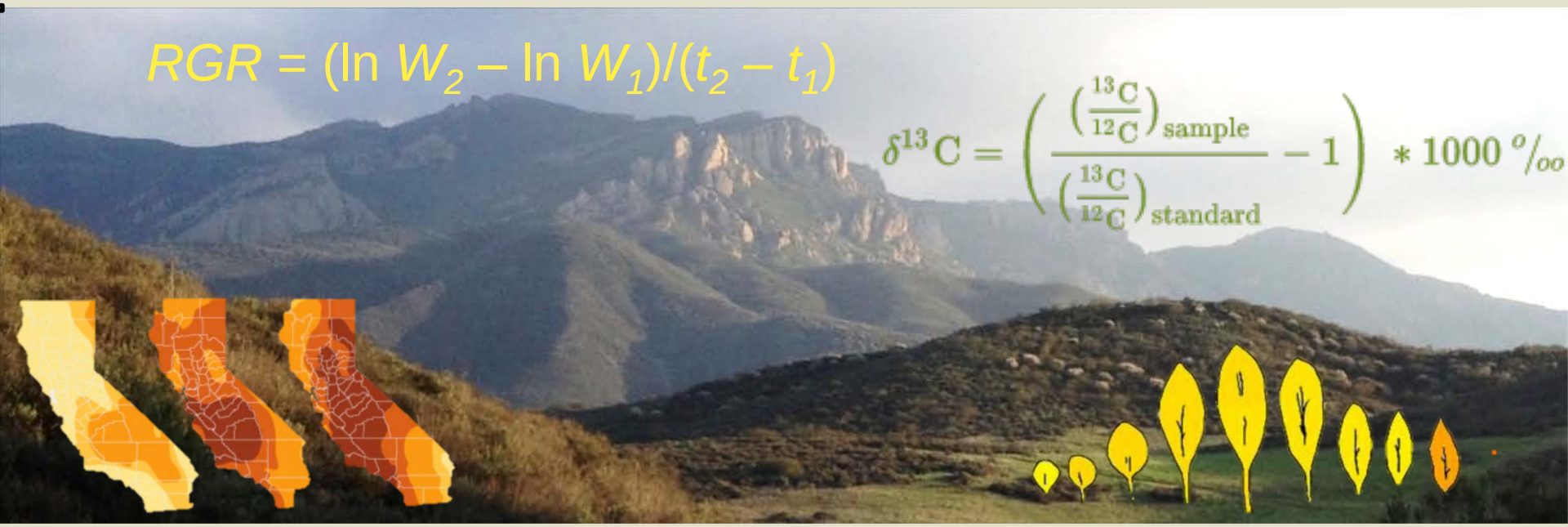
Exploring Traits and Tradeoffs in Native and Invasive Plant Species of California's Coastal Sage Scrub Under Global Change



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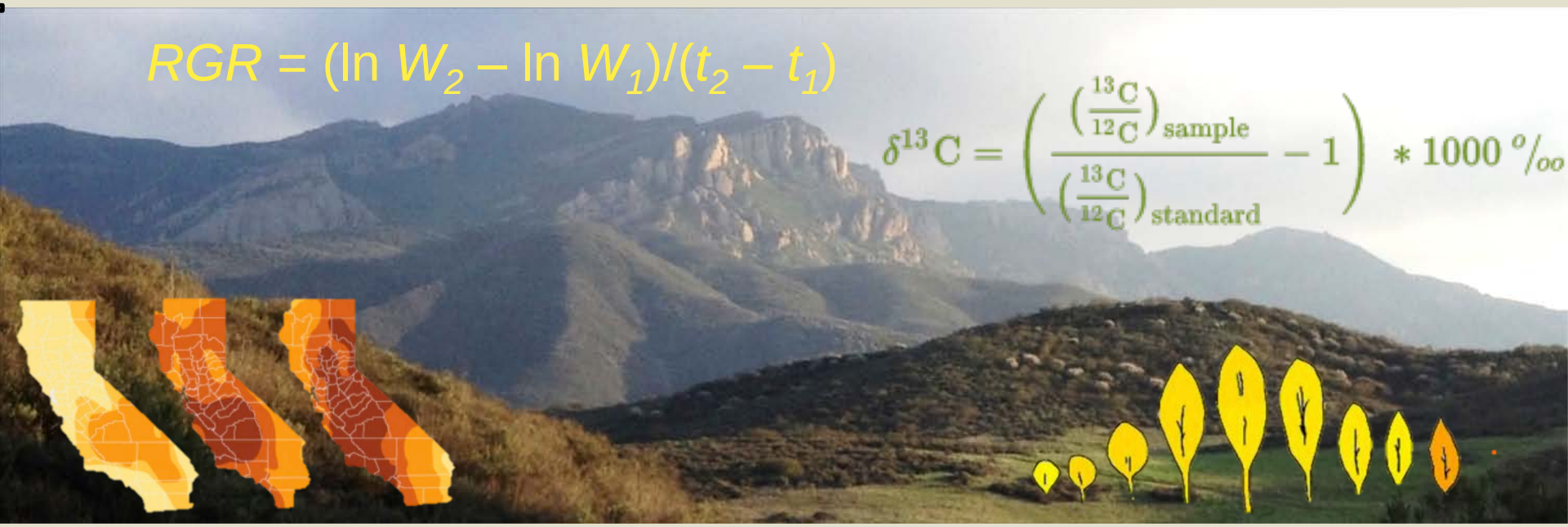
California Invasive Plant Council Symposium

November 4, 2016

Plant Winners, Losers and Cheaters Under Global Change in California's Coastal Sage Scrub



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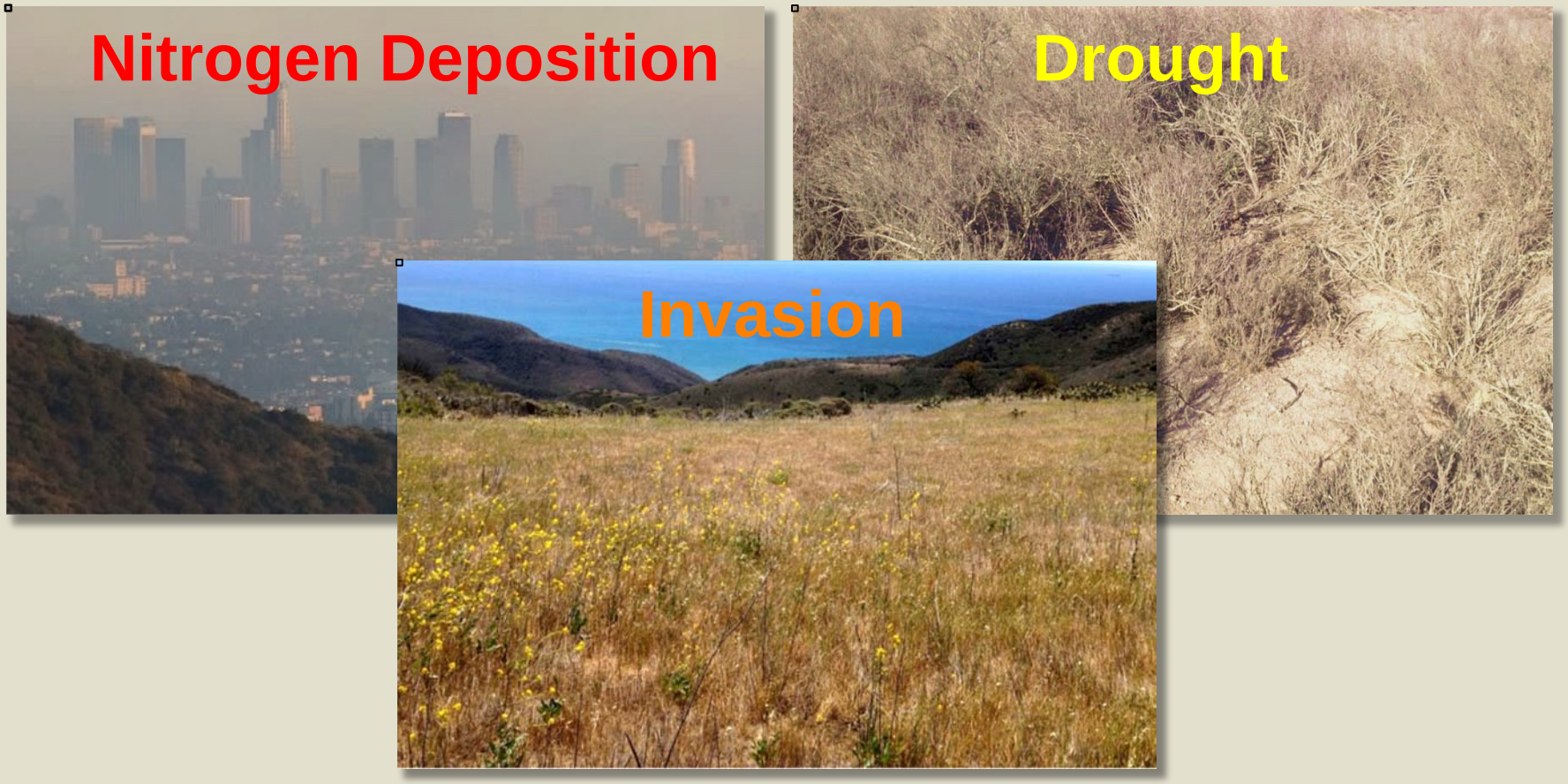
Where will global change leave California's native plant communities?

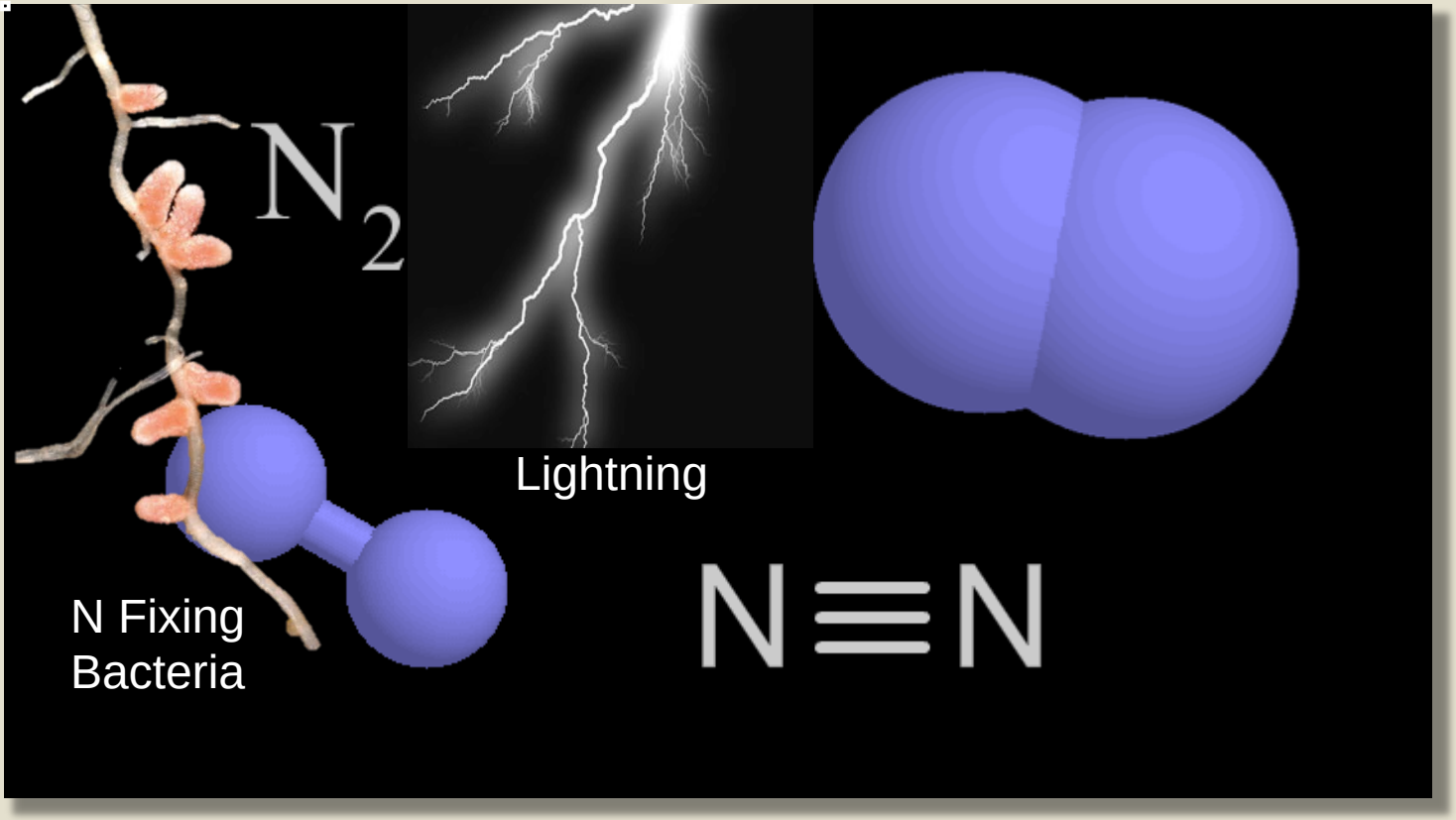
Where will global change leave California's native plant communities?

