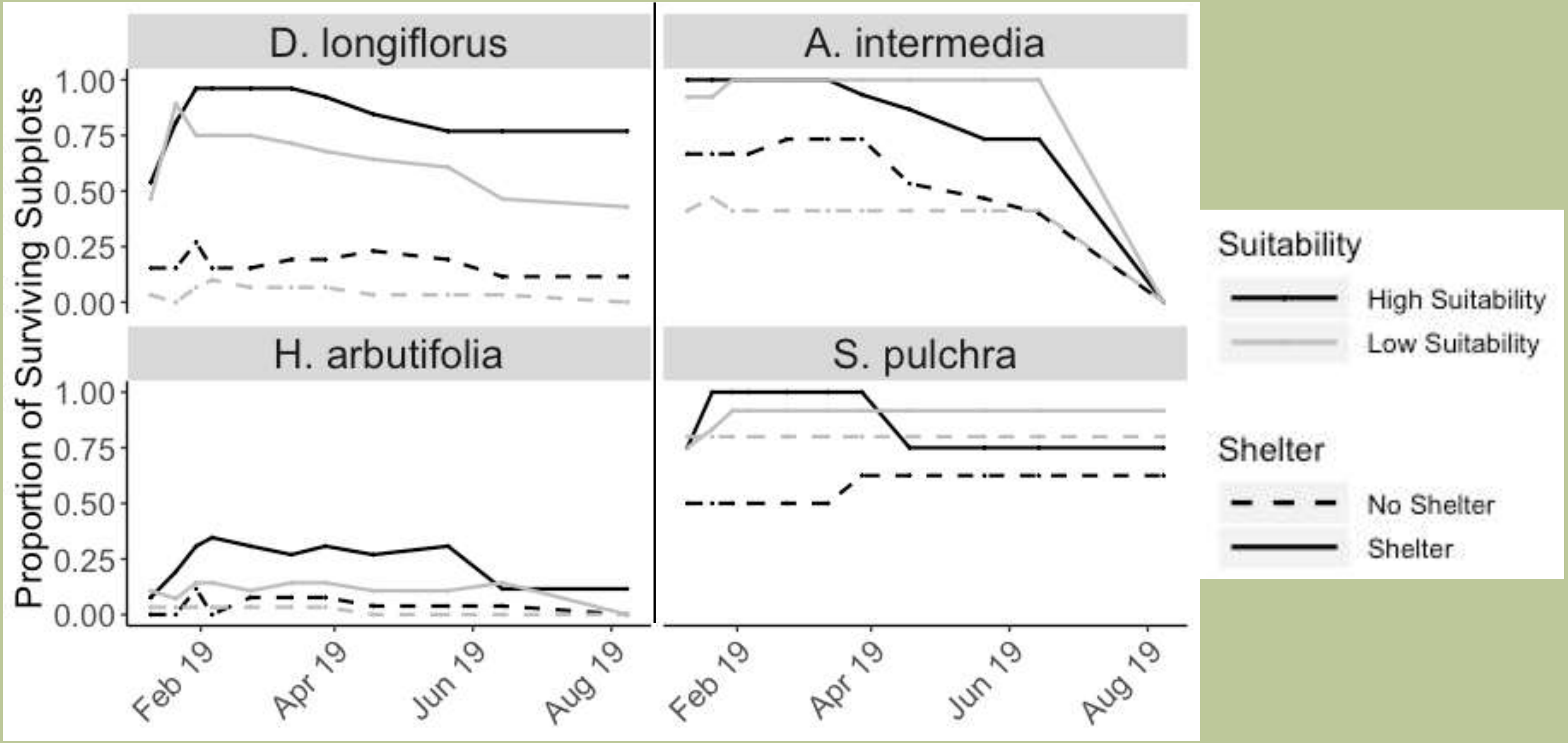
Results: Growth

Shelter plants significantly larger for *A. intermedia, D. longiflorus,* and *H. arbutifolia*

