ARIDITY CONSTRAINS THE ADAPTIVE POTENTIAL OF PLANT INVADERS UNDER NITROGEN DEPOSITION

California Invasive Plant Council Symposium

October 16, 2023

Justin Valliere, Assistant Professor of Cooperative Extension, UC Davis

How will environmental change & invasive species impact California's native plant communities?

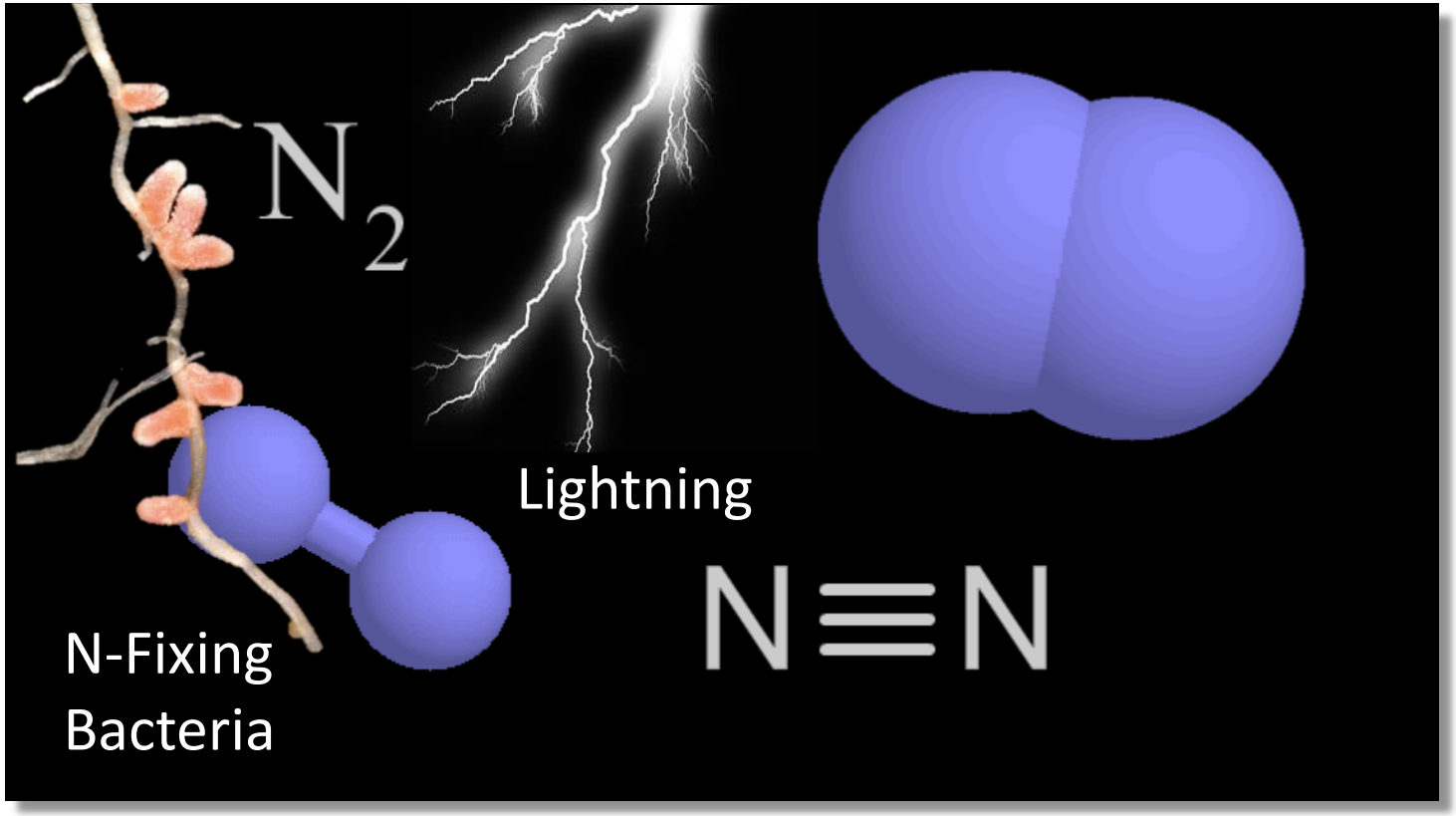
How will environmental change & invasive species impact California's native plant communities?

Nitrogen deposition

Climate change

Nonnative plant invasion

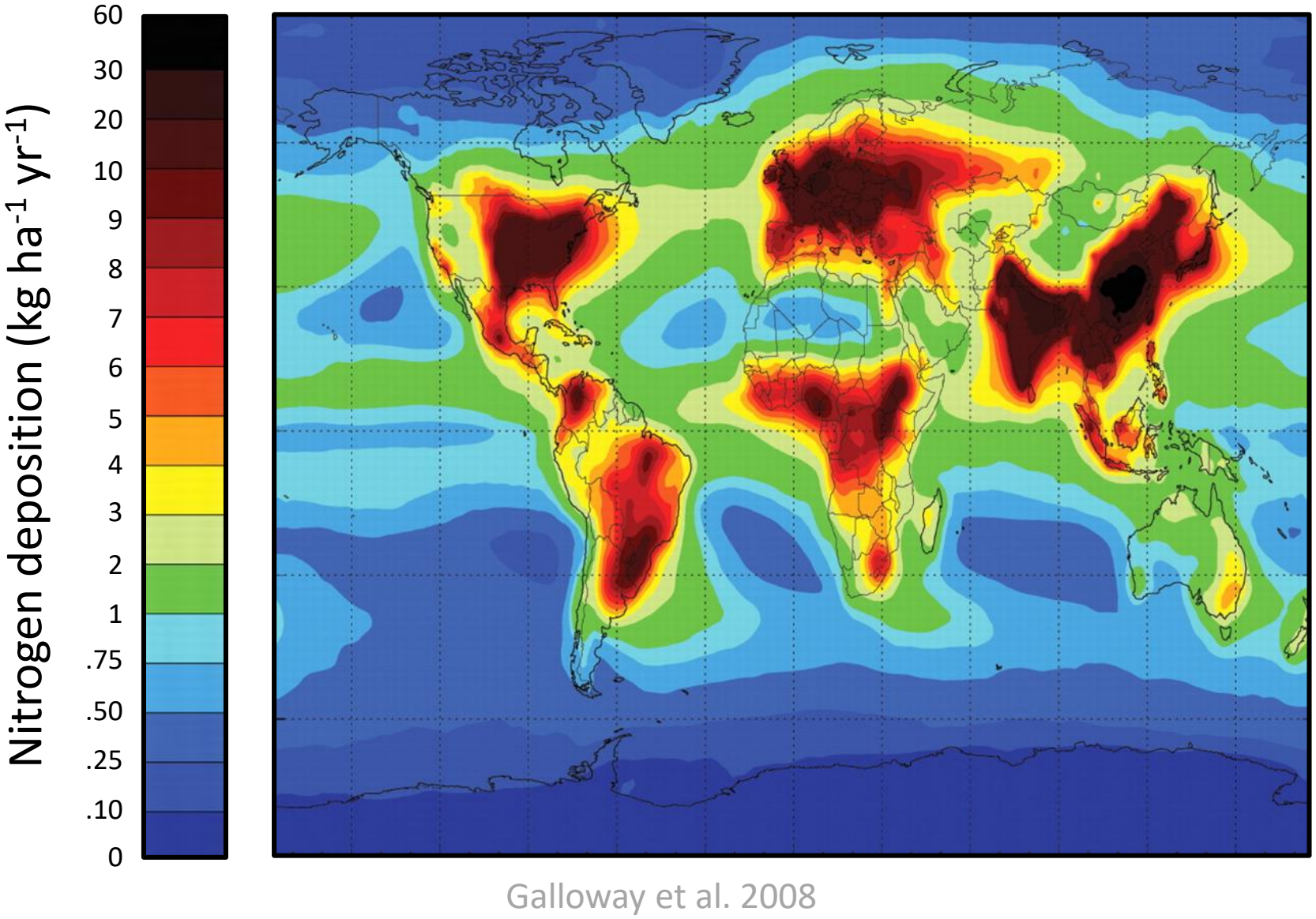
Nitrogen gas makes up about 78% of the Earth's atmosphere…



…yet bioavailable nitrogen is limiting in most ecosystems.

Nitrogen deposition: The input of reactive nitrogen from the atmosphere to the earth's surface