High N

Dry

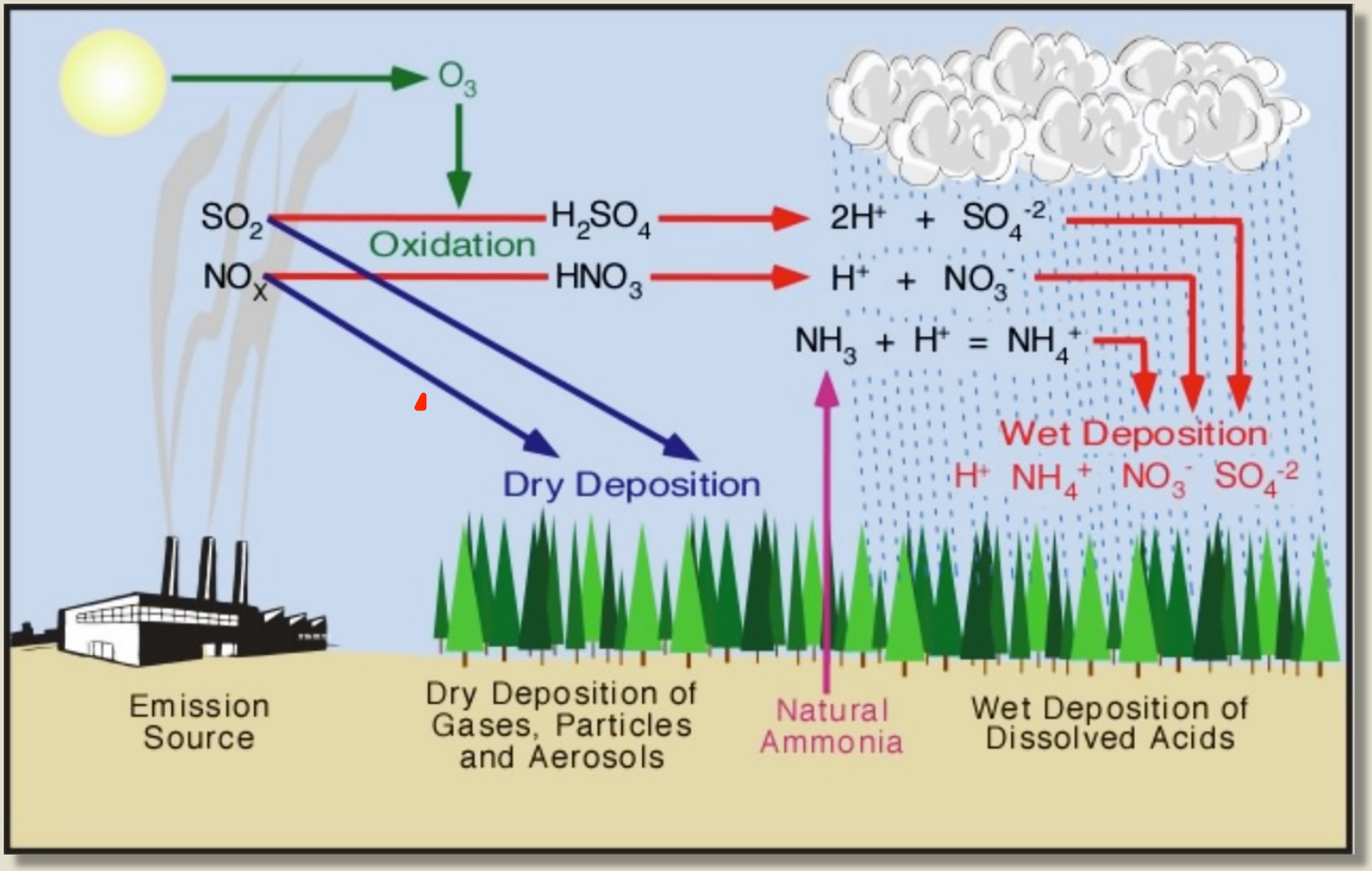


Nitrogen gas makes up about 78% of the Earth's atmosphere…

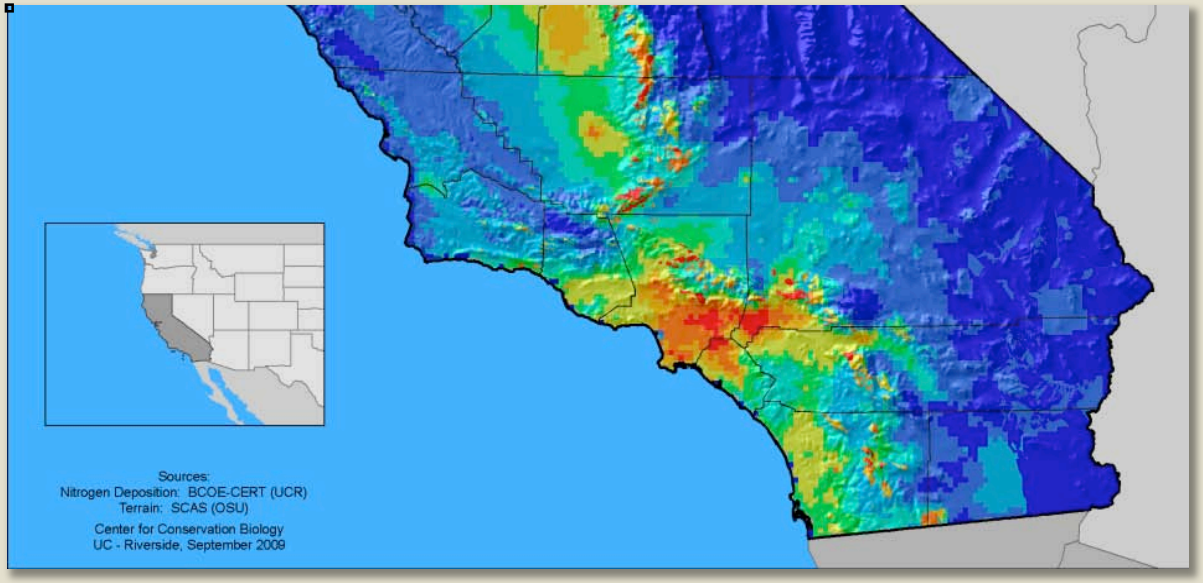


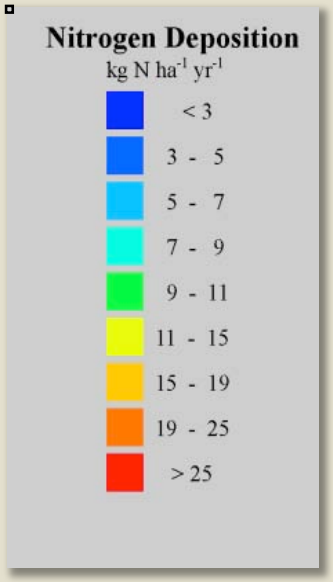
…yet bioavailable nitrogen is limiting in most ecosystems

Nitrogen deposition – the input of reactive nitrogen to the Earth's surface from the atmosphere



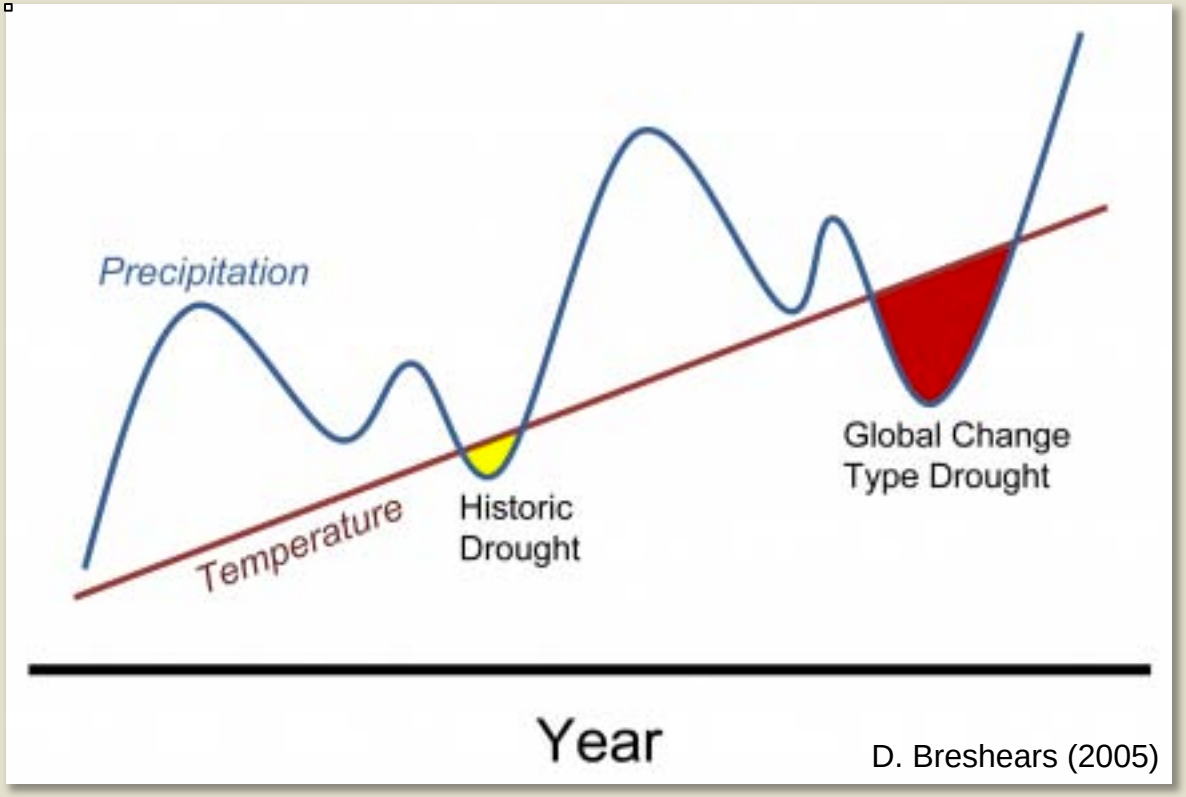
Nitrogen Deposition in Southern California





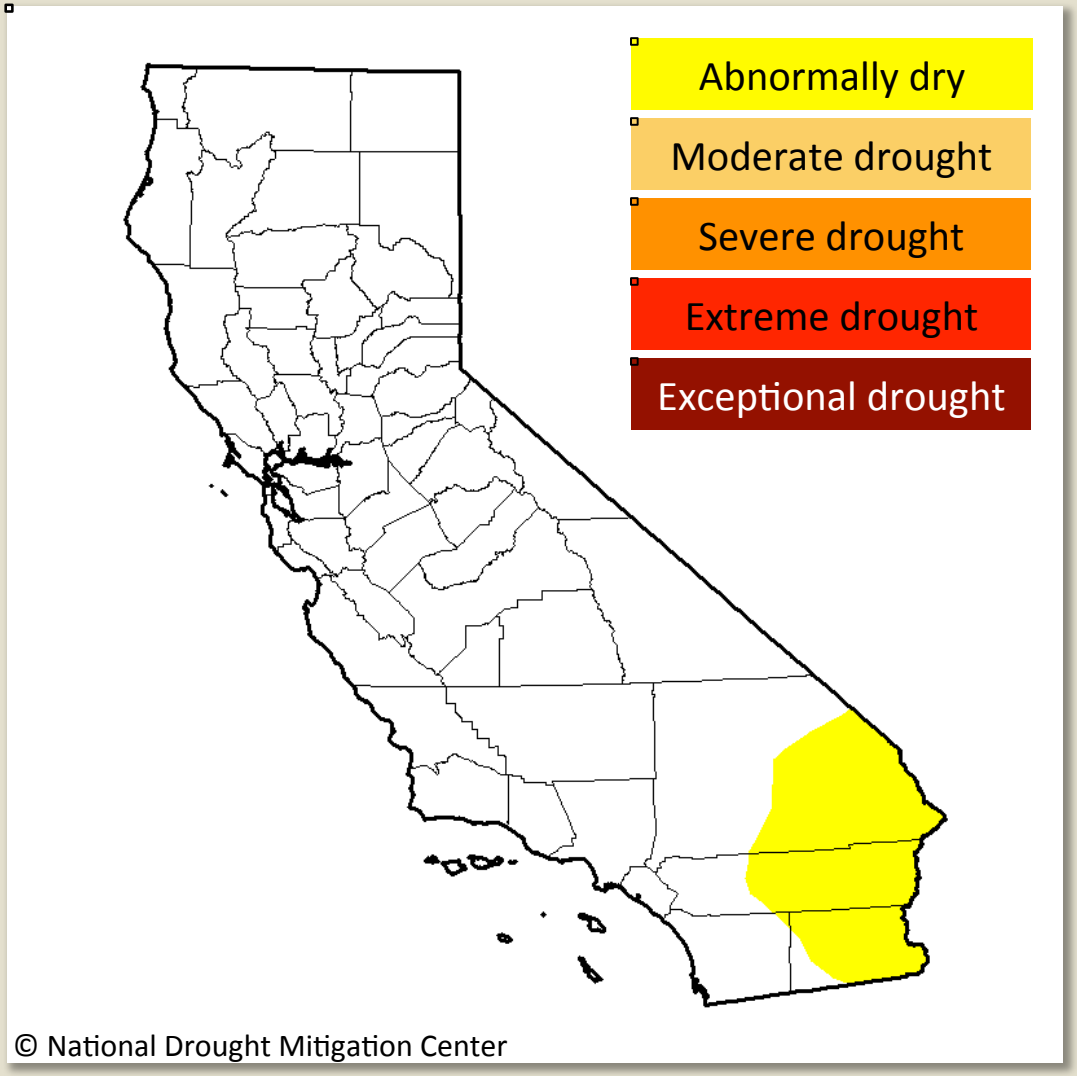
Climate change and extreme drought

In addition to reactive N, air pollution also contains greenhouse gases…



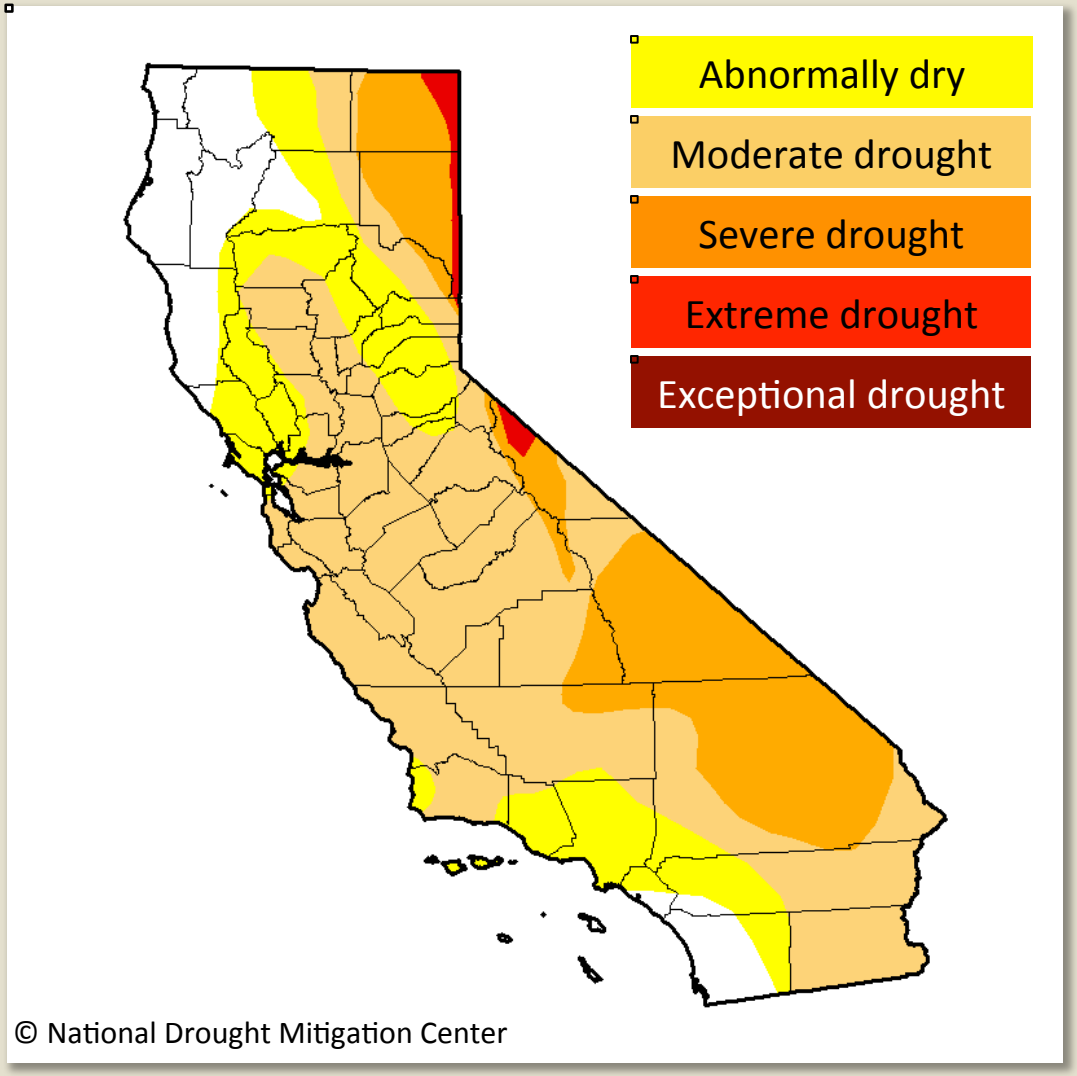
Global change-type drought: when precipitation is below long-term averages under warmer conditions