Results: Survival, Year 2



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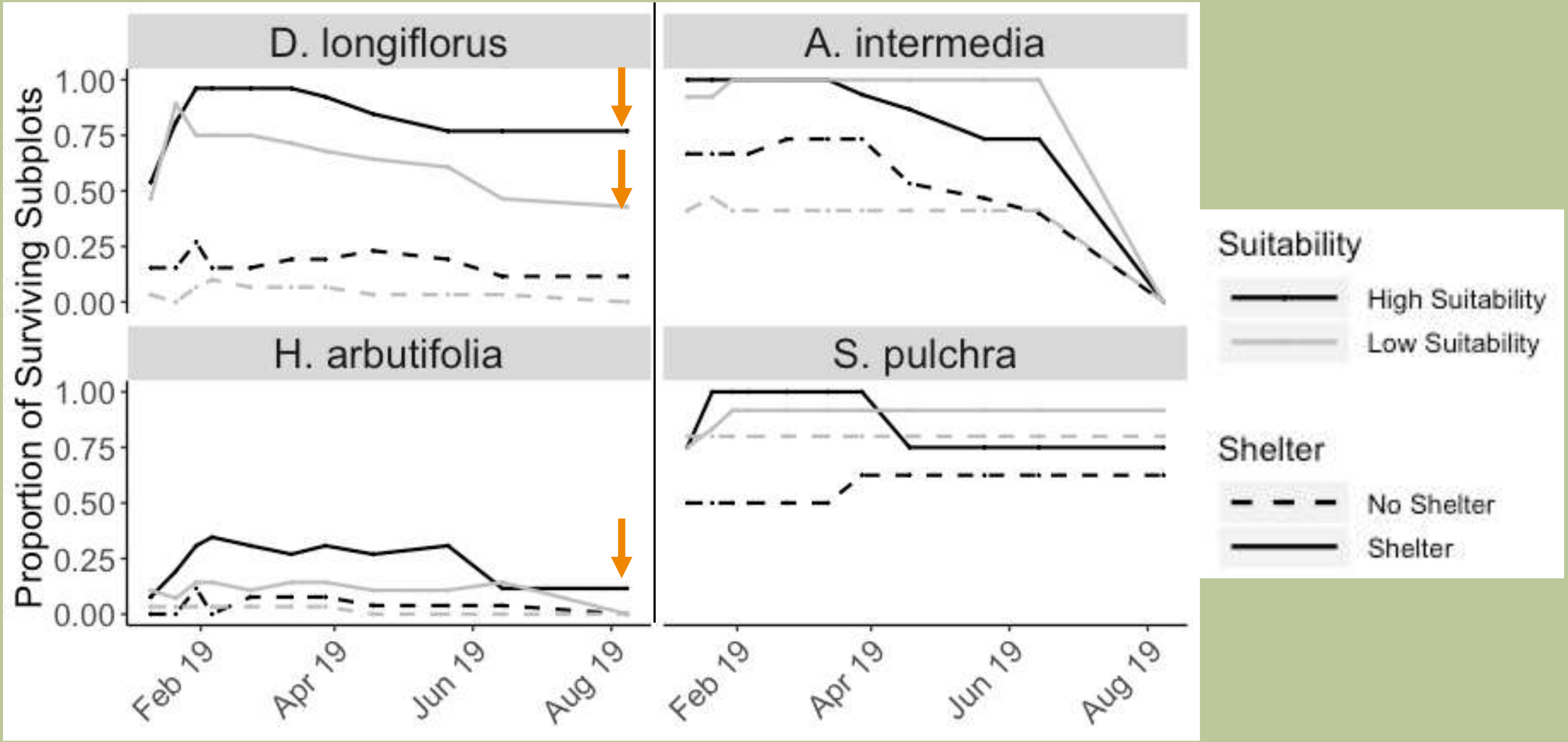