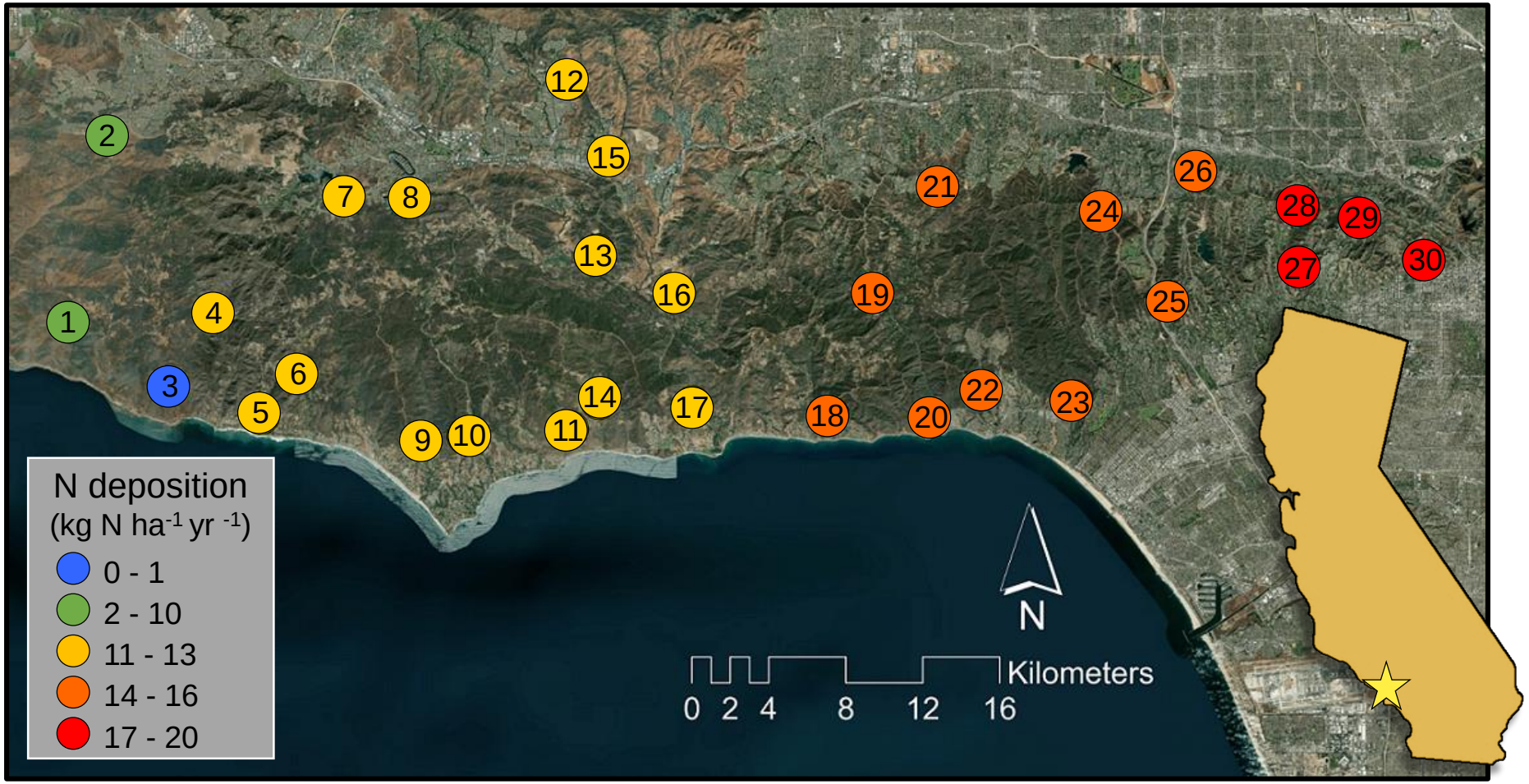
David Iliff 2005



Galloway et al. 2008

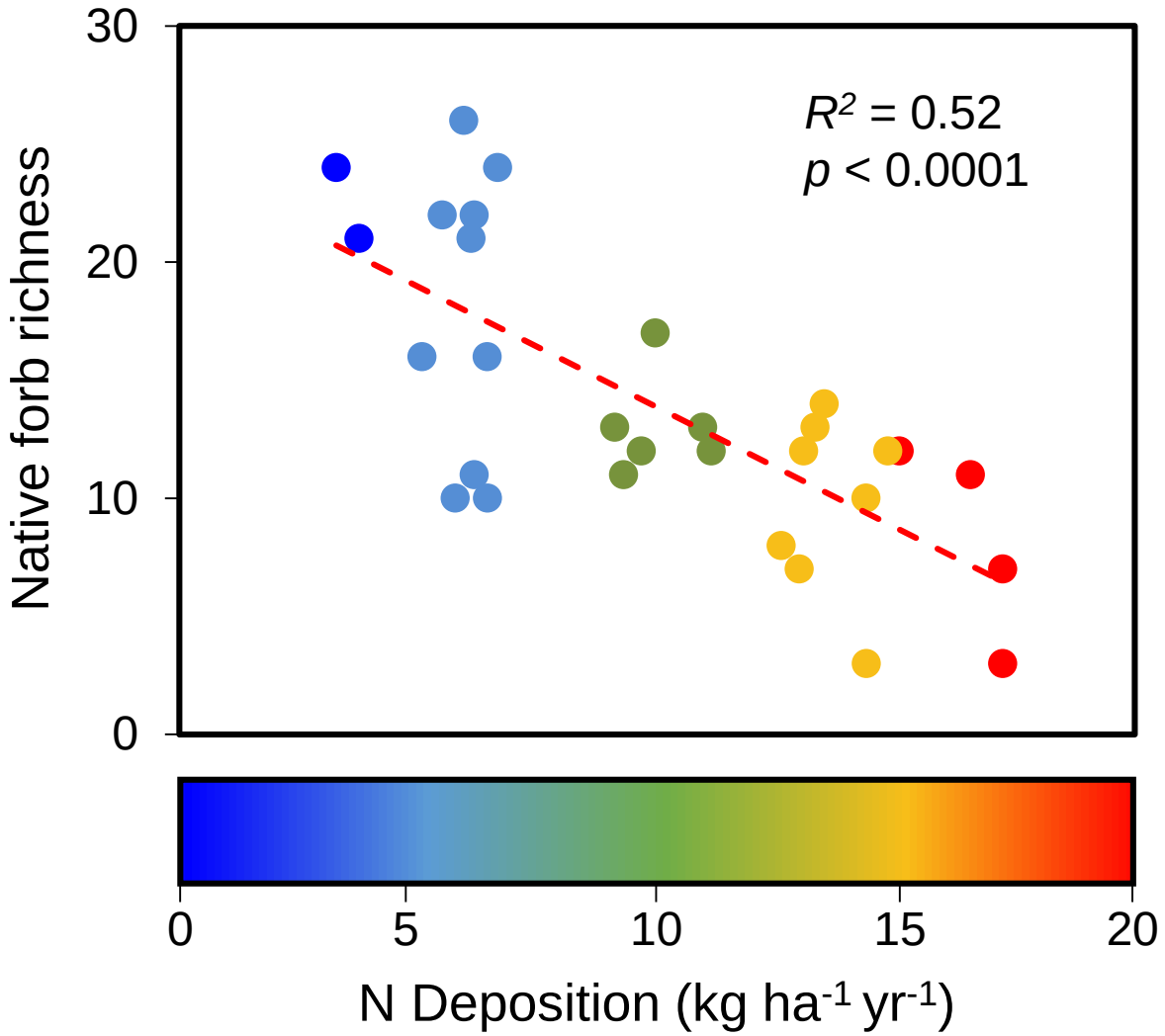
Human alteration of the global nitrogen cycle

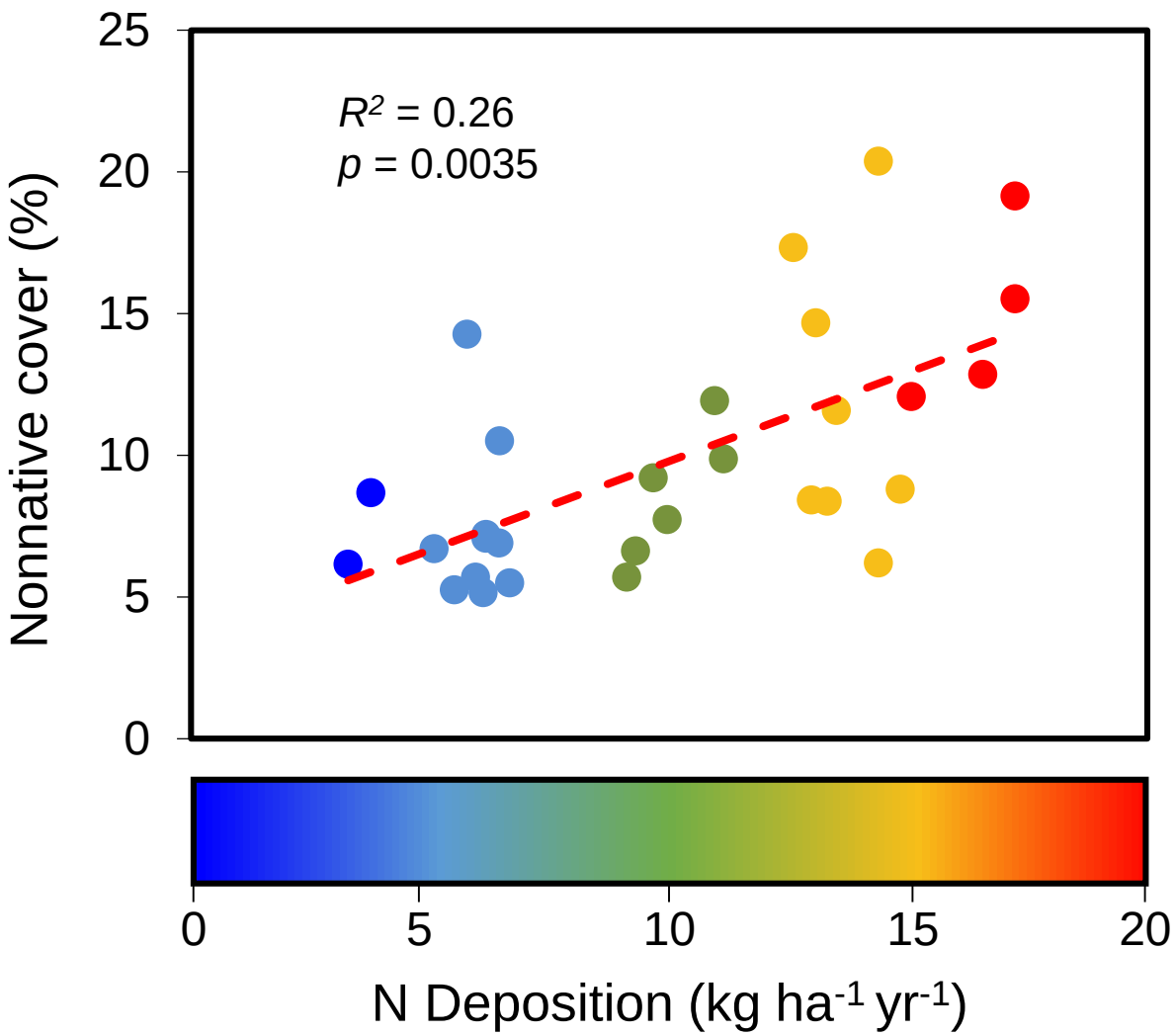
Nitrogen deposition gradient of the Santa Monica Mountains



Valliere et al. *Ecosphere*.

Nitrogen deposition is associated with reduced diversity & increased invasion





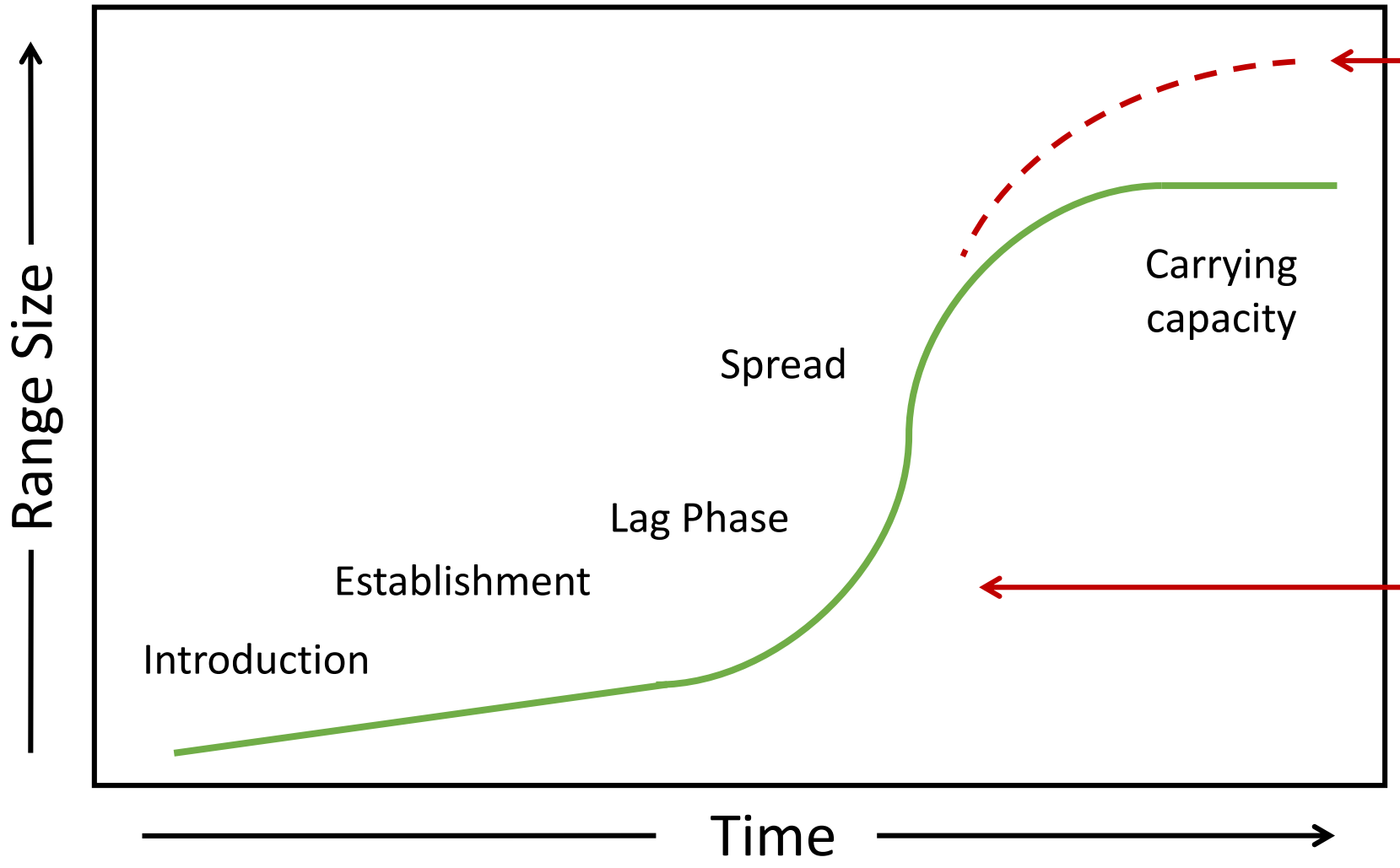
Valliere et al. 2020. *Ecosphere*.

What are the evolutionary consequences of environmental change on invasive plant species?