Extreme California Drought 2011-2016



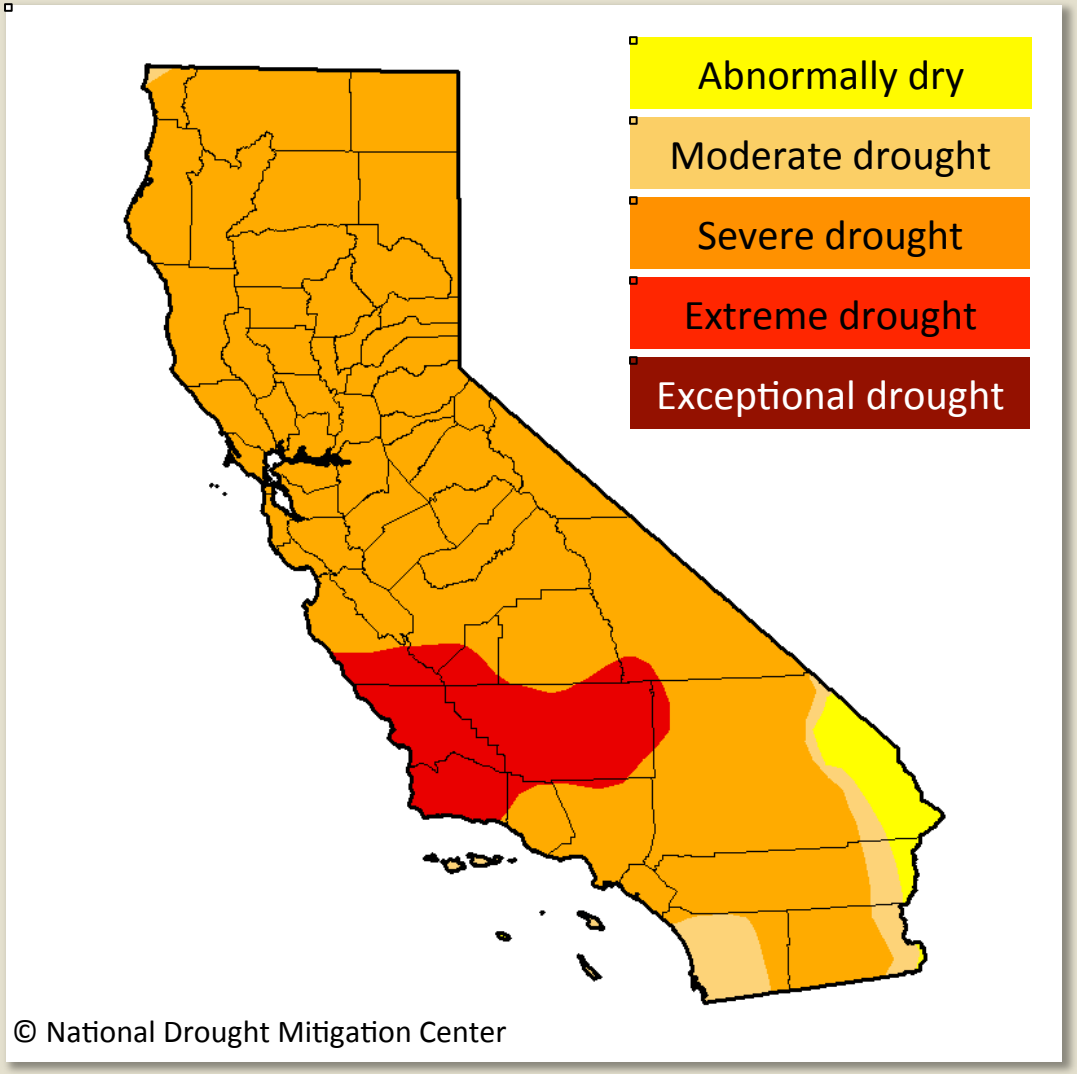
September 2011

Extreme California Drought 2011-2016



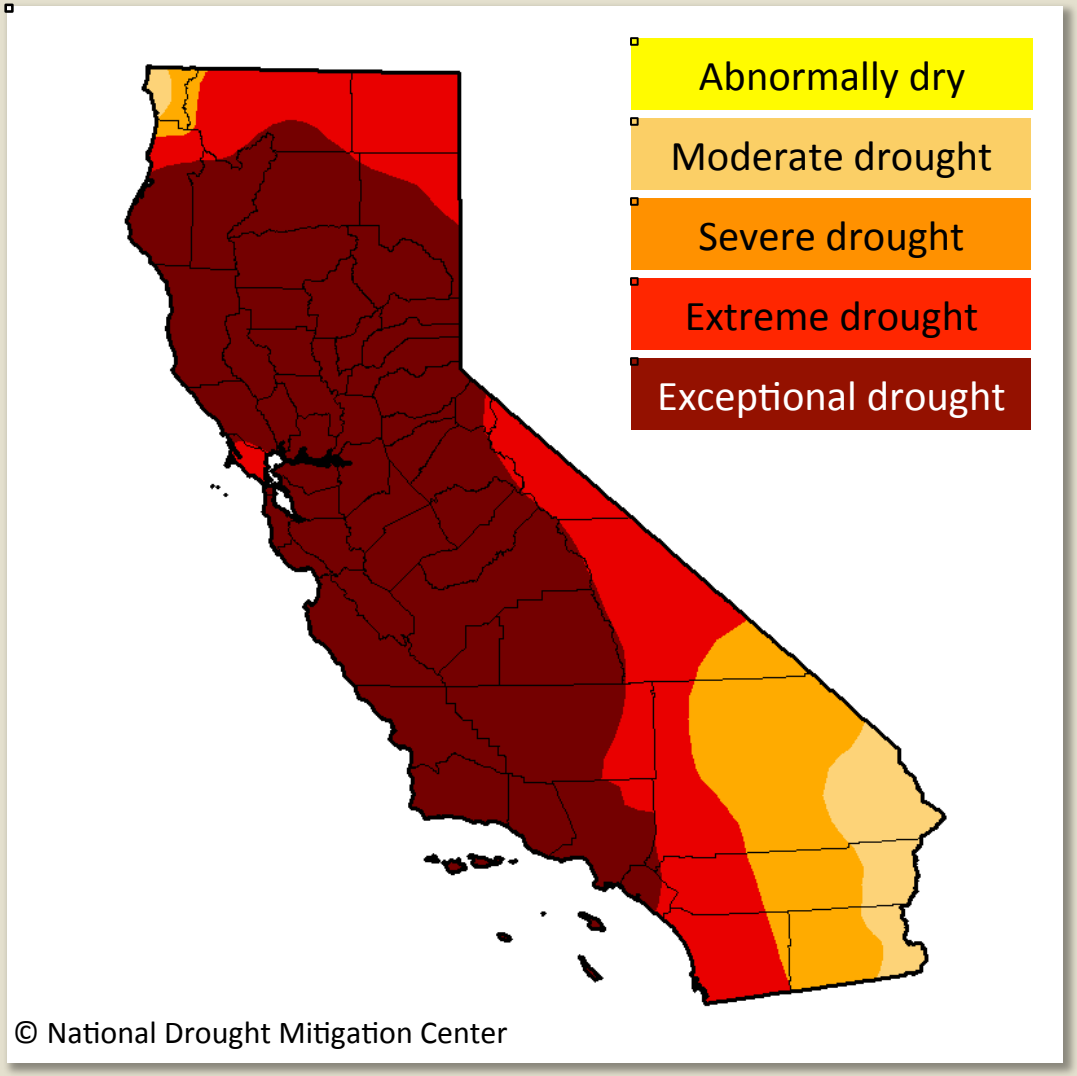
September 2012

Extreme California Drought 2011-2016



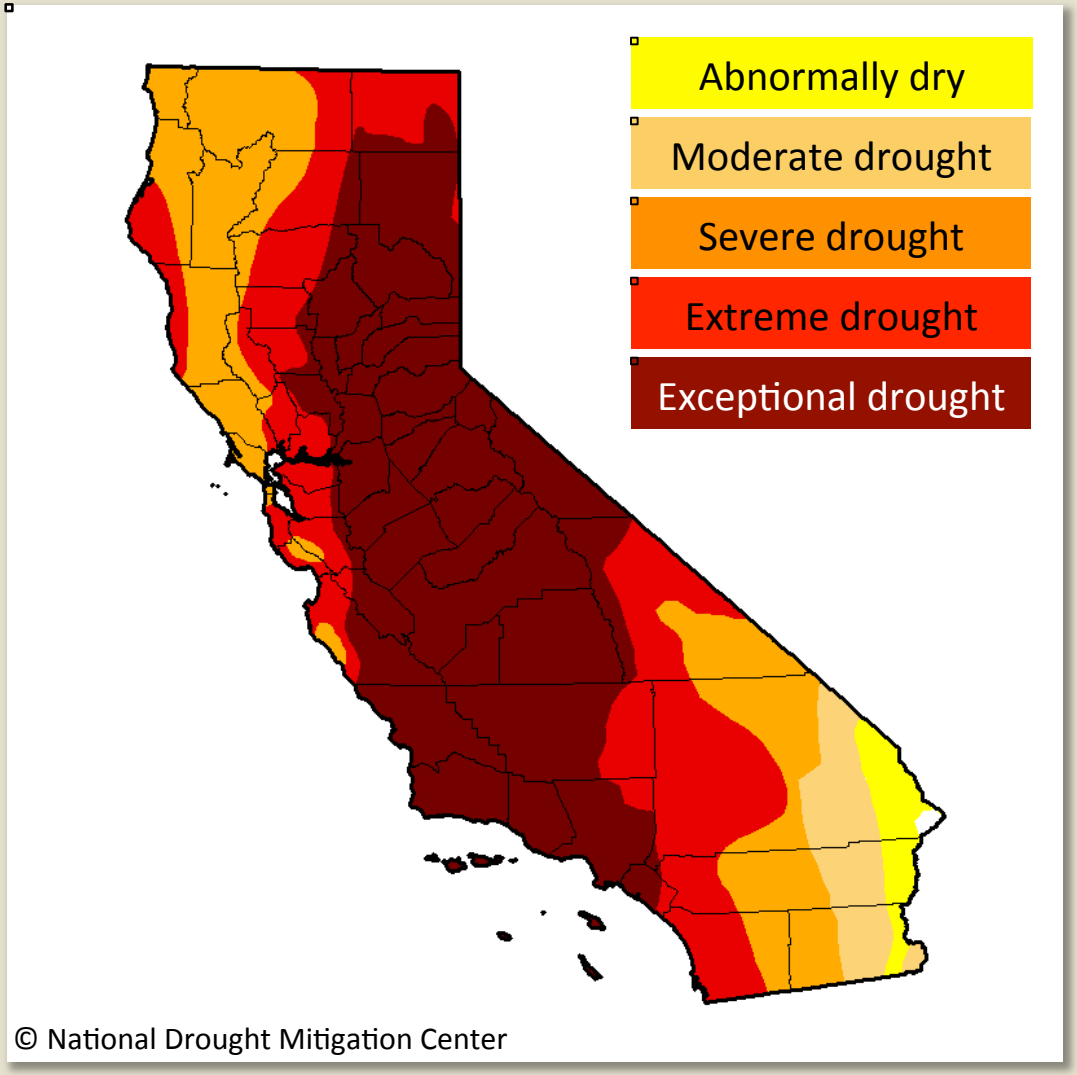
September 2013

Extreme California Drought 2011-2016



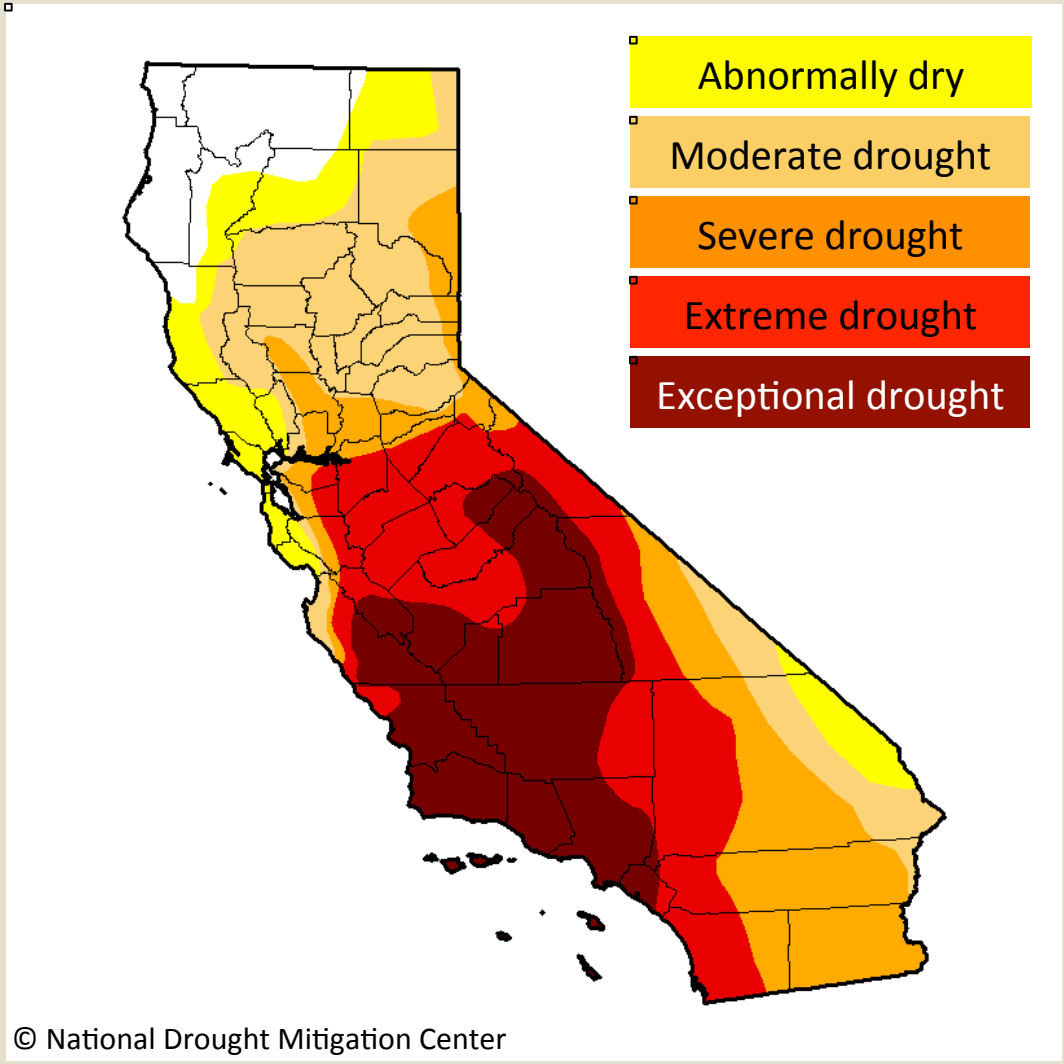
September 2014

Extreme California Drought 2011-2016



September 2015

Extreme California Drought 2011-2016



October 2016

Nonnative plant invasion in California

Avena fatua

Bromus diandrus

Centaurea melitensis

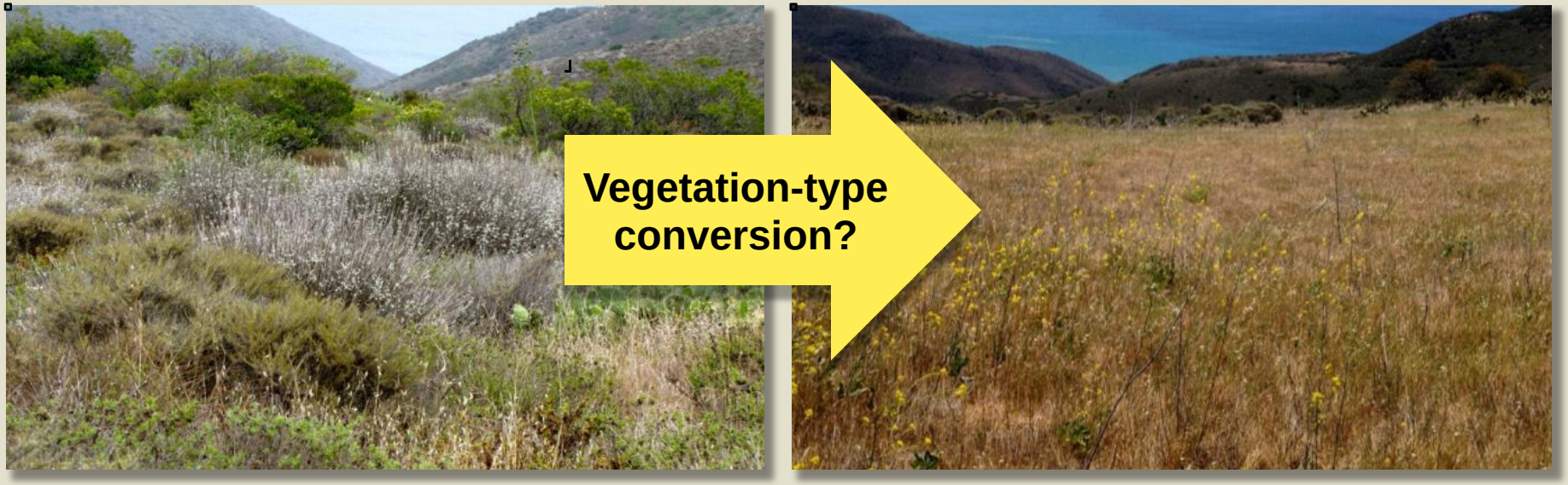
Erodium cicutarium

Hirschfeldia incana

Impacts of multiple drivers of global change on California's coastal sage scrub

Coastal Sage Scrub

Exotic Annual Grassland



Why/how are some plants successful invaders?

Why do N deposition and drought favor invasive plant species over natives?

Plant Functional Traits

Morphological: height, biomass, seed set, leaf traits, rooting depth