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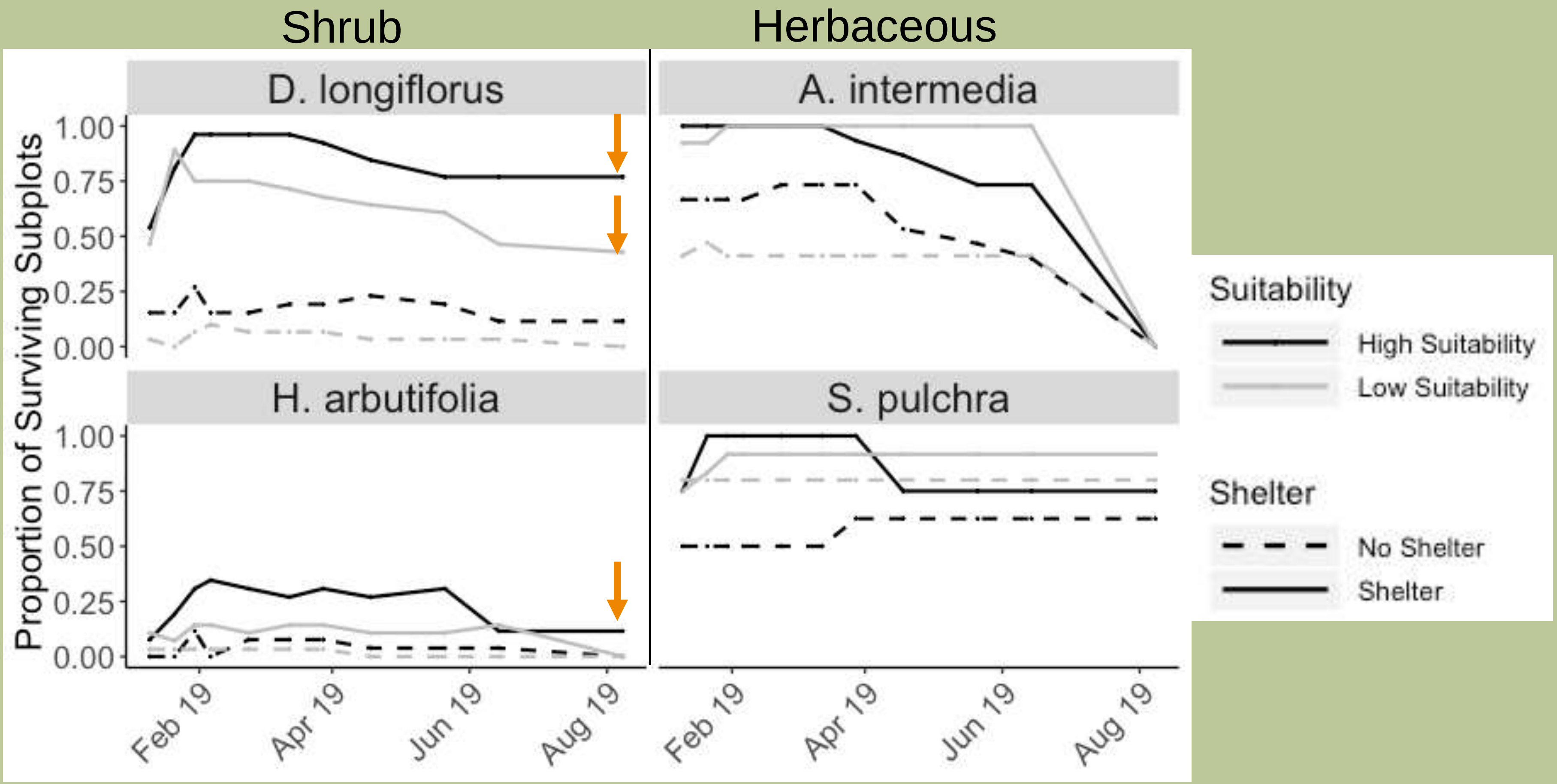