Bromus diandrus

Centaurea melitensis

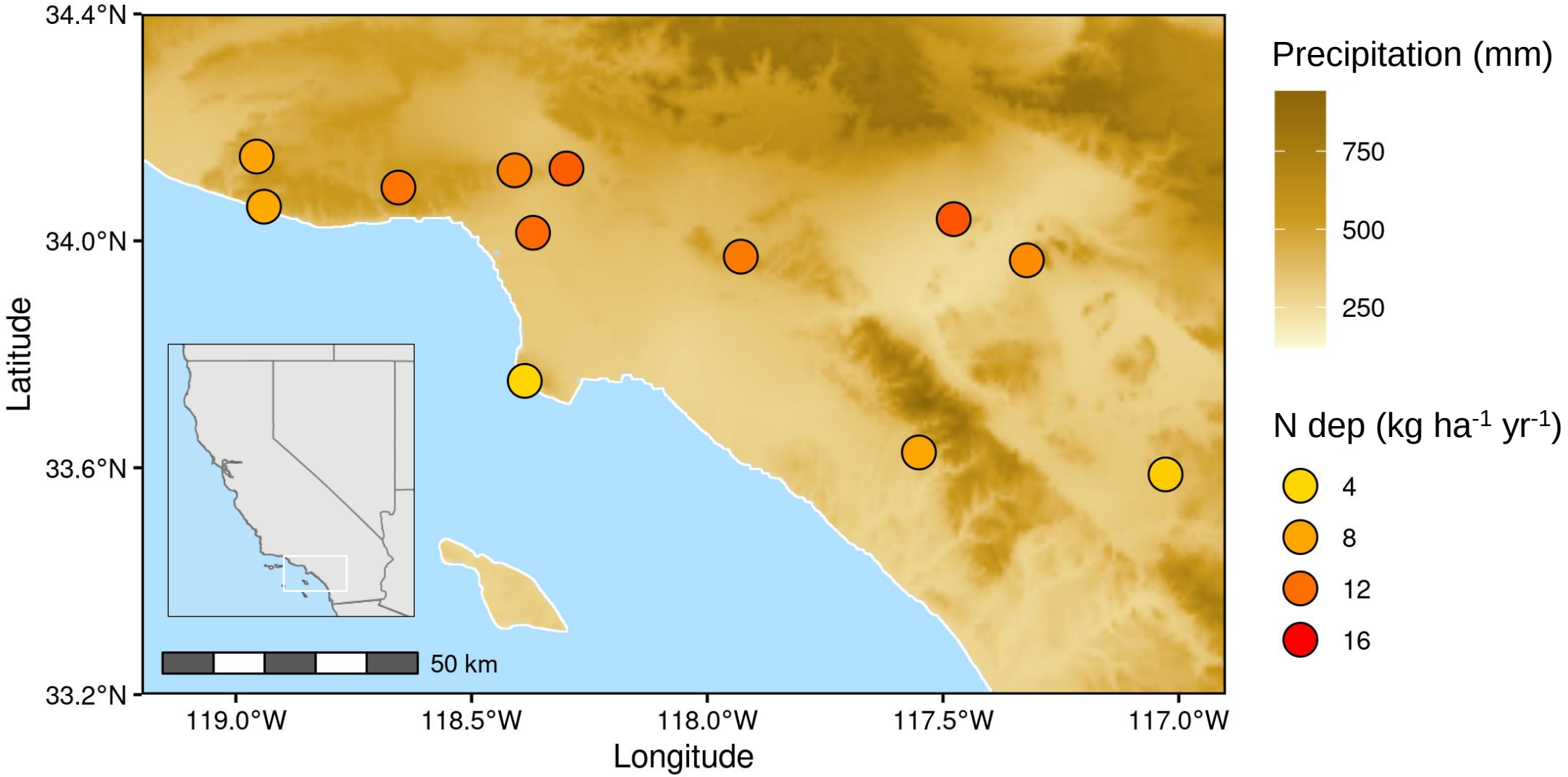
Stages of Nonnative Plant Invasion

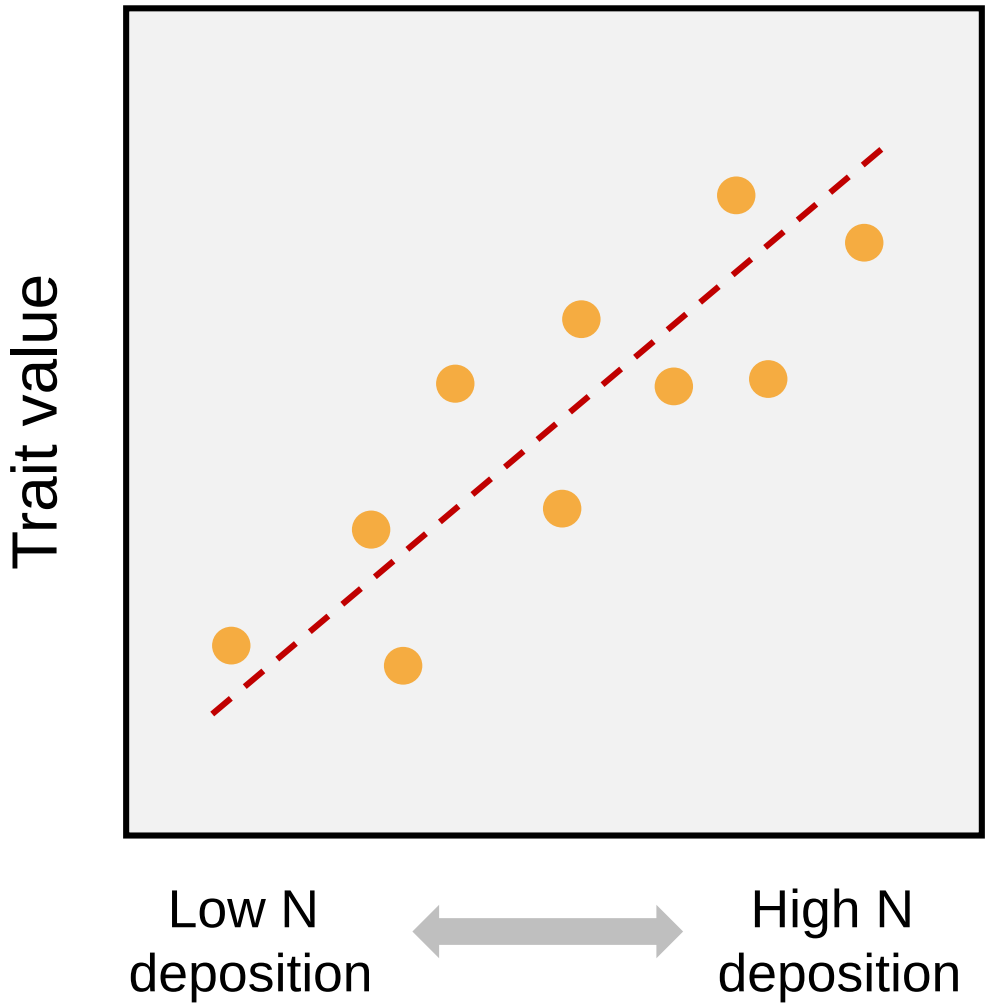


Will environmental change increase the success of plant invaders?

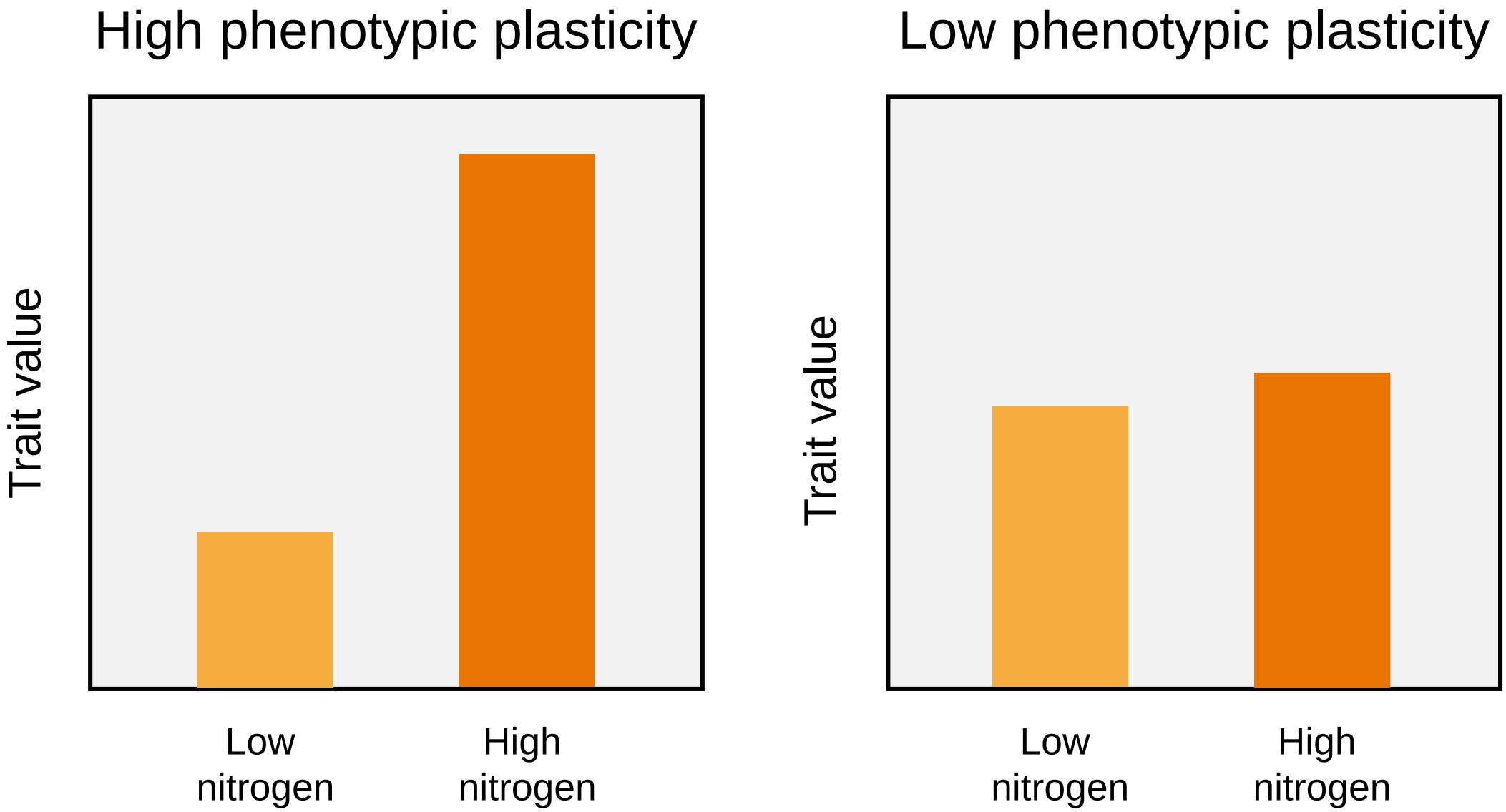
Post-introduction evolution during lag phase?

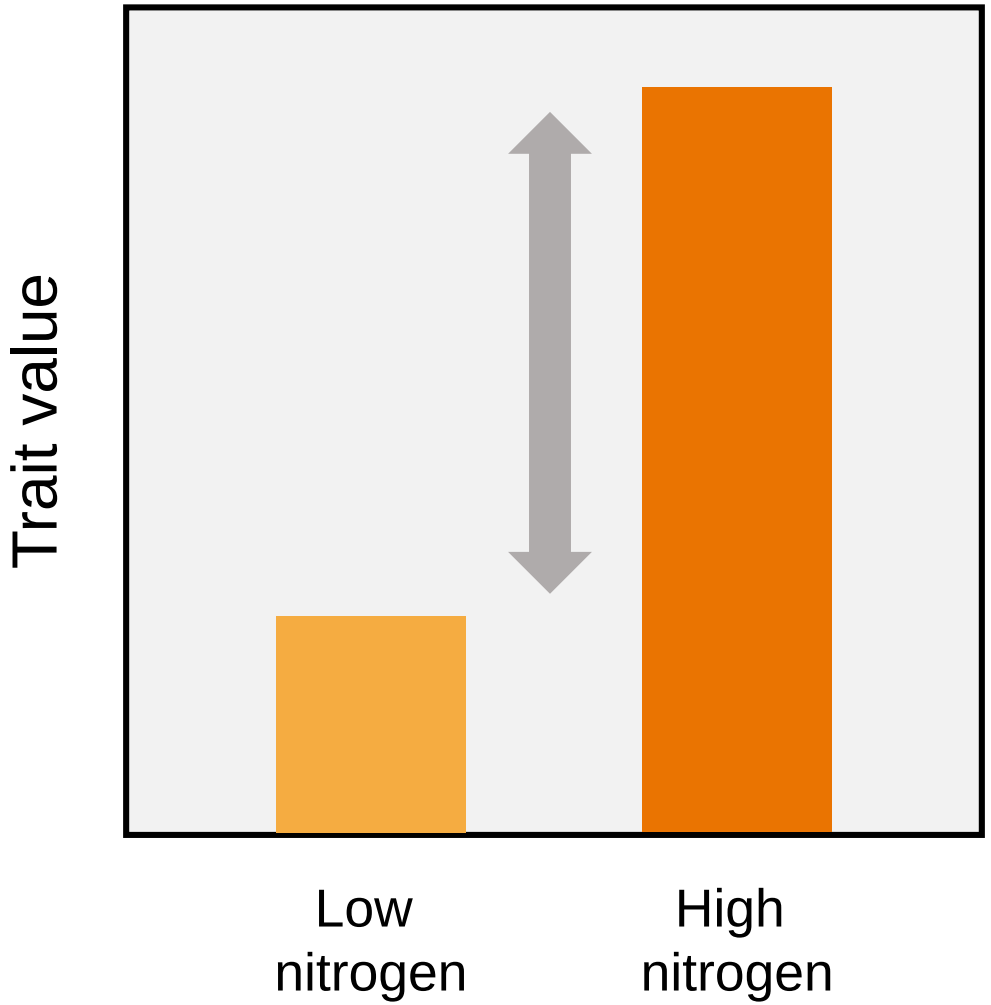
Have invasive plant species adapted to aridity or N deposition?