Physiological: carbon assimilation, C:N ratio, water-use efficiency (WUE)

Phenological: life history strategy, germination timing, relative growth rate (RGR), flowering phenology

Plant Functional Traits

Morphological: height, biomass, seed set, leaf traits, rooting depth

Physiological: carbon assimilation, C:N ratio, **water-use efficiency (WUE)**

Phenological: life history strategy, germination timing, **relative growth rate (RGR)**, flowering phenology

Plant Functional Traits

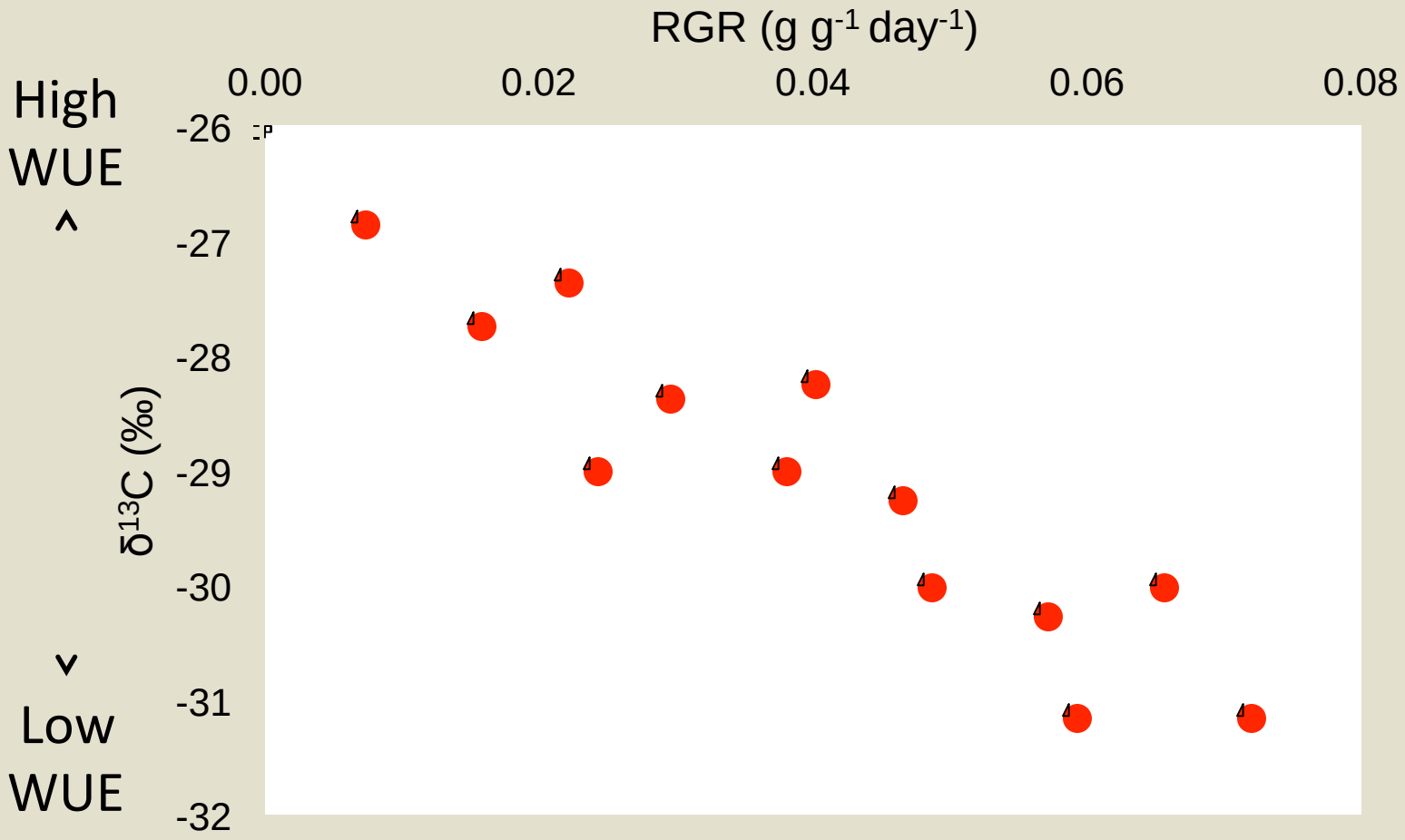
Relative growth rate (RGR) – growth rate of a plant relative to the total biomass of the plant

$$RGR = \frac{(\ln W_2 - \ln W_1)}{(t_2 - t_1)}$$

Water-use efficiency (WUE) – amount of water used per unit of biomass

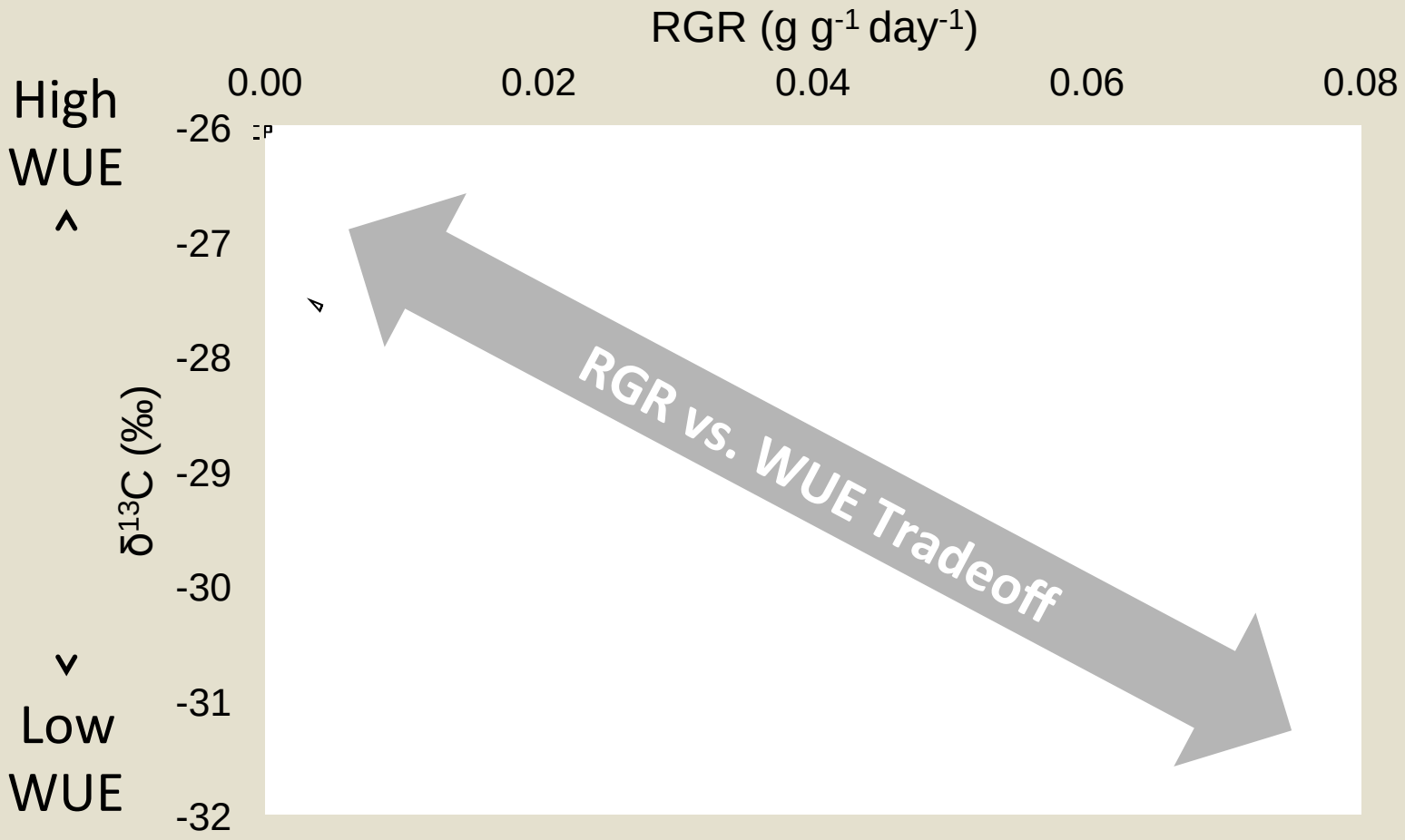
$$\delta^{13}\mathrm{C} = \left(\frac{\left(\frac{^{13}\mathrm{C}}{^{12}\mathrm{C}}\right)_{\mathrm{sample}}}{\left(\frac{^{13}\mathrm{C}}{^{12}\mathrm{C}}\right)_{\mathrm{standard}}} - 1 \right) * 1000\ {}^{o}/_{oo}$$