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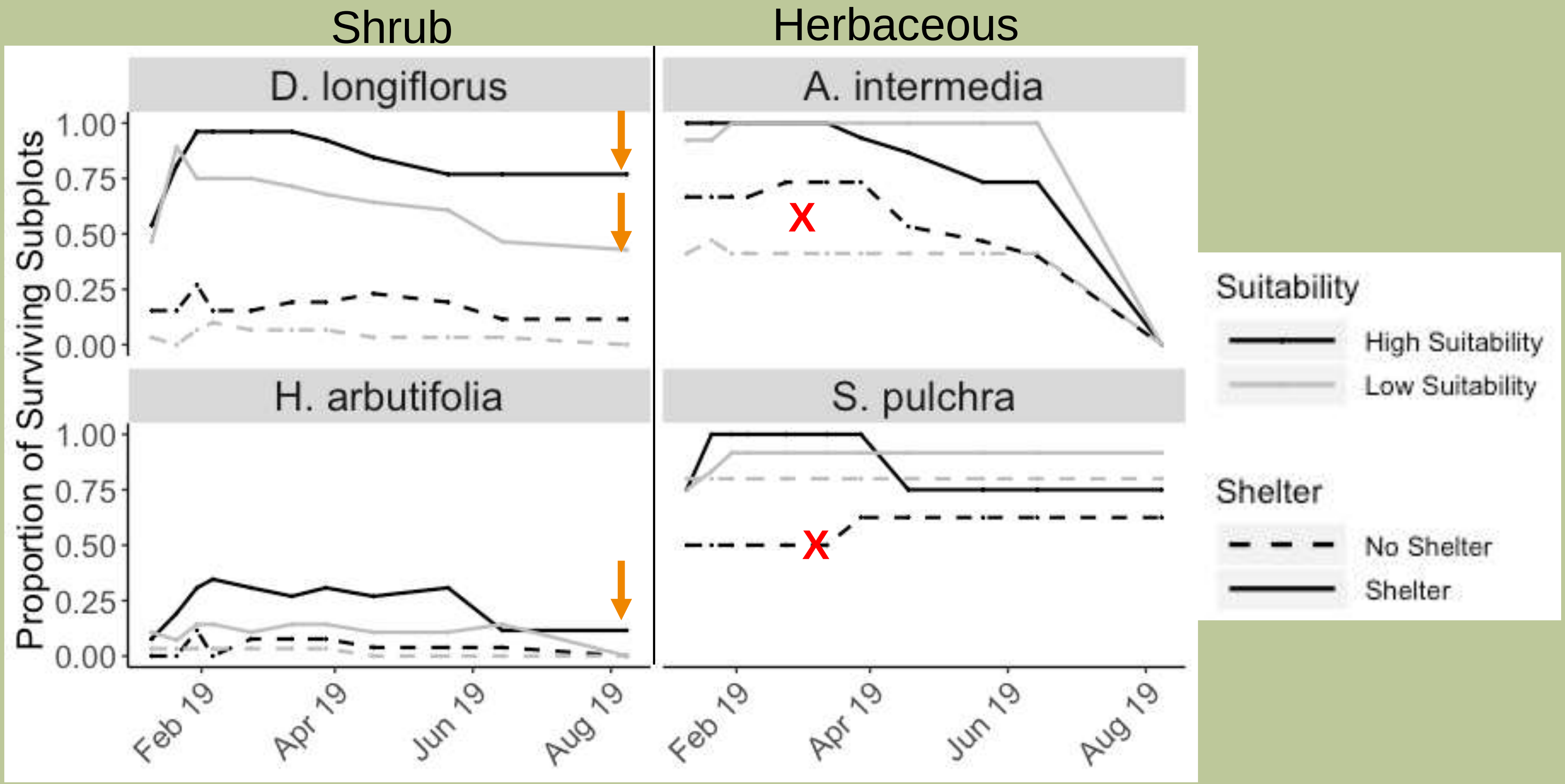

Conclusions and Recommendations

1. **Shelters** increased germination and survival, especially for shrubs

2. Shelters played a larger role than Suitability in seedling establishment and growth, but Shelters in **High Suitability** provided overall the best microclimate for seedlings

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3. Erosion mitigation may be as or more important than creating a microclimate.

Conclusions and Recommendations

1. **Shelters** increased germination and survival, especially for shrubs and shade-tolerant species

2. Shelters played a larger role than Suitability in seedling establishment and growth, but Shelters in **High Suitability** provided overall the best microclimate for seedlings

Recommendations:

1. Diversify plant addition strategies between seeding and planting in shelters, especially for sensitive species and low suitability areas

2. Experiment with seeding more species in shelters, and share results!

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Funding:

MENTORES

CNPS-San Gabriel Mountains Chapter Research Grant

Agricultural Research Initiative (ARI)


Questions?