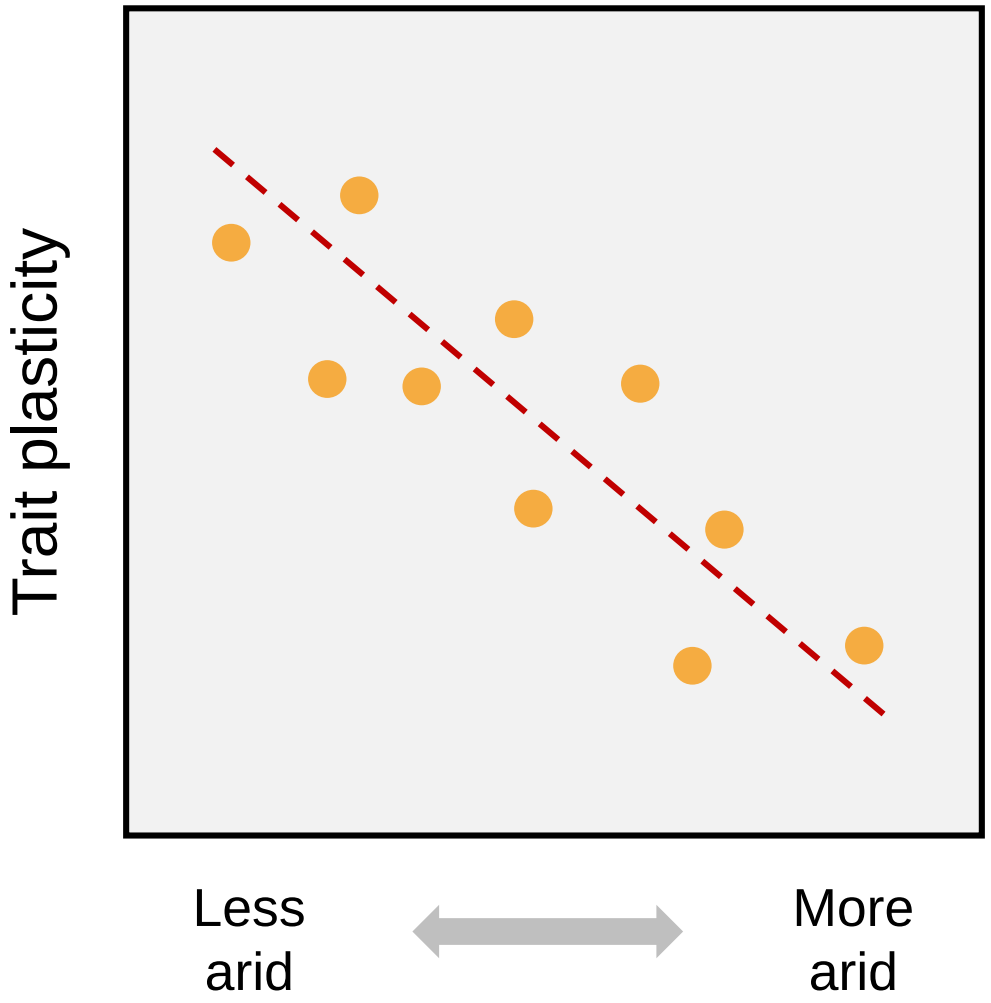


Are plant functional traits shaped by the local environment experienced by source populations?


High phenotypic plasticity
Trait value
Low nitrogen
High nitrogen
Low phenotypic plasticity
Trait value
Low nitrogen
High nitrogen



$$\text{Log response ratio} = \frac{(\text{Trait}_{\text{High N}} - \text{Mean}_{\text{Low N}})}{\text{Mean}_{\text{Low N}}}$$



Is trait plasticity shaped by the local environment experienced by source populations?