RGR vs. WUE Tradeoff



Venable and Brown 1988, Angert et al. 2007, Huxman et al. 2008

RGR vs. WUE Tradeoff



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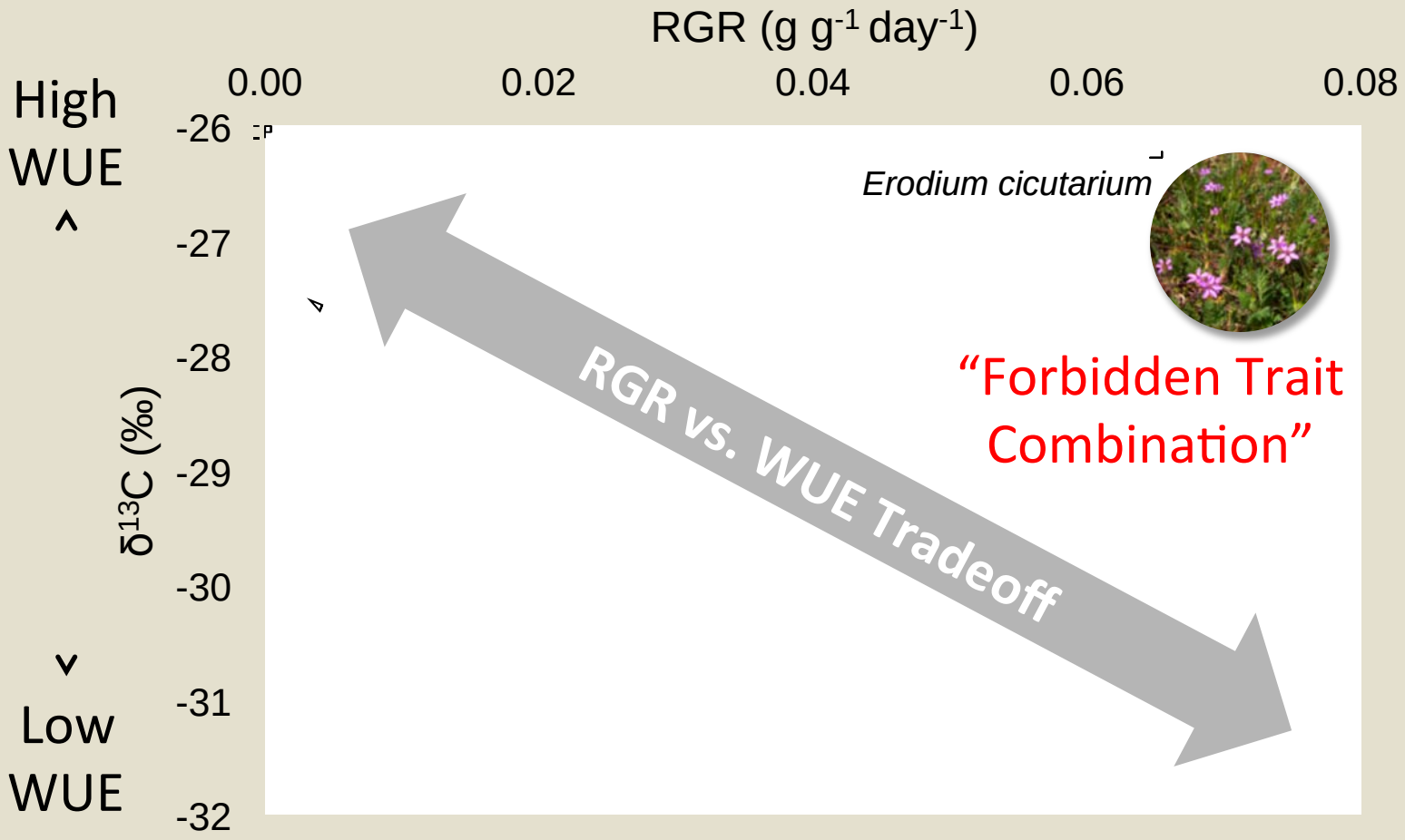
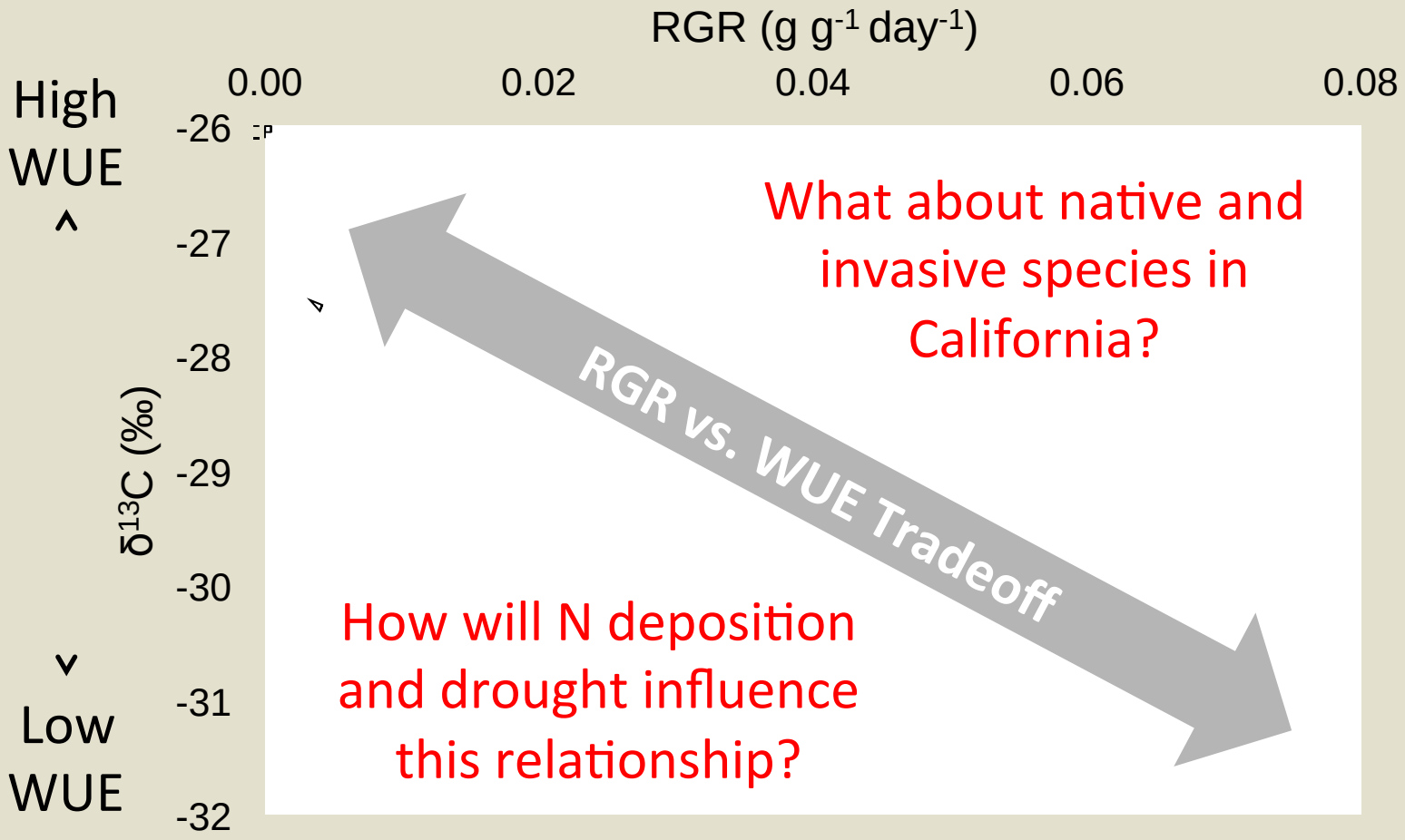
RGR vs. WUE Tradeoff



Kimball, Sarah, et al. (2016) "High water-use efficiency and growth contribute to success of non-native Erodium cicutarium in a Sonoran Desert winter annual community." Conservation Physiology 2.1.

RGR vs. WUE Tradeoff



Plant Community Mesocosm Experiment

How do N deposition and drought influence RGR and WUE in native and invasive plant species of coastal sage scrub?

Native Coastal Sage Scrub Perennials

Acmispon glaber

Artemisia californica

Encelia californica

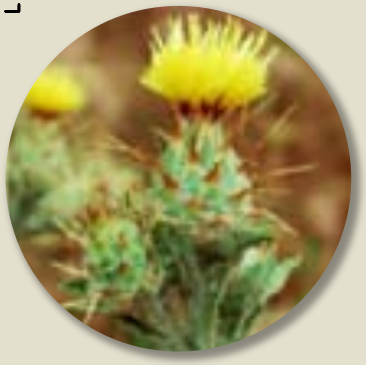
Salvia Mellifera

Stipa Pulchra

Invasive Mediterranean Annuals

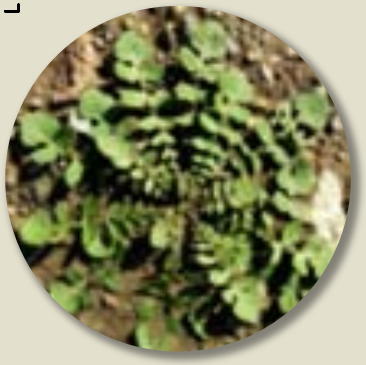
Avena fatua

Bromus diandrus



Centaurea melitensis

Erodium cicutarium



Hirschfeldia incana

Plant Community Mesocosm Experiment

1. Established communities in 5 gallon bins from seed

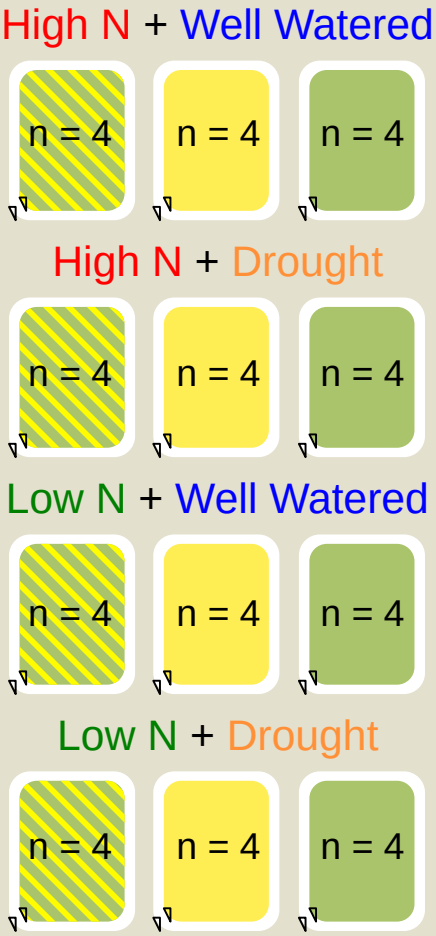
Natives

Invasives

Natives + Invasives

Plant Community Mesocosm Experiment

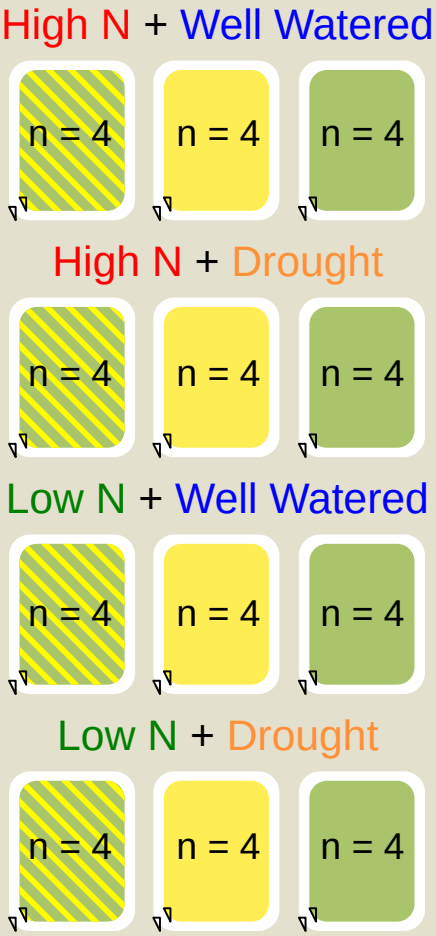
1. Established communities in 5 gallon bins from seed



2. Plants grown under different N and water availability in factorial design

Plant Community Mesocosm Experiment

1. Established communities in 5 gallon bins from seed



2. Plants grown under different N and water availability in factorial design

3. Measured relevant plant functional traits

Relative Growth Rate (RGR)

$$RGR = \frac{(\ln W_2 - \ln W_1)}{(t_2 - t_1)}$$

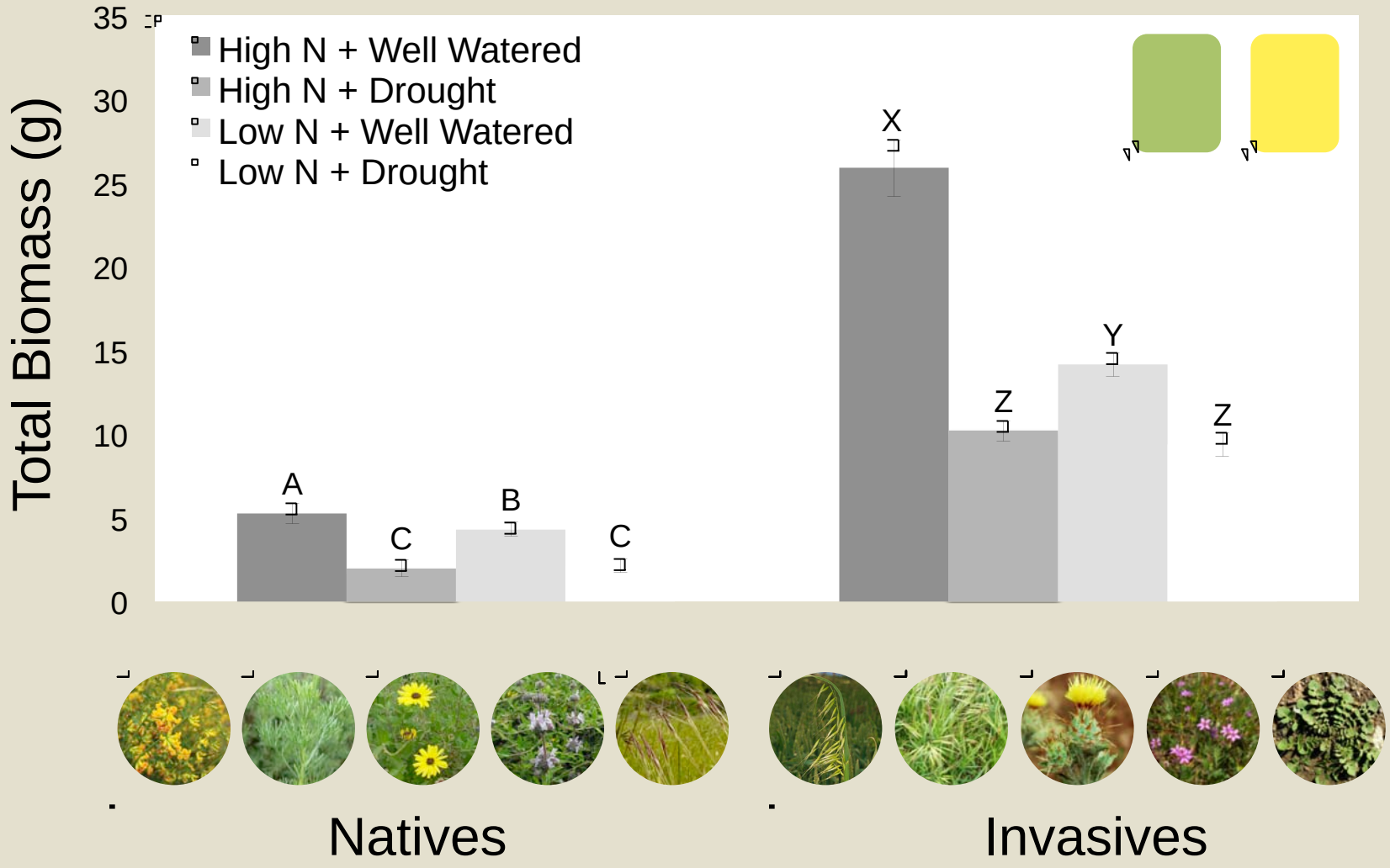
Water-Use Efficiency (WUE)