Results: Sediment Erosion

Block	Plot Slope (°)		% Bare ground		Date	Sediment Erosion (g)	
	HS	LS	HS	LS		High	Low
1	20	27	37	51	1	13.42 ± 1.84	2,449 ± 1,875
					2	32.24 ± 10.92	2,740 ± 1,941
2	22	25	55	82	1	5.17 ± 3.31	858 ± 538
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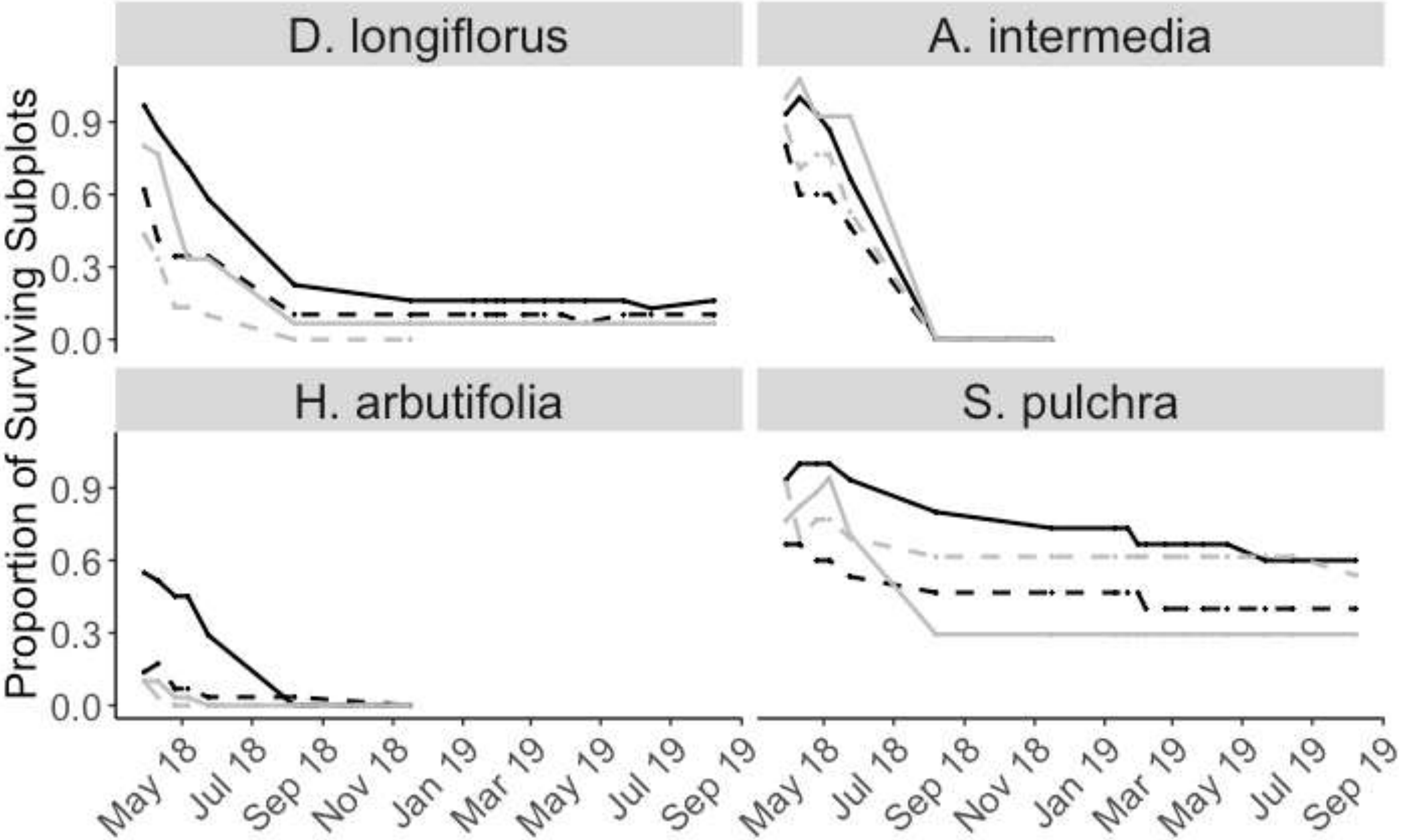
Economics of Restoration

- Multi-billion dollar industry – at least **$3 billion** spent annually in US alone[1,2]
- **40%** of restoration projects include "active restoration"[3] = **$1.2 billion** per year on native species addition in degraded habitats
- **Survival** rate is highly variable (by climate , plant community, etc.)
- Estimated **$8,700** to **$18,200** per acre to restore California CSS habitat[1]
- Future: increased need for, and cost of, restoration in semi-arid landscapes

Precision Restoration

- Resource efficiency
- Uses ecological theory, remote sensing, and plant science/agriculture
- Precision agriculture integrates geospatial variability into crop management to develop specific microsite plans that optimally utilize resources[4]
- Recently becoming a tool in restoration ecology[5]

Cropaia.com



D. longiflorus
A. intermedia
H. arbutifolia
S. pulchra
Proportion of Surviving Subplots
0.0
0.3
0.6
0.9
May 18
Jul 18
Sep 18
Nov 18
Jan 19
Mar 19
May 19
Jul 19
Sep 19