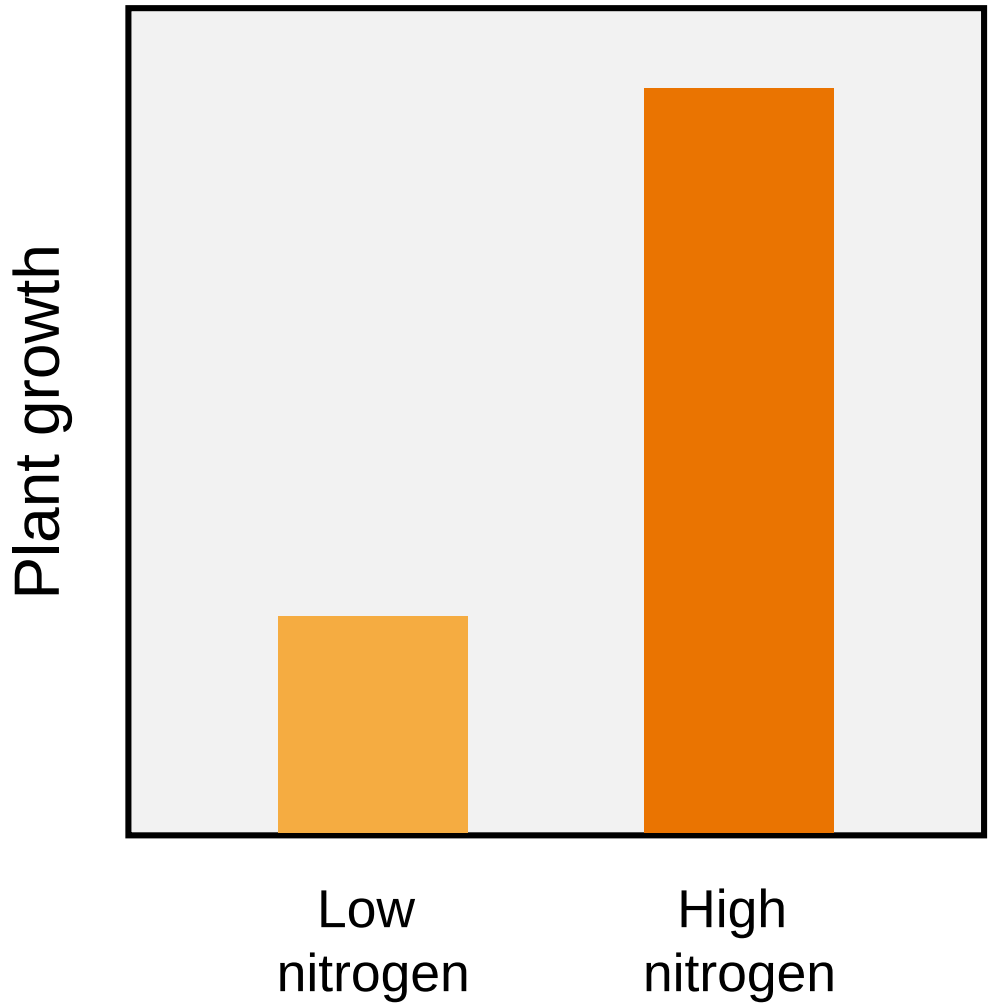
Hypotheses

1. N addition will improve plant performance, but this will vary across populations

2. Populations will exhibit local adaption to N deposition and aridity

3. Populations from more arid sites will exhibit lower plasticity in growth and traits

4. Trait plasticity will be unrelated to levels of N deposition experienced by populations



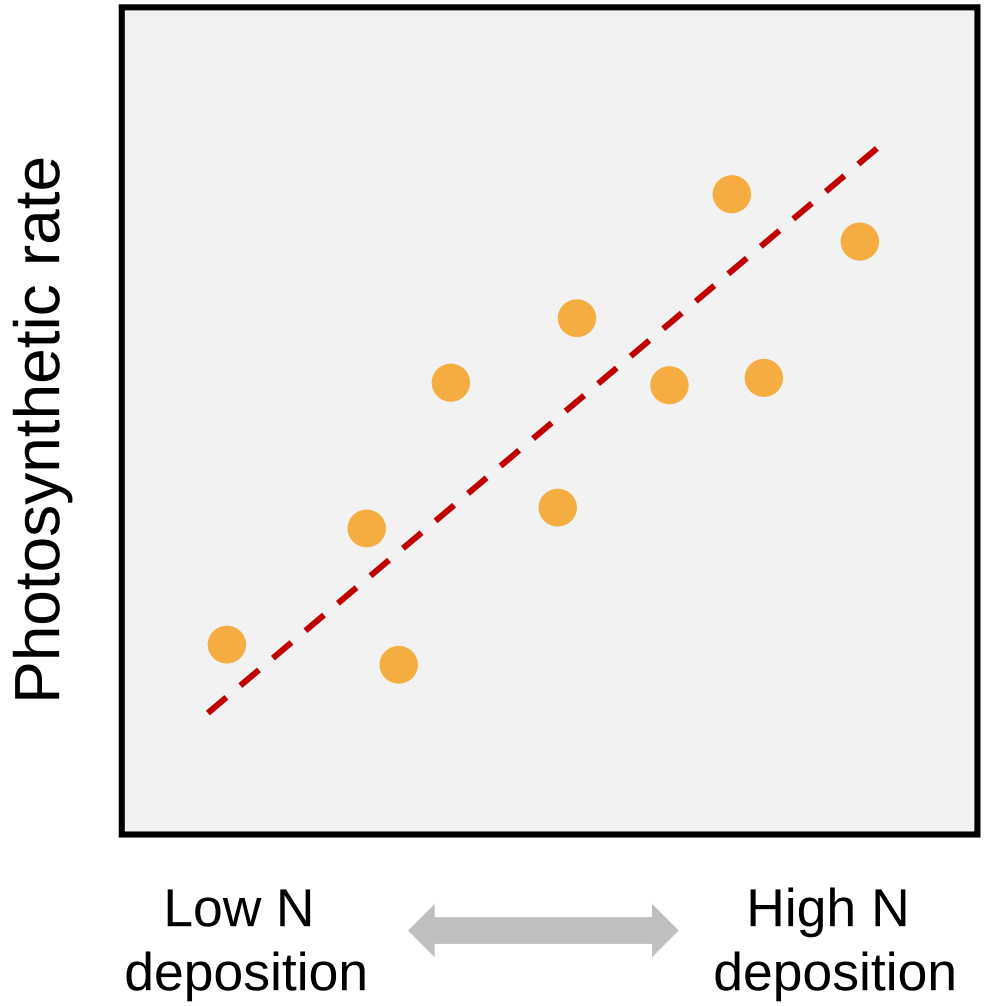
Hypotheses

1. N addition will improve plant performance, but this will vary across populations

2. Populations will exhibit local adaption to N deposition and aridity

3. Populations from more arid sites will exhibit lower plasticity in growth and traits

4. Trait plasticity will be unrelated to levels of N deposition experienced by populations



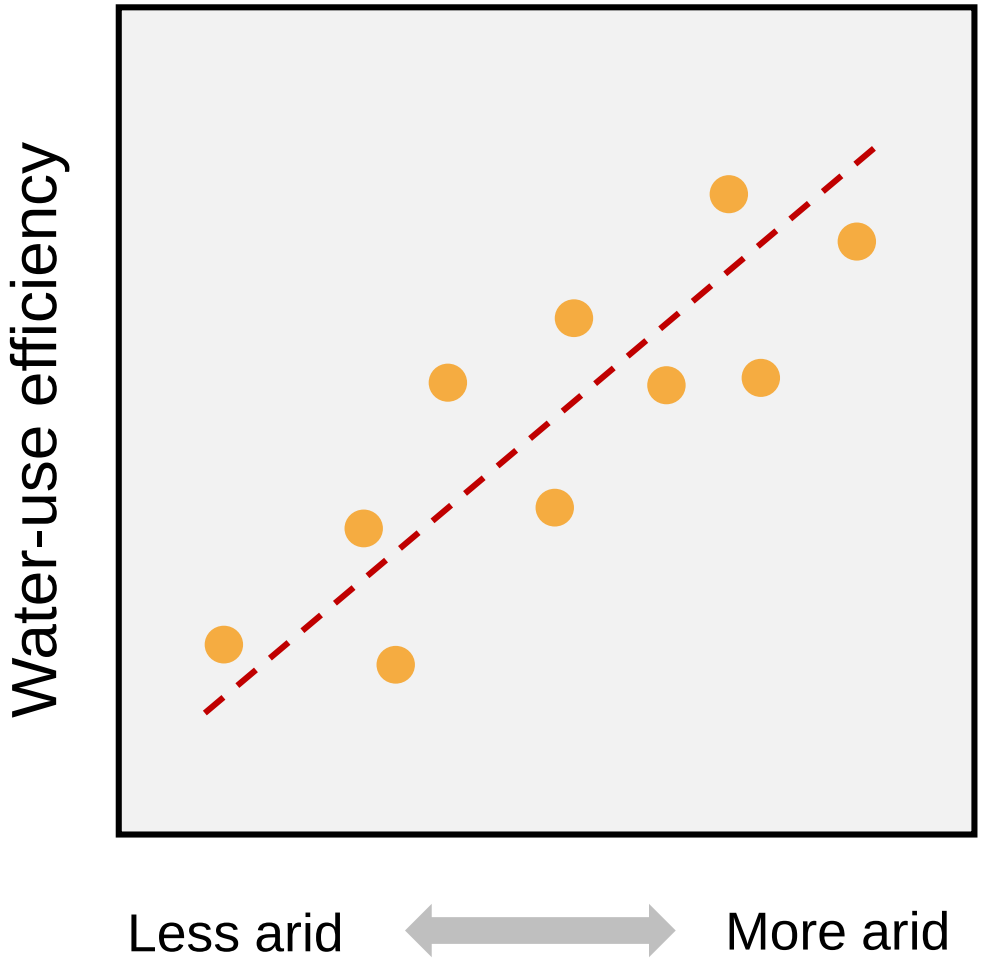
Hypotheses

1. N addition will improve plant performance, but this will vary across populations

2. Populations will exhibit local adaption to N deposition and aridity

3. Populations from more arid sites will exhibit lower plasticity in growth and traits

4. Trait plasticity will be unrelated to levels of N deposition experienced by populations



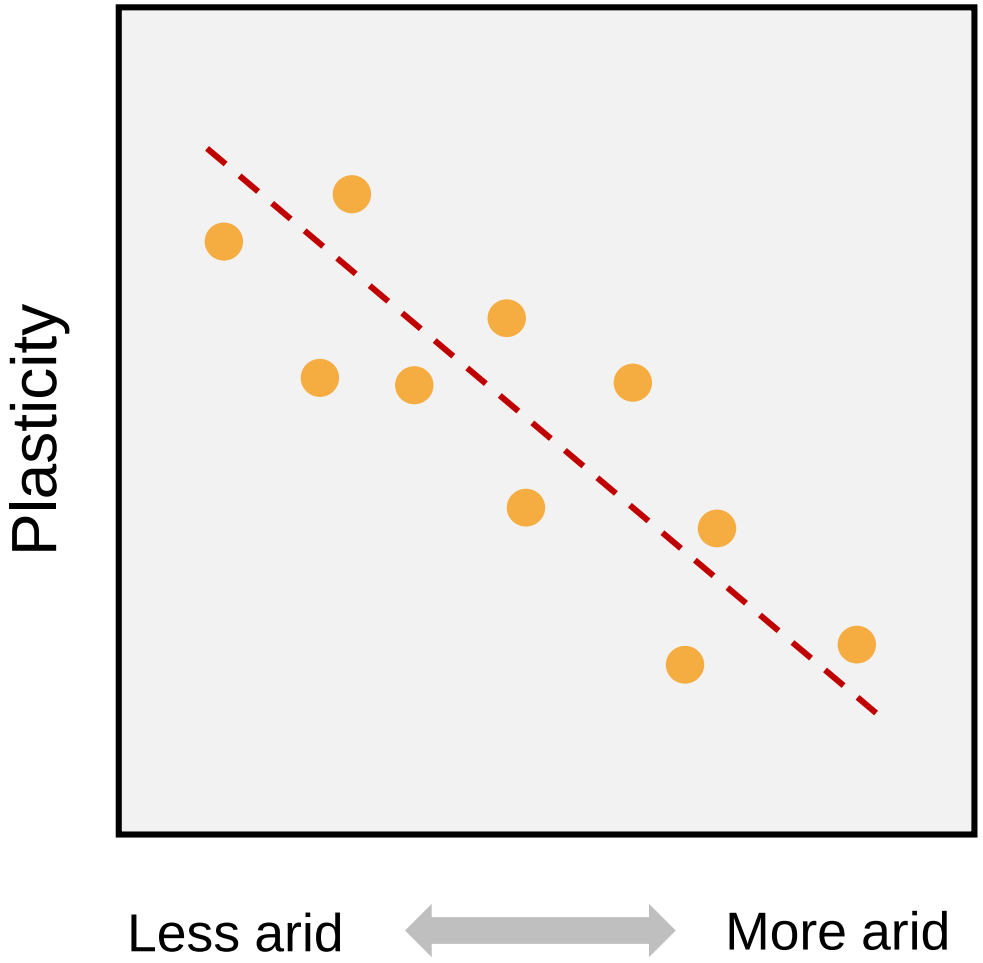
Hypotheses

1. N addition will improve plant performance, but this will vary across populations

2. Populations will exhibit local adaption to N deposition and aridity

3. Populations from more arid sites will exhibit lower plasticity in growth and traits

4. Trait plasticity will be unrelated to levels of N deposition experienced by populations



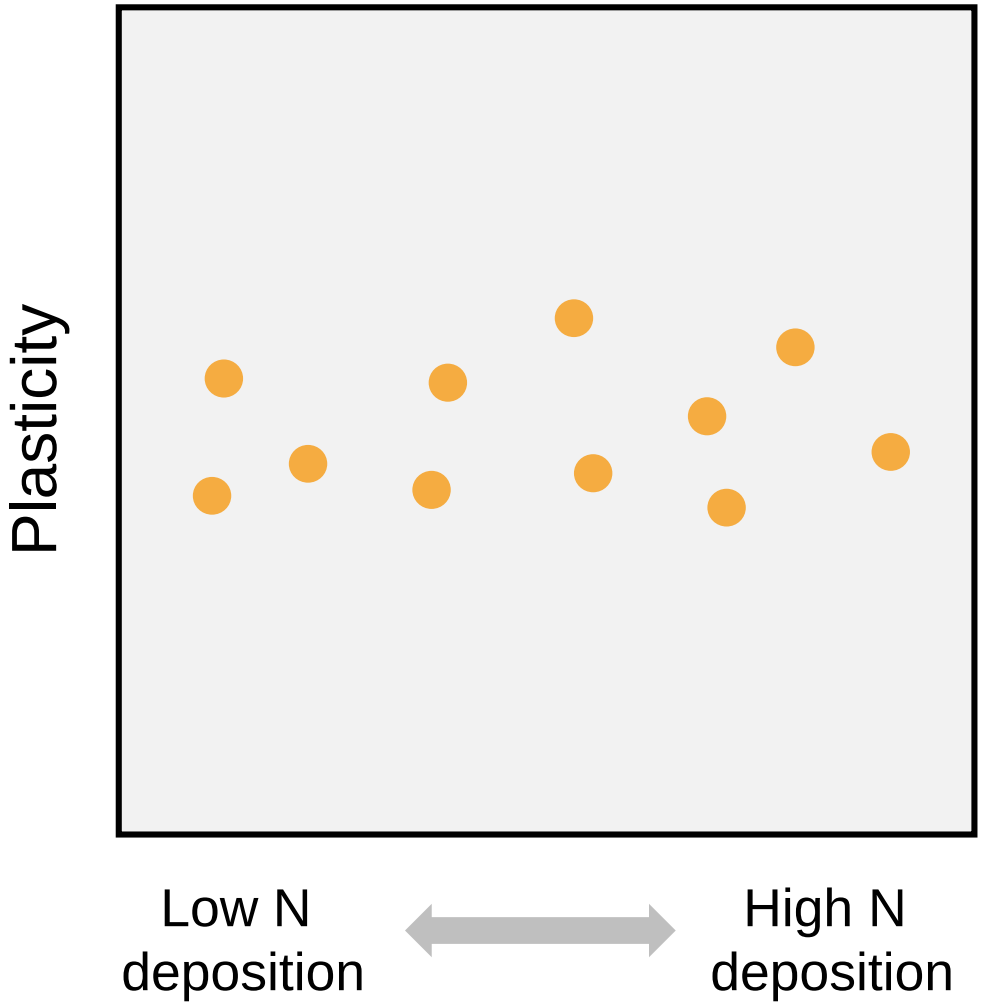
Hypotheses

1. N addition will improve plant performance, but this will vary across populations

2. Populations will exhibit local adaption to N deposition and aridity

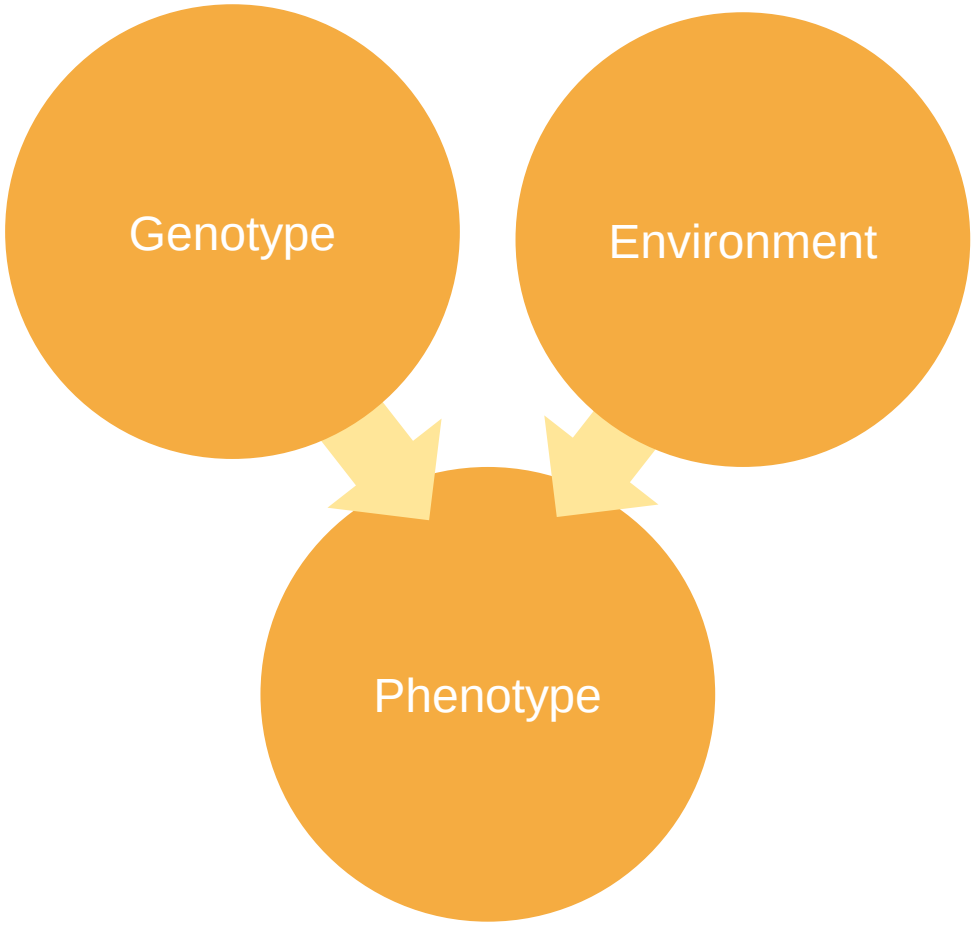
3. Populations from more arid sites will exhibit lower plasticity in growth and traits

4. Trait plasticity will be unrelated to levels of N deposition experienced by populations



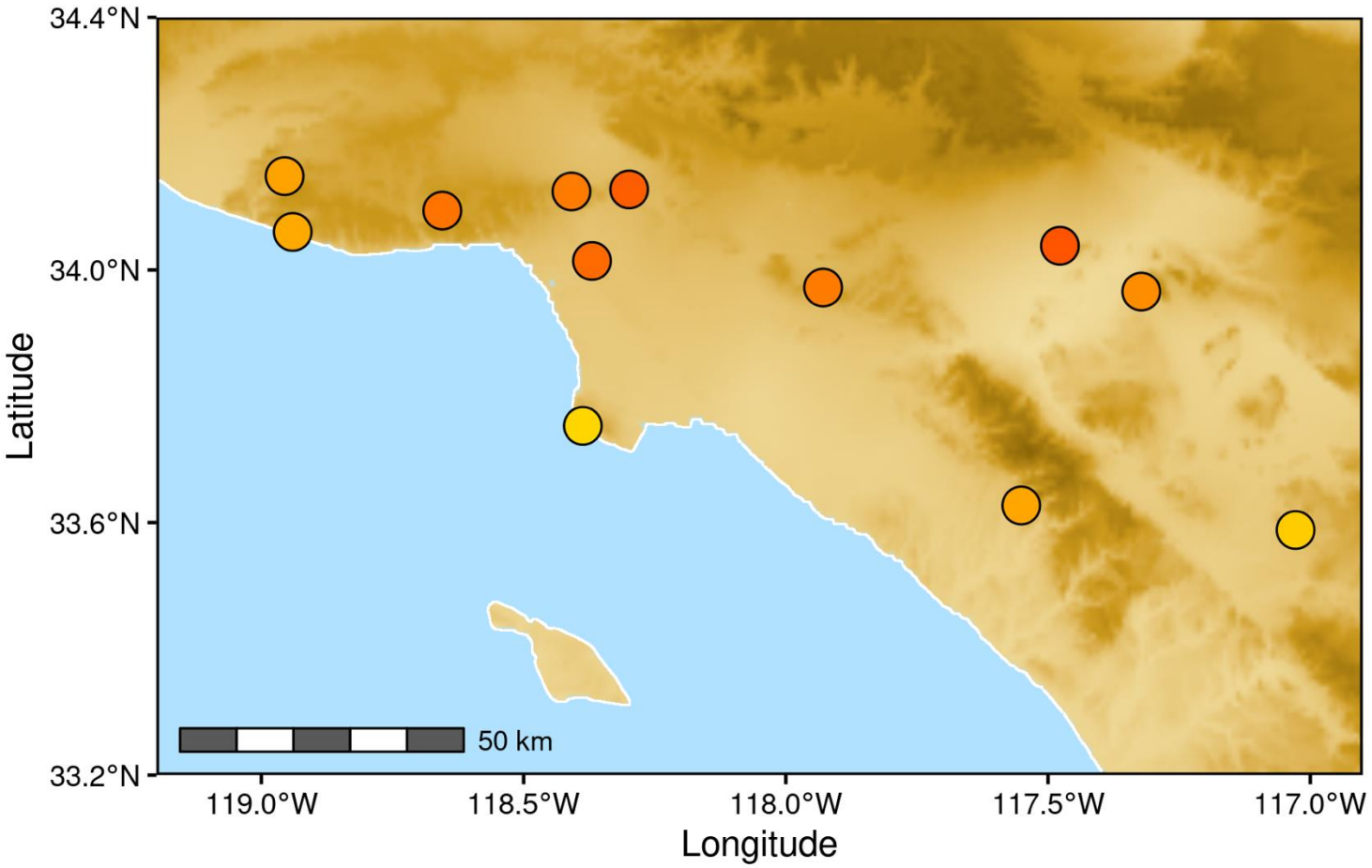
Common garden experiment:

Are there genetically based trait differences?