Carbon Isotope Discrimination

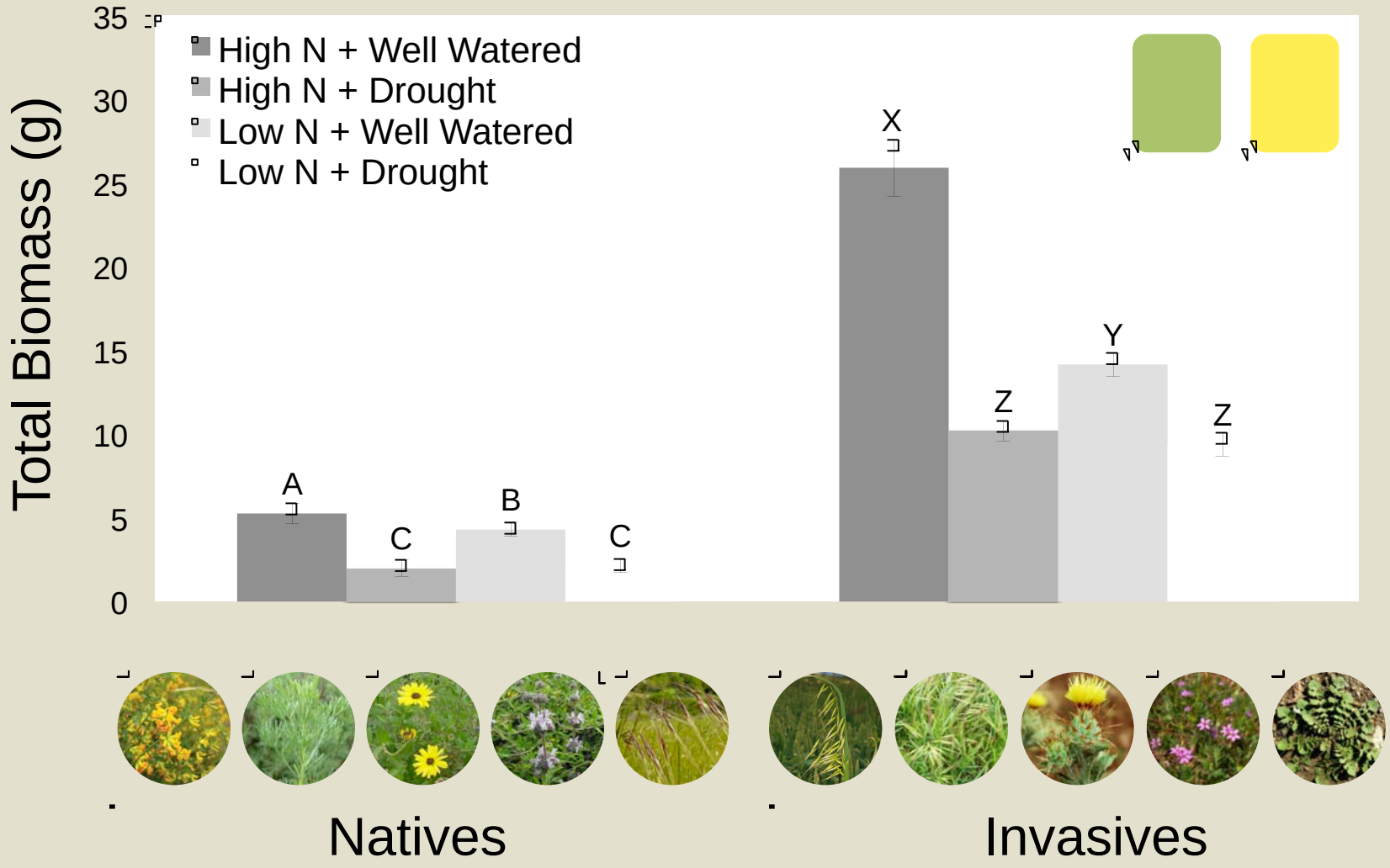
$$\delta^{13}C = \left(\frac{\left(\frac{^{13}C}{^{12}C}\right)_{sample}}{\left(\frac{^{13}C}{^{12}C}\right)_{standard}} - 1 \right) * 1000\ ‰$$

Plant Community Mesocosm Experiment

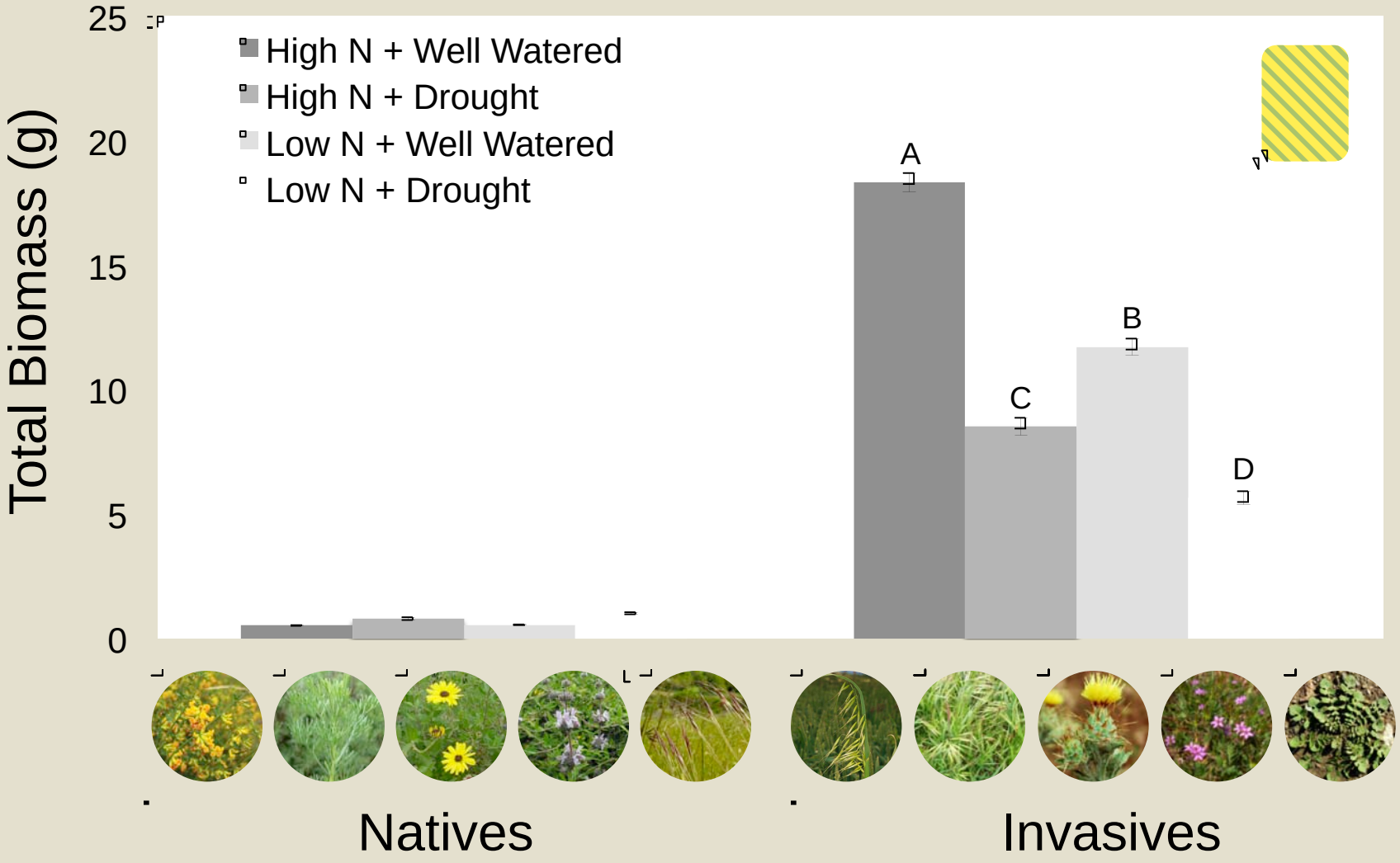
When grown separately invasives amassed significantly greater biomass than natives in all resource treatments



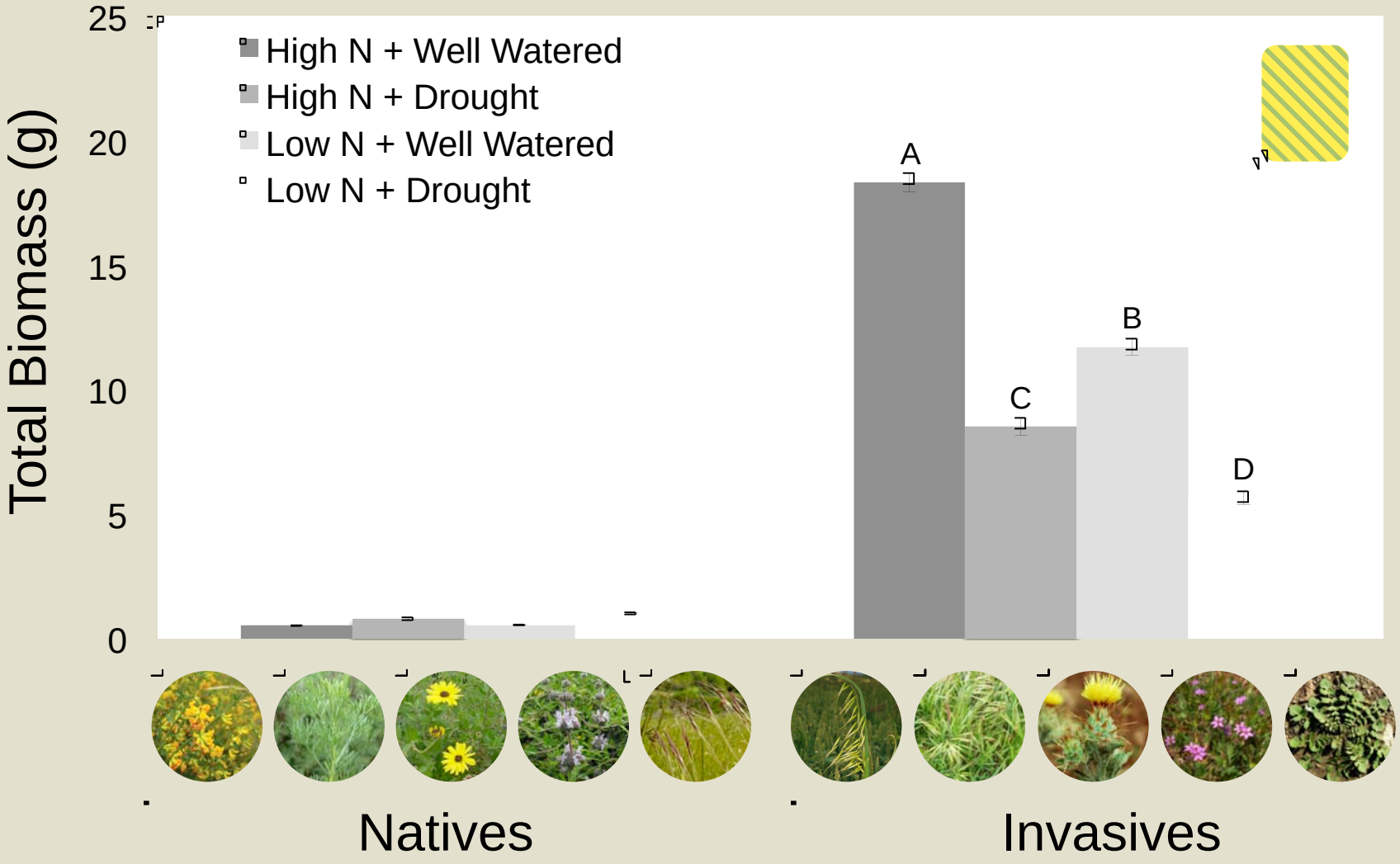
Generally species responded similarly to resource availability, with greater biomass under high N and water



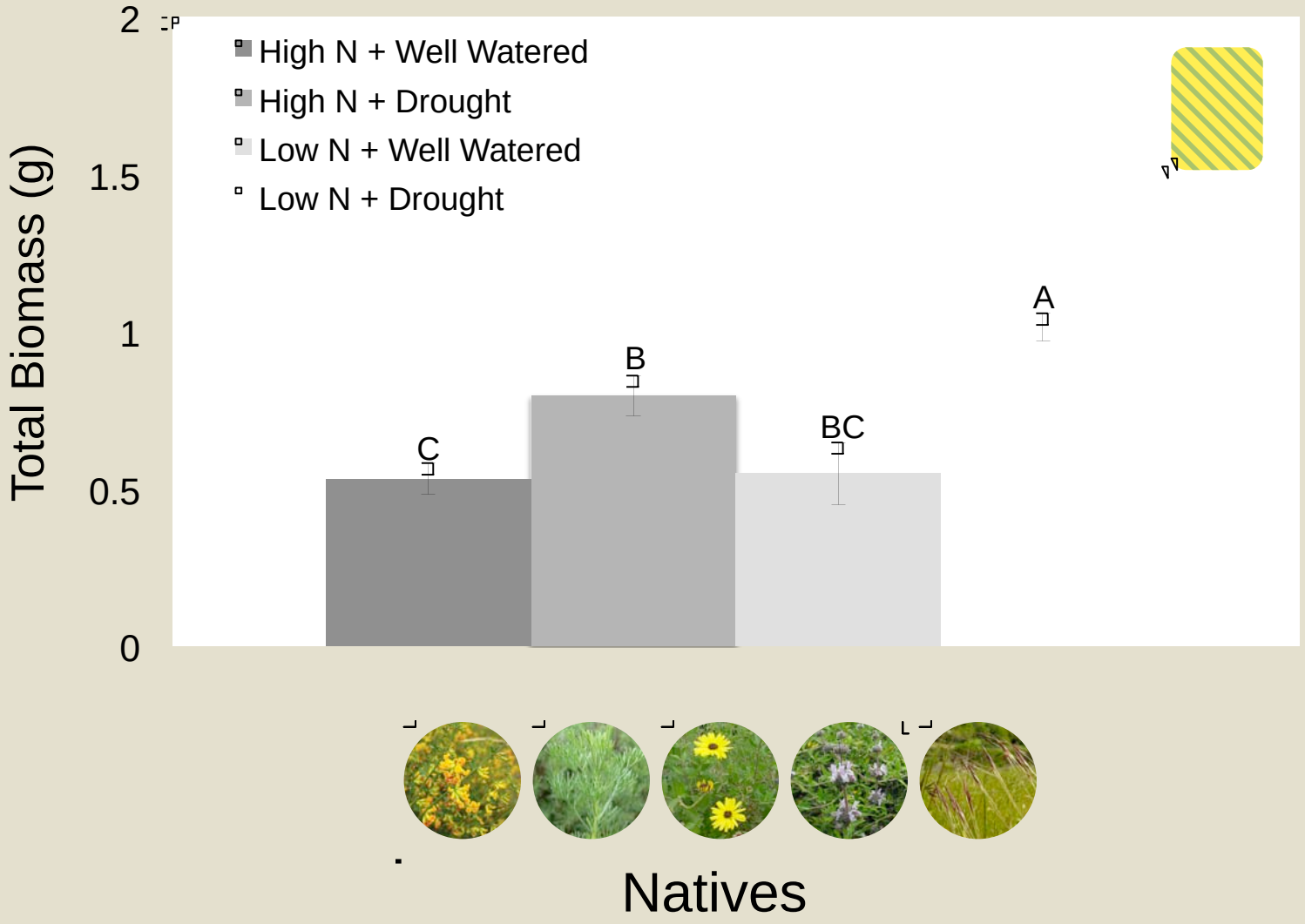
When grown together, invasive biomass responded similarly across treatments, with greater biomass under high N and water