Results: Sediment erosion

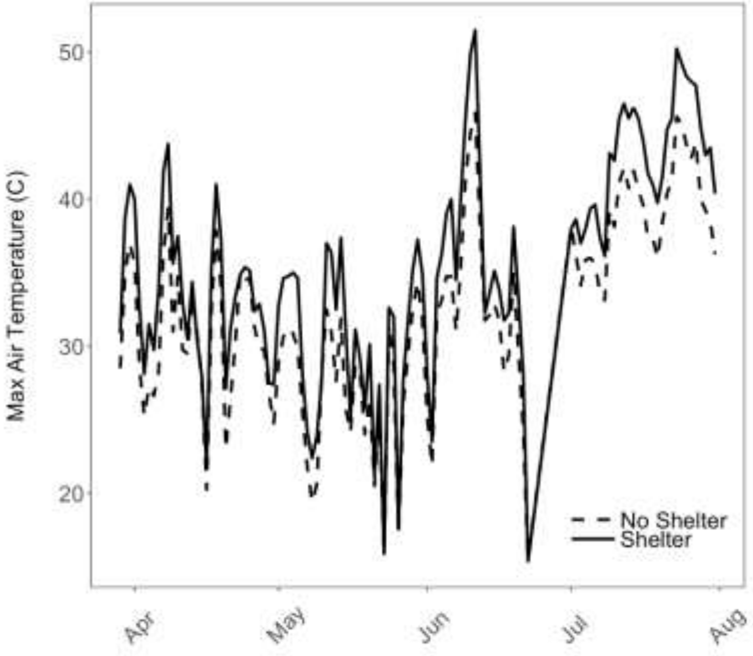
Cost Model

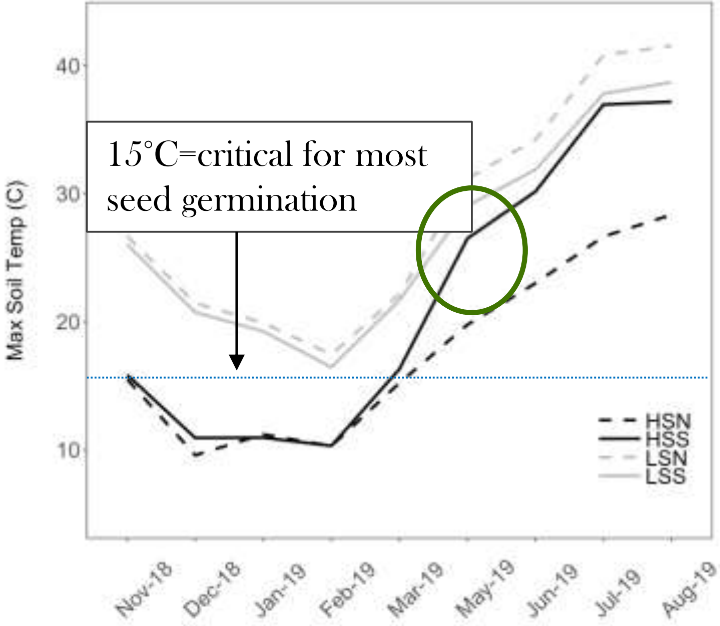
Will keep detailed records of equipment and labor hours involved in all aspects of *restoration project* (not experimental design and abiotic data)

Model will compare these costs to conventional restoration projects in similar habitat involving outplanting of nursery seedlings and *no* shelter/suitability model treatments

Project Stage	Seeding Experiment	Restoration Planting
Pre-restoration	-Seed collecting/order -Pre-treatments -Weed treatment	-Nursery production (includes phyto-sanitation, plant material, soil, pots, labor) -Field preparation (weeding, herbivore exclusions)
Restoration	-Cost of shelters -Seeding labor	-Outplanting labor -Herbivory shelters
Maintenance	-Weeding	-Weeding -Watering
Total	$ Total	$ Total
Cost Per Plant	$ Total # of Plants	$ Total # of Plants
% Survival	# Added # Surviving	# Added # Surviving
Cost Per Surviving Plant	$ Totall % Survival	$ Total % Survival

Results: Temperature





Results: Survival

Coastal sage scrub

Audubon California

- Altered disturbance regimes → Type Conversion
- 10-15% of historic range; once 2.5% of land area in California (Westman, 1981)
- 71% occurs on private lands (Davis 1994)

Future Directions

- Large-scale shelter seeding study in Angeles National Forest (direct-sowing and outplanting 5 chaparral species) in High and Low Suitability

- Look into weed management with Shelters: herbicide applications, and weed distribution/ composition in suitability classes and shelters