Common garden experiment:

Are there genetically based trait differences?



1. Collected seed of twelve different populations of ***Bromus*** and ***Centaurea*** across southern California

2. Grew plants in a common garden pot experiment under **high N** and **low N** availability

3. Quantified plant growth, flowering phenology, reproductive output, and functional traits

4. Evaluated if differences in traits and plasticity were related to source environment

Only a single trait was related to N deposition experienced by source populations;
Populations of ***Bromus*** from high deposition sites had lower photosynthetic rates when N was limiting

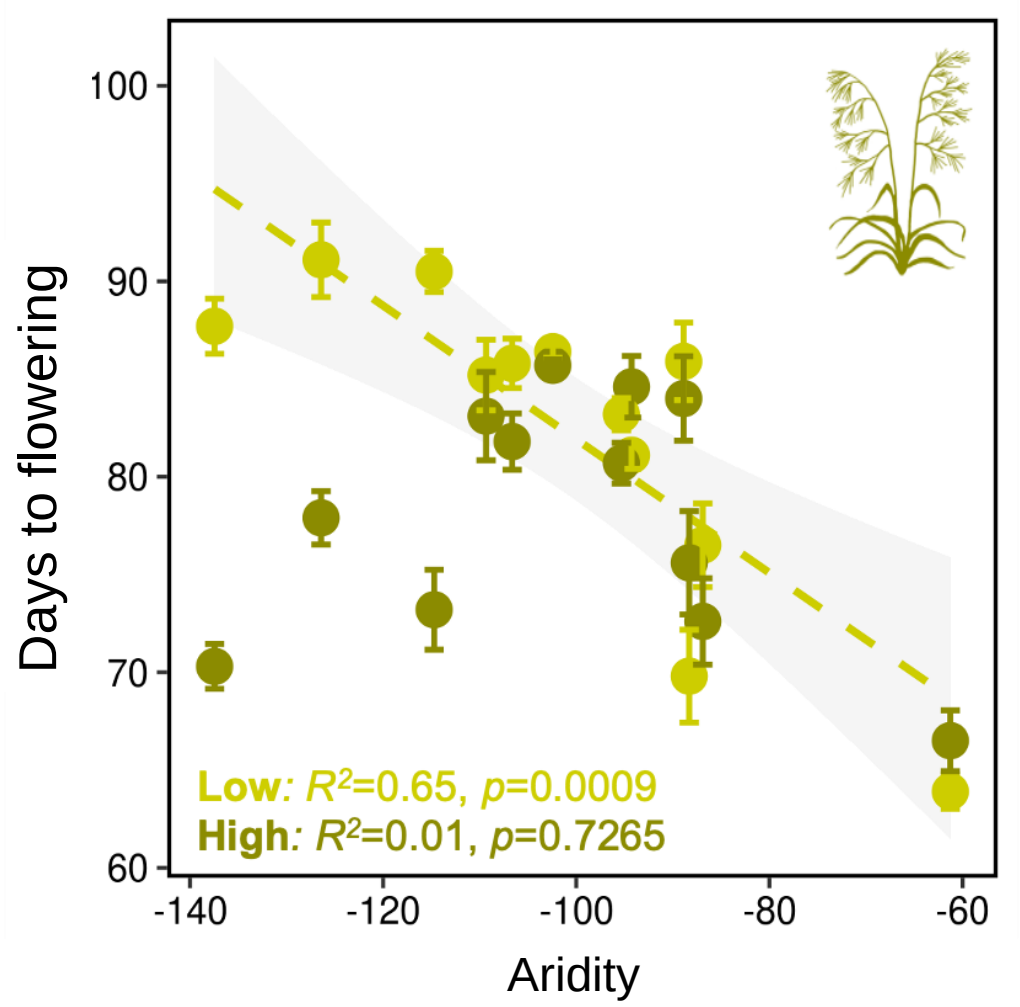
	Bromus diandrus				***Centaurea melitensis***			
	N deposition		Aridity		N deposition		Aridity	
Trait	Low N	High N	Low N	High N	Low N	High N	Low N	High N
Root mass	-0.09	-0.09	-0.09	-0.10	0.05	-0.08	-0.06	**0.58****
Shoot mass	0.02	0.04	-0.09	0.20	0.02	-0.07	-0.03	**0.34***
Leaf mass	-0.06	-0.08	-0.10	-0.10	-0.10	-0.02	-0.05	**0.45****
Repr. mass	0.01	0.13	-0.09	**0.42***	-0.08	-0.06	-0.09	-0.03
Total mass	-0.01	-0.04	-0.09	0.07	0.09	-0.08	-0.01	-0.04
LMR	-0.09	0.02	-0.10	-0.06	-0.07	-0.04	0.11	**0.33***
RMR	-0.10	-0.04	-0.09	-0.01	-0.09	-0.08	-0.10	**0.58****
Seed mass	-0.10	-0.07	-0.10	-0.08	-0.09	0.25	-0.05	0.04
DTF	-0.02	0.03	**0.65*****	-0.09	-0.10	-0.09	**0.27***	0.19
A_{max}	**0.33***	0.13	**0.33***	**0.35***	-0.04	-0.09	0.01	-0.06
WUE	-0.04	-0.02	**0.49****	**0.39***	0.01	-0.08	0.01	-0.10
SLA	0.04	-0.03	0.08	0.22	0.18	-0.09	-0.08	-0.01
N	0.10	0.19	0.02	-0.06	-0.01	-0.09	-0.10	-0.10
$\delta^{13}C$	0.06	-0.05	0.14	0.01	-0.04	-0.07	-0.09	-0.09

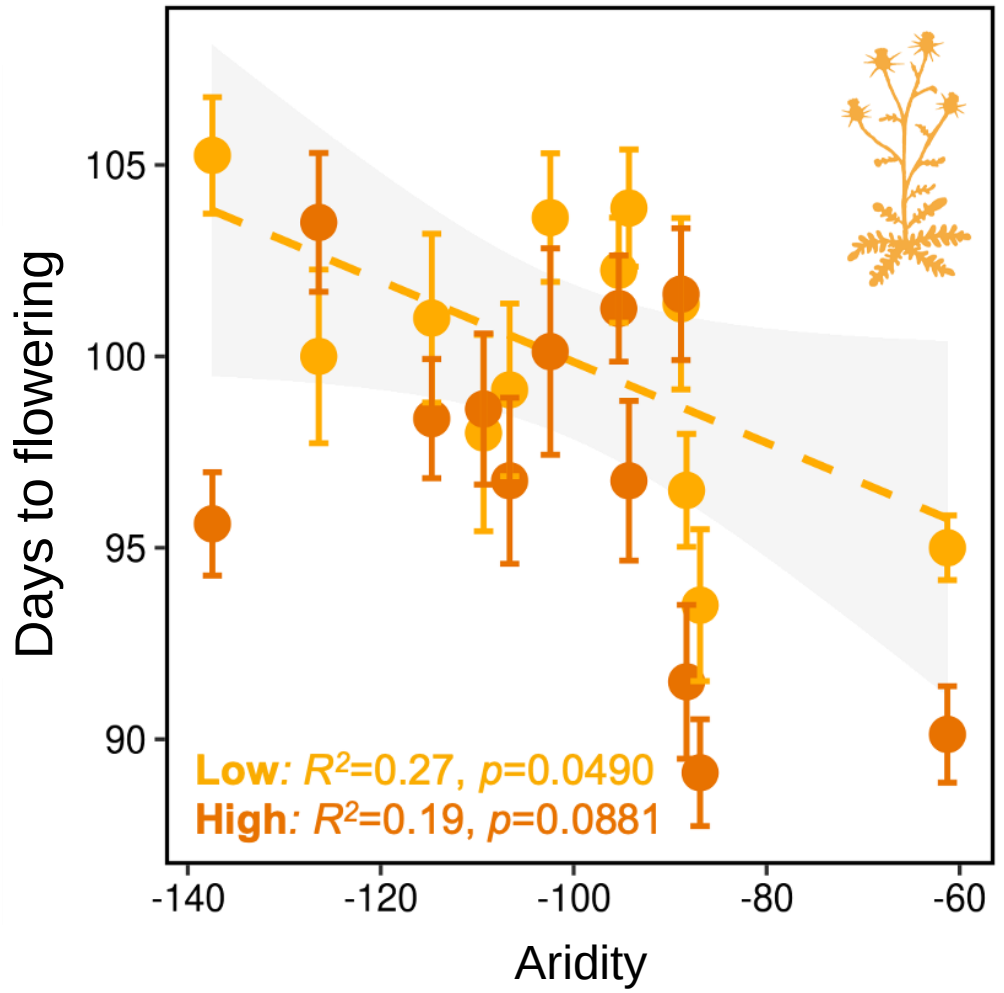
Multiple plant traits were significantly related to aridity

Plants from more arid sites exhibited traits associated with rapid growth as well as conservative water use

	Bromus diandrus				*Centaurea melitensis*			
	N dep		Aridity		N dep		Aridity	
Trait	Low N	High N	Low N	High N	Low N	High N	Low N	High N
Root mass	-0.09	-0.09	-0.09	-0.10	0.05	-0.08	-0.06	**0.58****
Shoot mass	0.02	0.04	-0.09	0.20	0.02	-0.07	-0.03	**0.34***
Leaf mass	-0.06	-0.08	-0.10	-0.10	-0.10	-0.02	-0.05	**0.45****
Repr. mass	0.01	0.13	-0.09	**0.42***	-0.08	-0.06	-0.09	-0.03
Total mass	-0.01	-0.04	-0.09	0.07	0.09	-0.08	-0.01	-0.04
LMR	-0.09	0.02	-0.10	-0.06	-0.07	-0.04	0.11	**0.33***
RMR	-0.10	-0.04	-0.09	-0.01	-0.09	-0.08	-0.10	**0.58****
Seed mass	-0.10	-0.07	-0.10	-0.08	-0.09	0.25	-0.05	0.04
DTF	-0.02	0.03	**0.65*****	-0.09	-0.10	-0.09	**0.27***	0.19
A_{max}	**0.33***	0.13	**0.33***	**0.35***	-0.04	-0.09	0.01	-0.06
WUE	-0.04	-0.02	**0.49****	**0.39***	0.01	-0.08	0.01	-0.10
SLA	0.04	-0.03	0.08	0.22	0.18	-0.09	-0.08	-0.01
N	0.10	0.19	0.02	-0.06	-0.01	-0.09	-0.10	-0.10
$\delta^{13}C$	0.06	-0.05	0.14	0.01	-0.04	-0.07	-0.09	-0.09

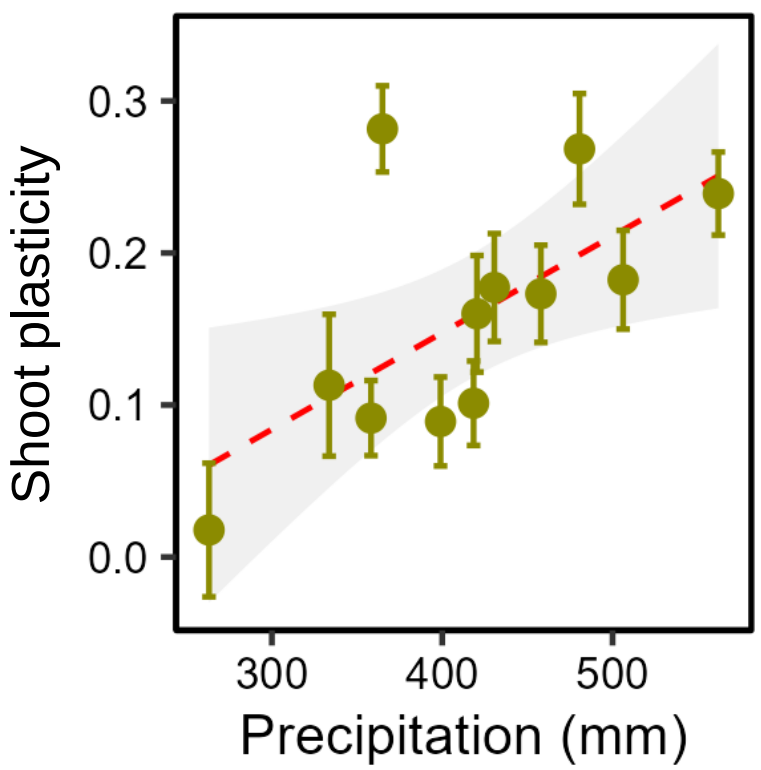
Populations of ***Bromus*** from less arid sites responded to N addition by flowering more rapidly