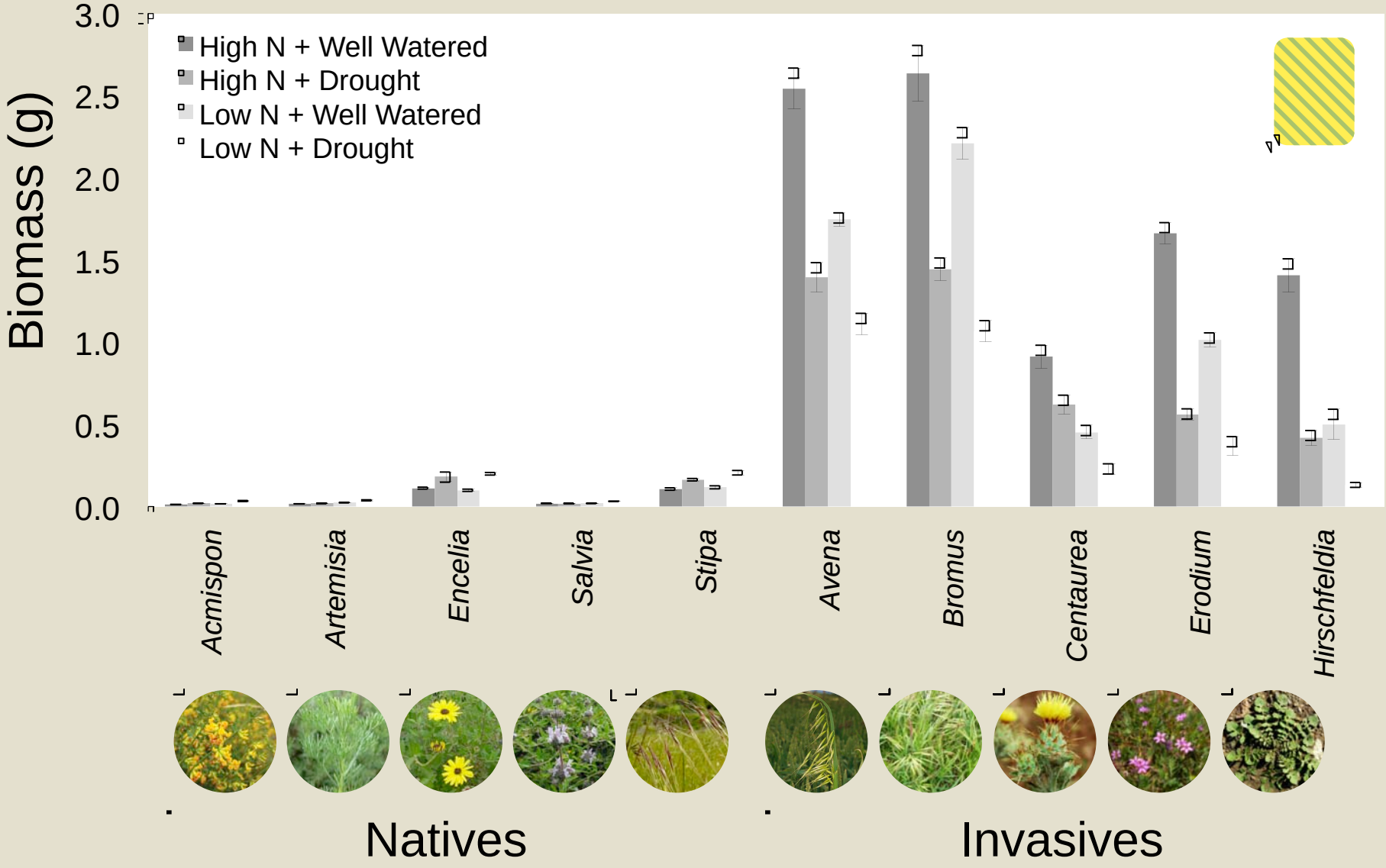


…but native biomass was greatly reduced in the presence of invasives

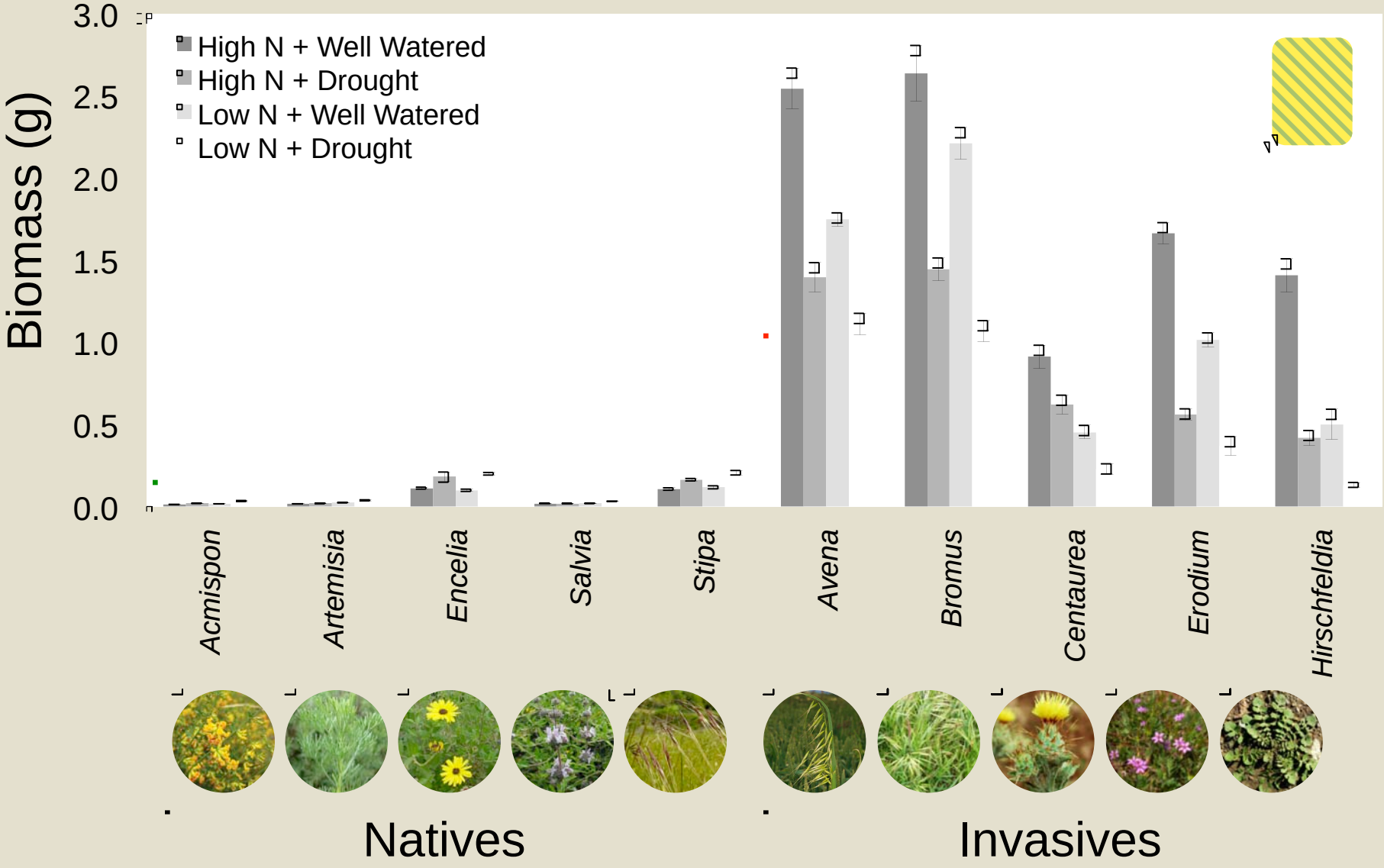


When grown with invasives, natives amassed greater biomass under low N and drought conditions

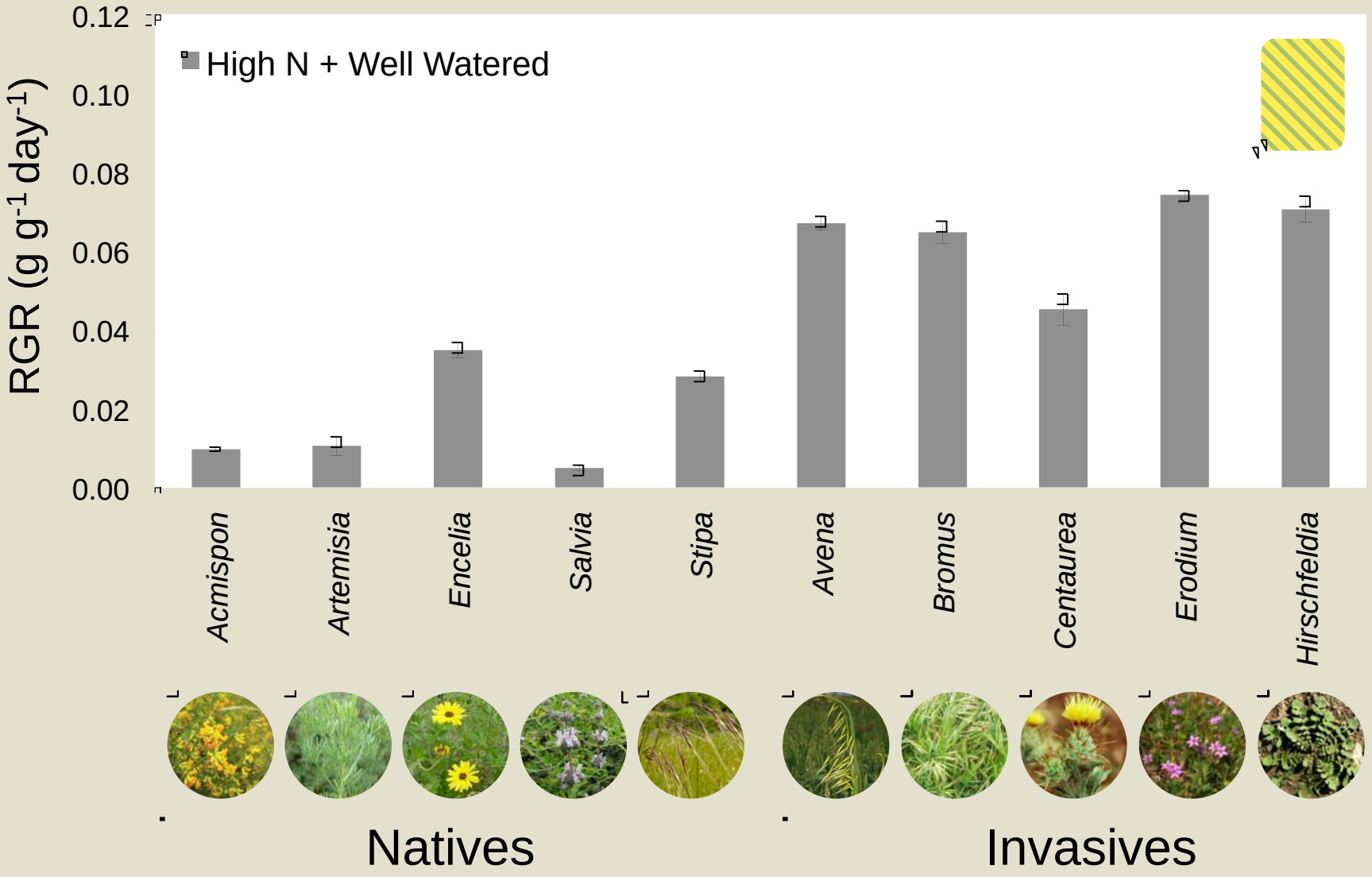



Biomass (g)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
High N + Well Watered
High N + Drought
Low N + Well Watered
Low N + Drought
Acmispon
Artemisia
Encelia
Salvia
Stipa
Avena
Bromus
Centaurea
Erodium
Hirschfeldia
Natives
Invasives