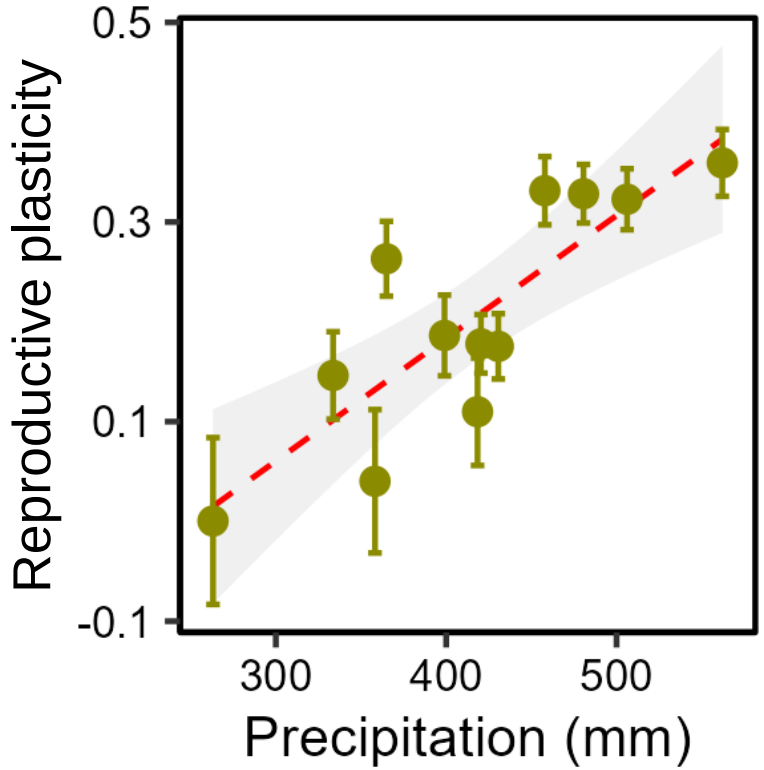


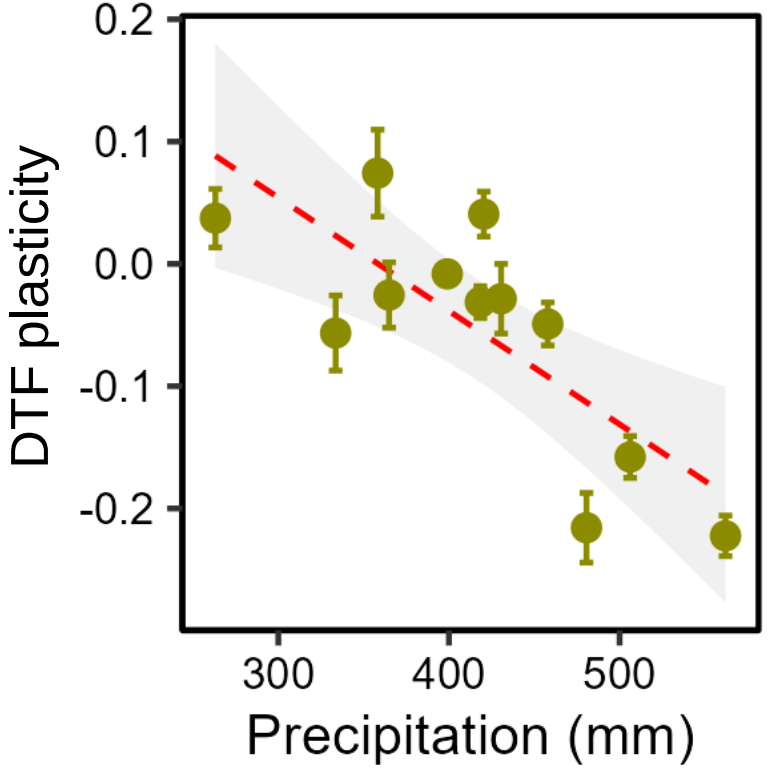


Less arid ⟷ More arid

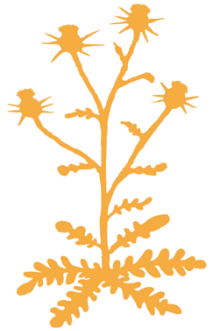
Bromus diandrus populations from more arid sites exhibit less plasticity in growth, reproductive output, and days to flowering



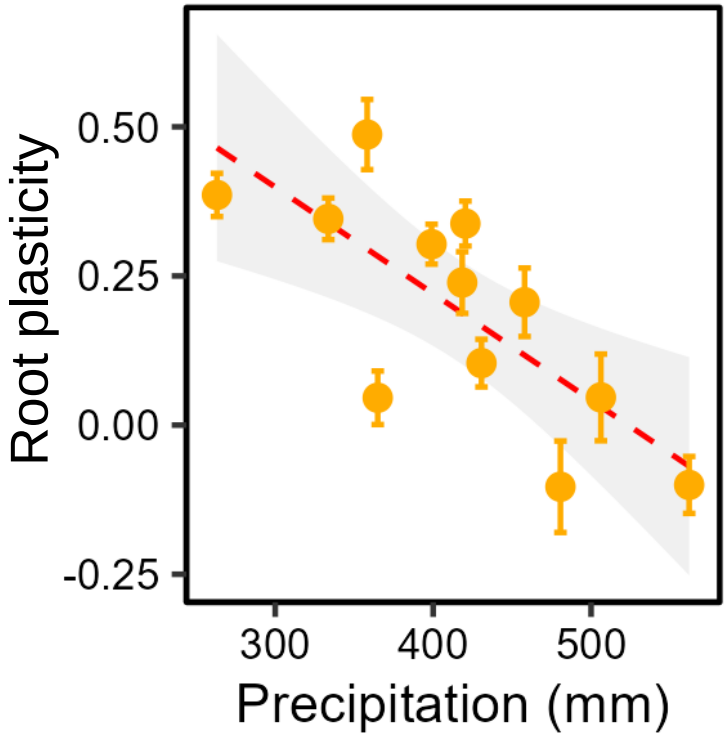


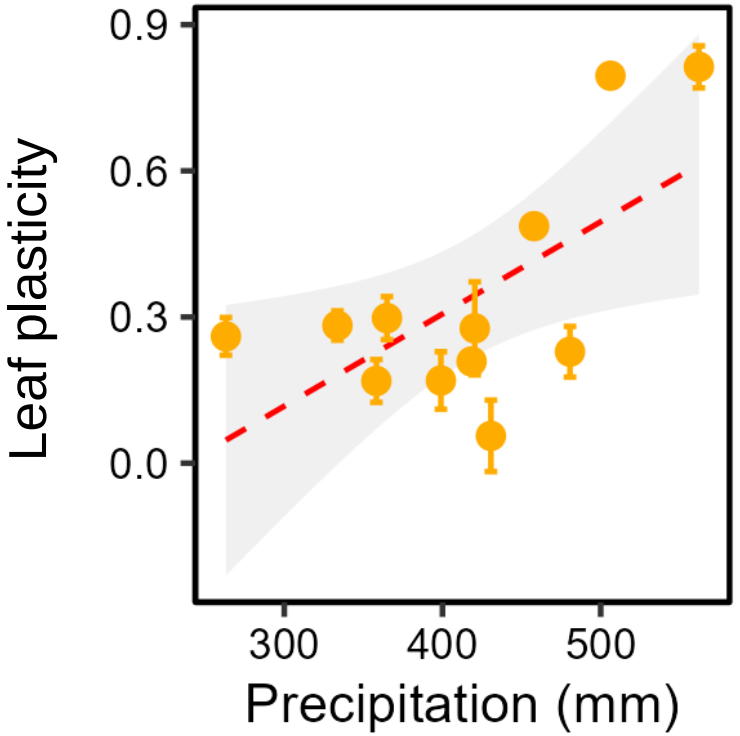


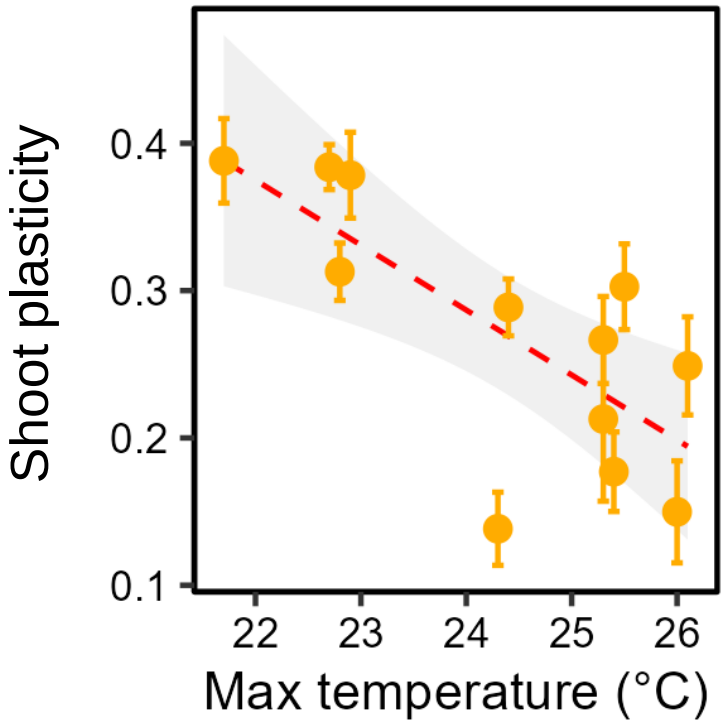
Populations from less arid sites are more responsive to N addition



Centaurea melitensis populations from more arid sites exhibit greater plasticity in root growth and lower plasticity in leaf growth. Populations from hotter sites exhibit lower shoot plasticity

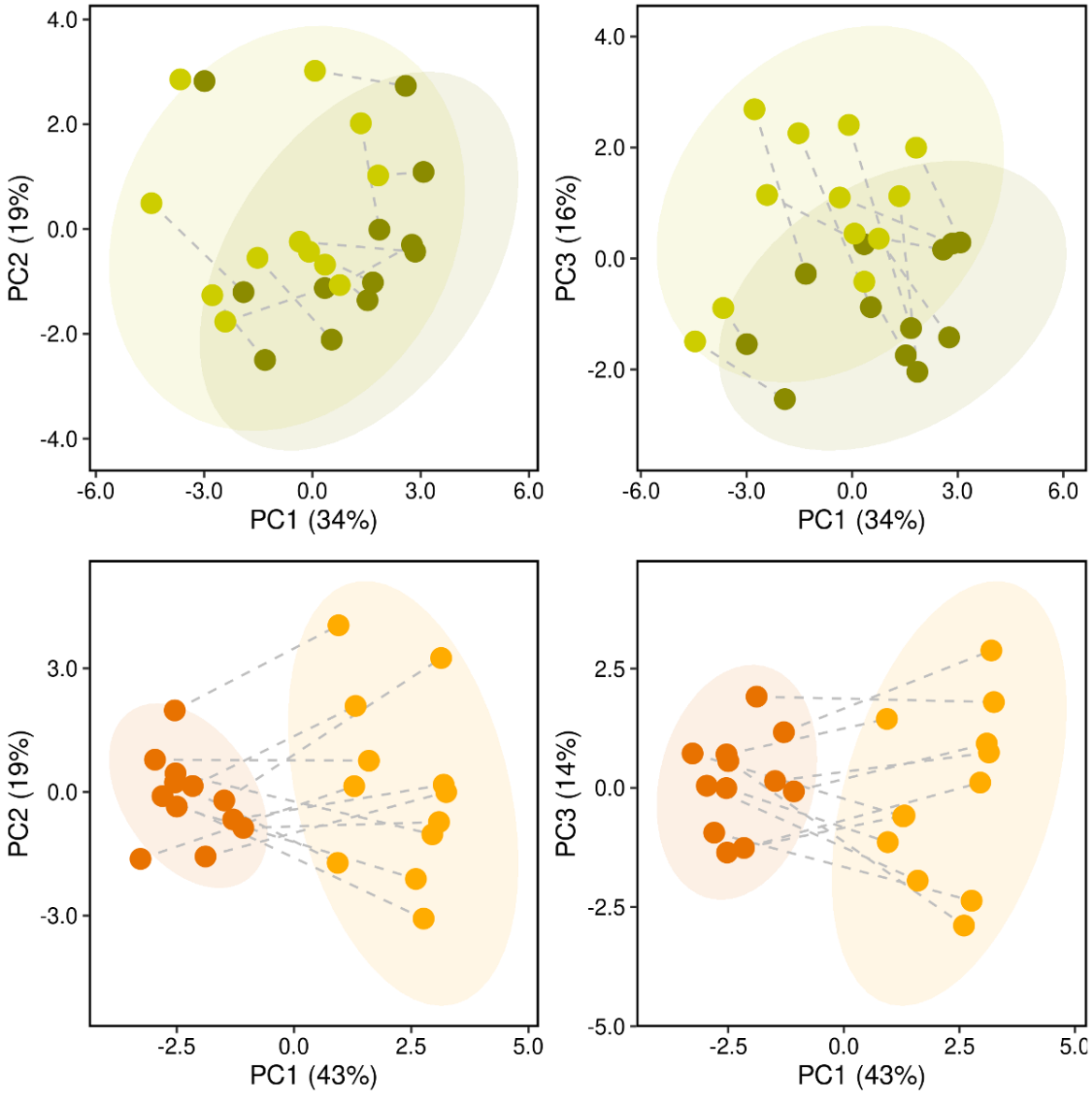


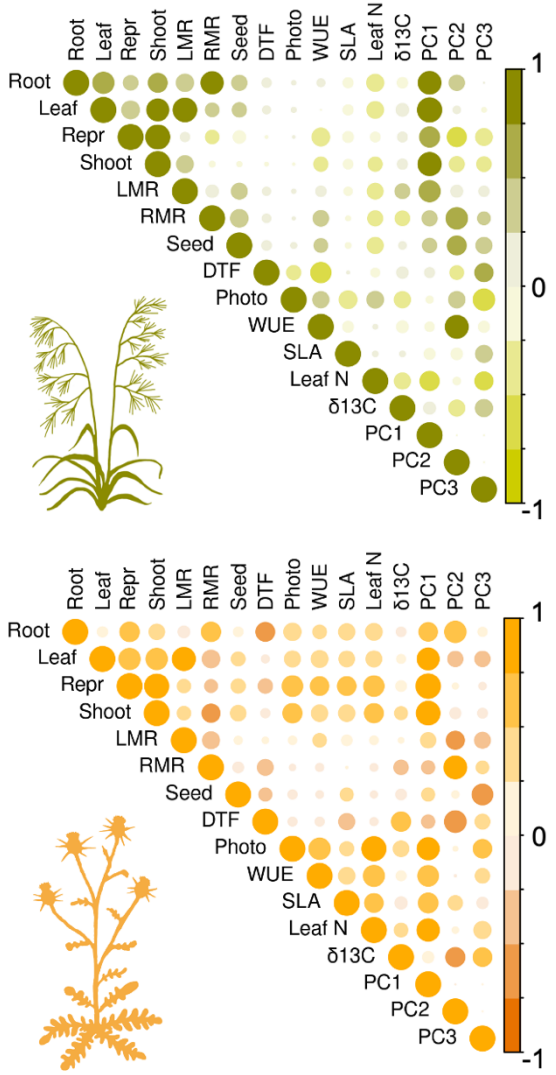




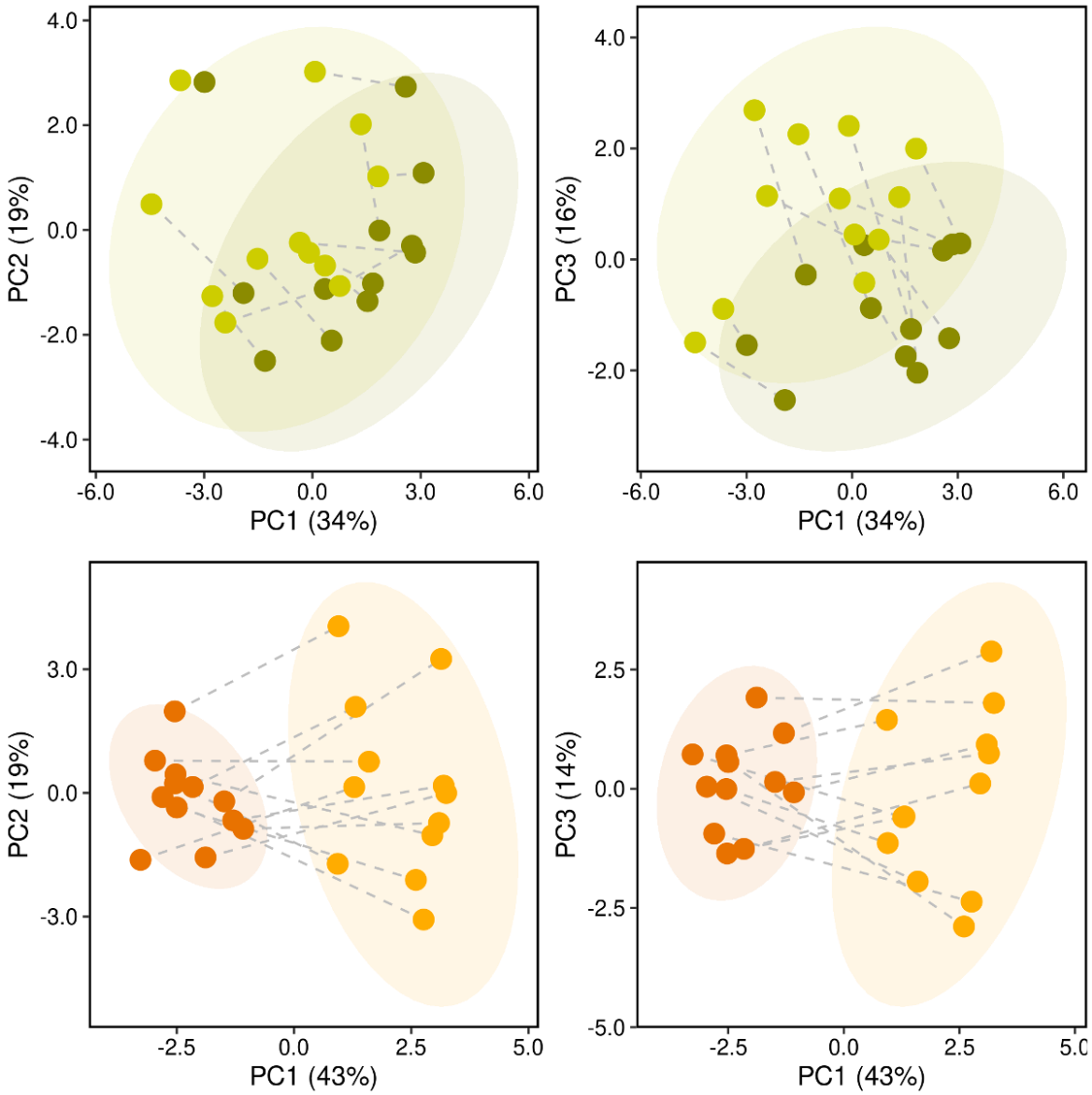
Under high N, arid populations invest in greater root growth, while populations from less arid sites invest in shoots

Multivariate plasticity index: Considering *all* trait variation at once





Multivariate plasticity index: Considering *all* trait variation at once



Nitrogen addition changes many traits simultaneously

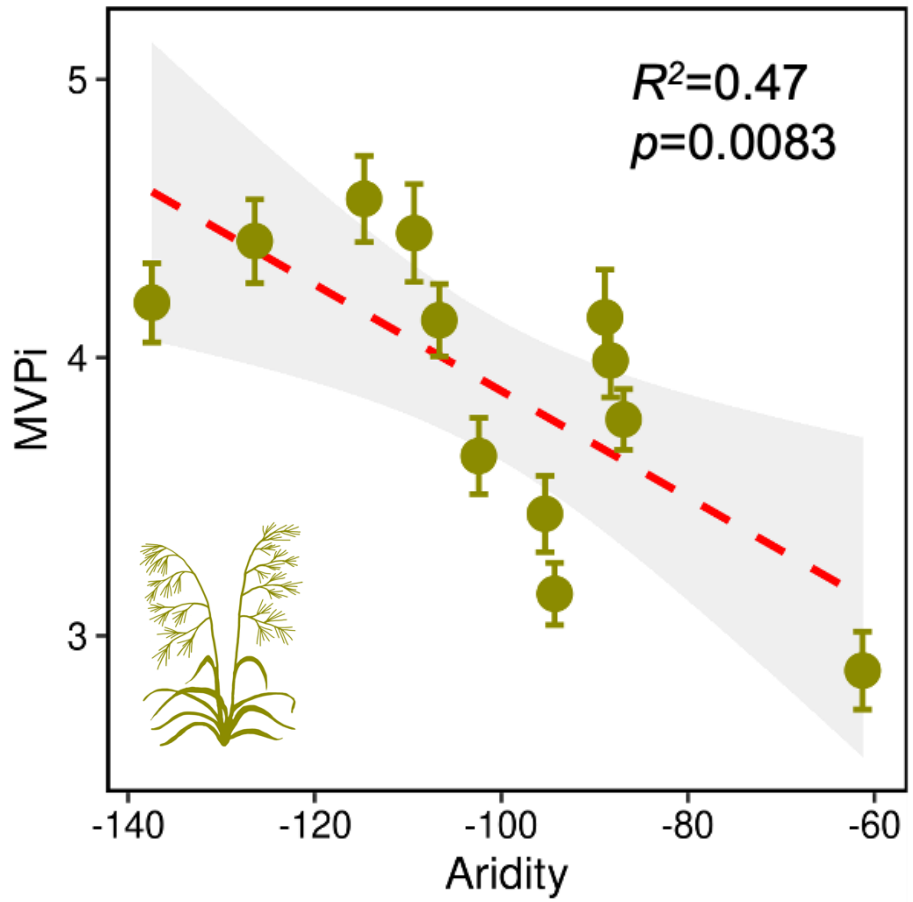
We can visualize those differences in “trait space” along axes that represent multiple traits

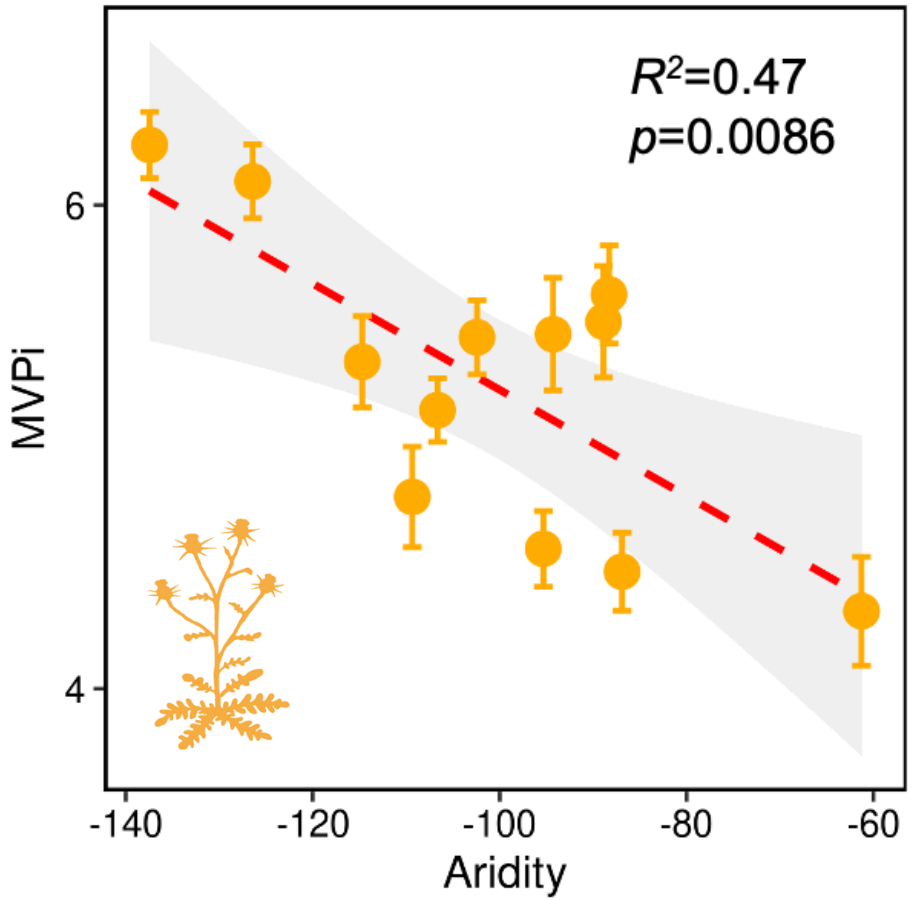
MVPi = the distance between populations grown under low and high N

Aridity shapes plant plasticity in both *Bromus* and *Centaurea*

More plastic

Less plastic





Less arid

More arid

Key findings

Nitrogen deposition undoubtedly contributes to increased invasion, but there is no evidence that invasives have adapted to high N deposition

Aridity exerts a strong selective pressure on plants, and this may constrain the ability of species to respond to N deposition evolutionarily

Aridity selects for traits associated with rapid growth and flowering, as well as traits associated with conservative water use

Plasticity in response to N addition is also constrained by aridity, likely because high plasticity (e.g., increased growth) is a risky strategy when water is very limiting

Acknowledgements

Coauthors

Mayra Hernández

Rasoul Sharifi

Phil Rundel

Funding

La Kretz Center for California Conservation Science

USDA NIFA Postdoctoral Fellowship

jmvalliere@ucdavis.edu

Photo credit: Title slide, Southwest Desert Flora