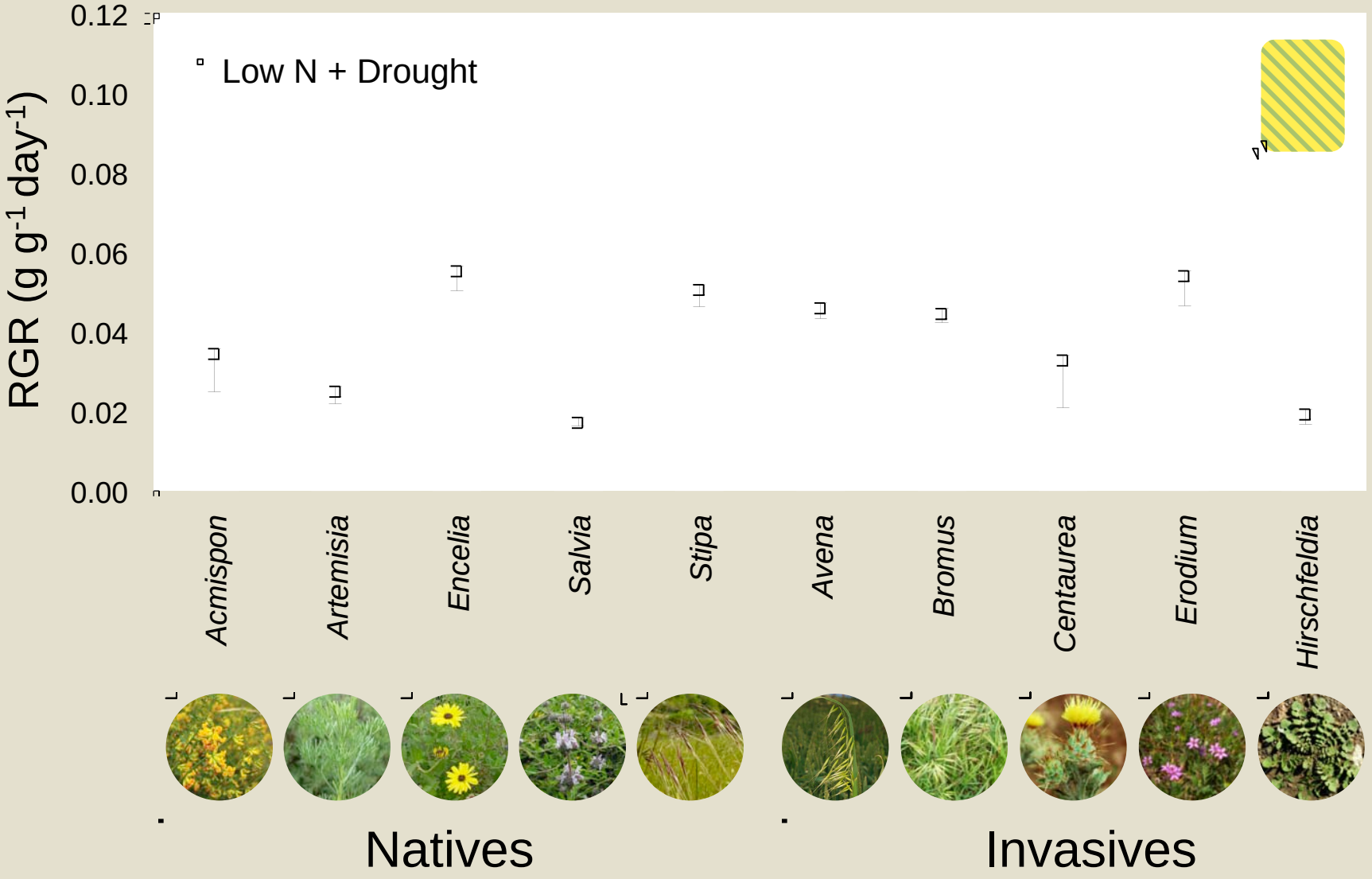
Invasive species amassed significantly greater biomass than natives



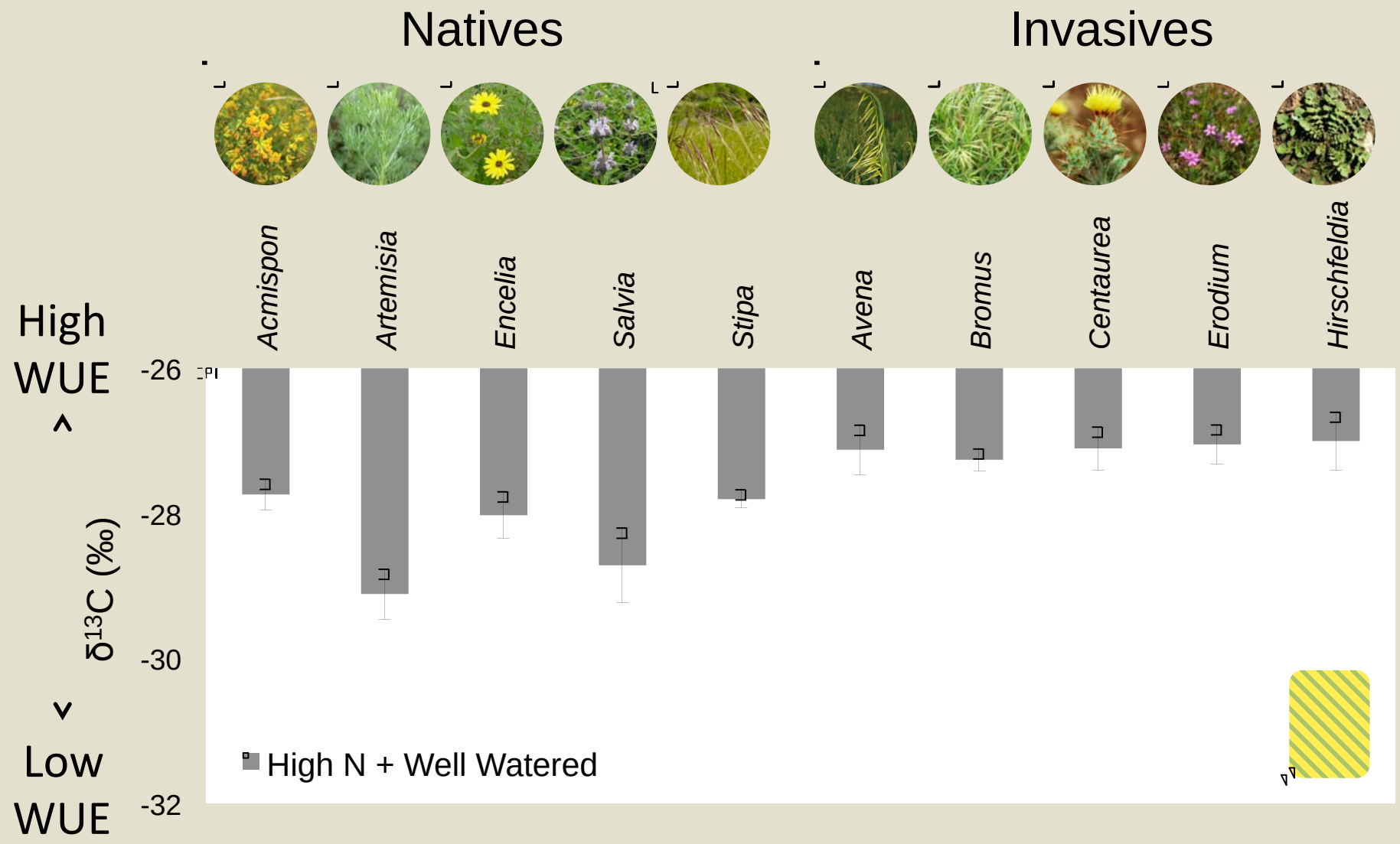
Invasive species exhibit higher RGR under high resource availability



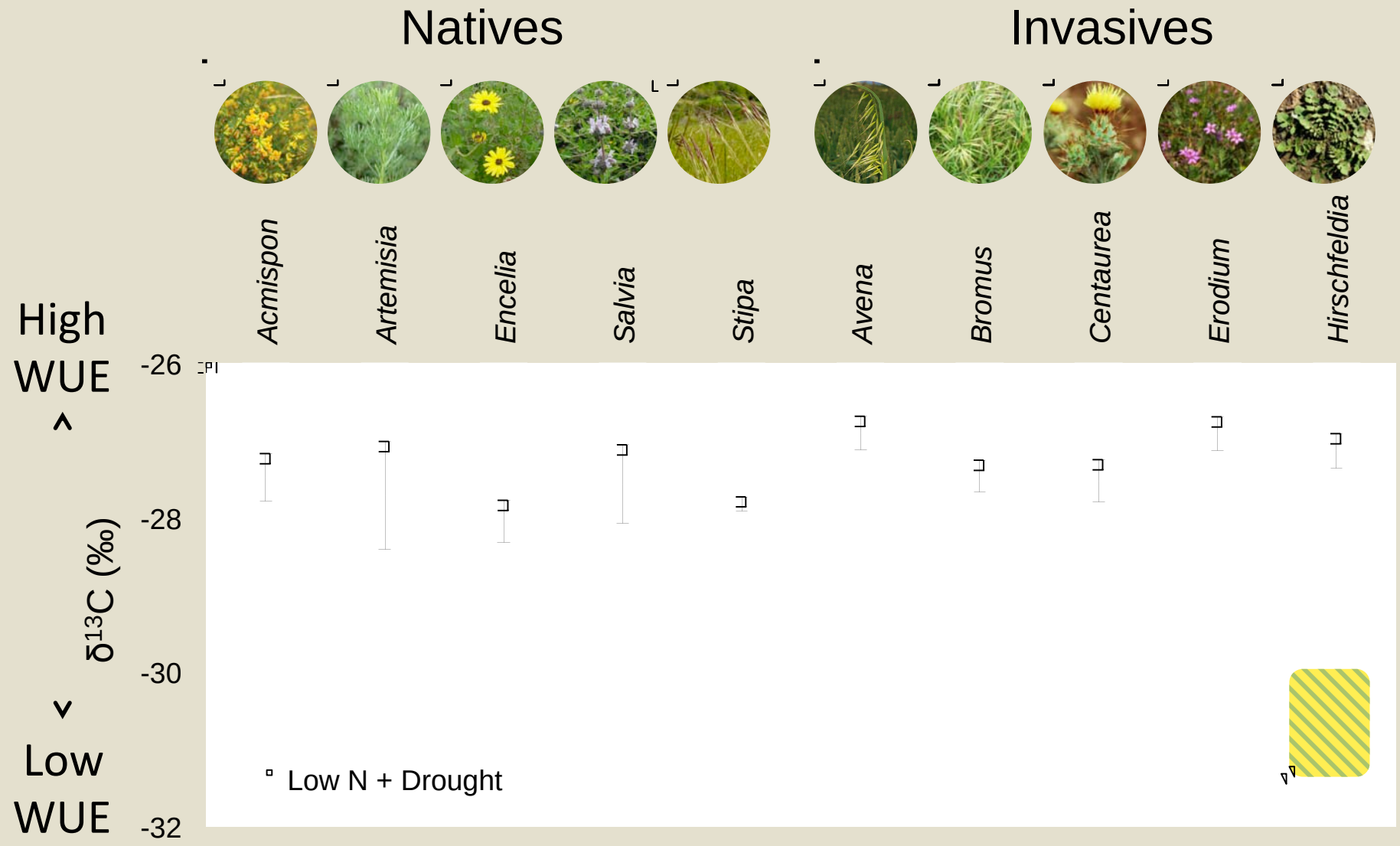
RGRs are more similar across species under low resource availability



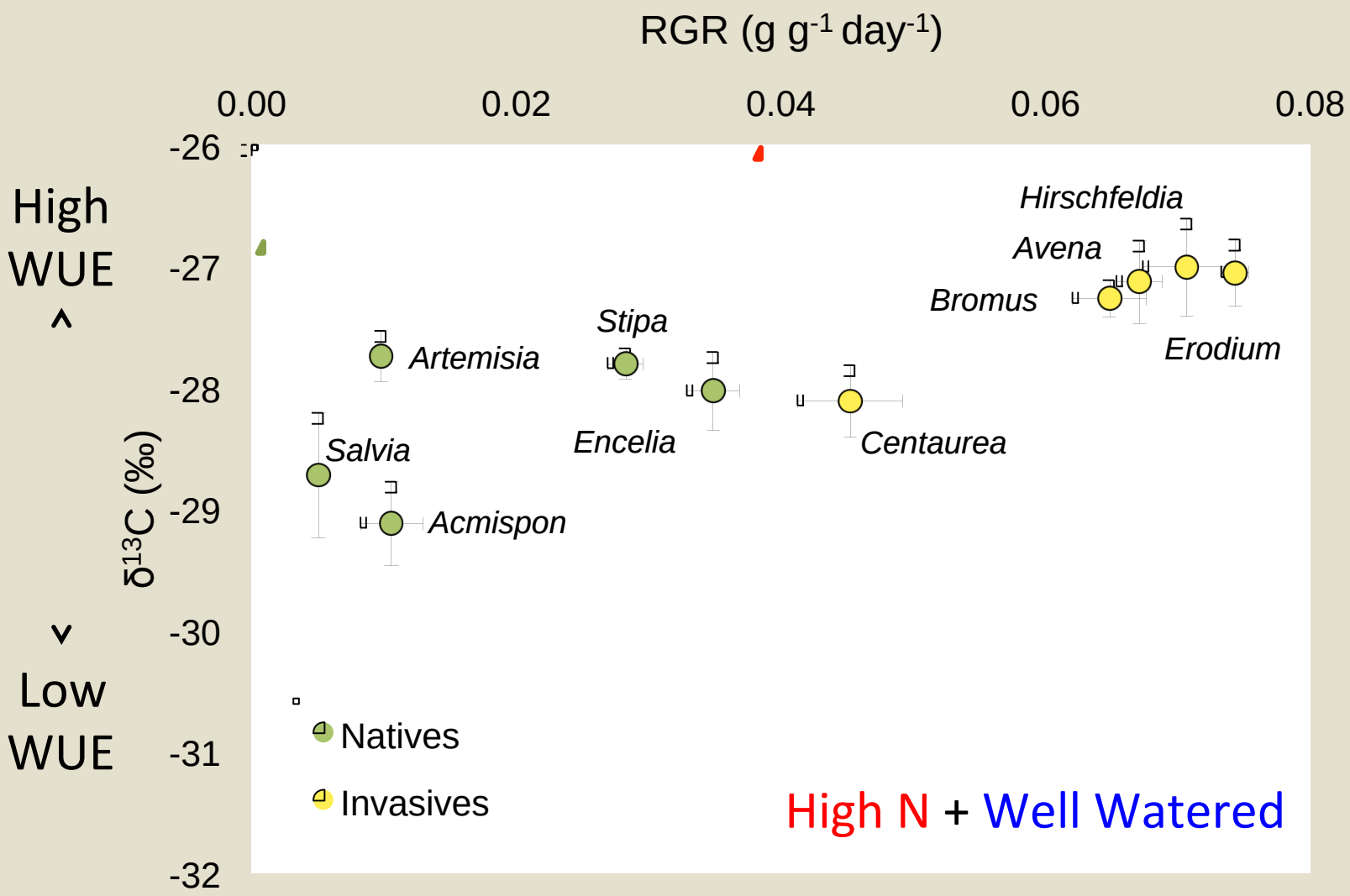
Under high resource availability, invasives have higher WUE



Under low resource availability, WUE is more similar across species



Do invasives possess forbidden trait combinations?



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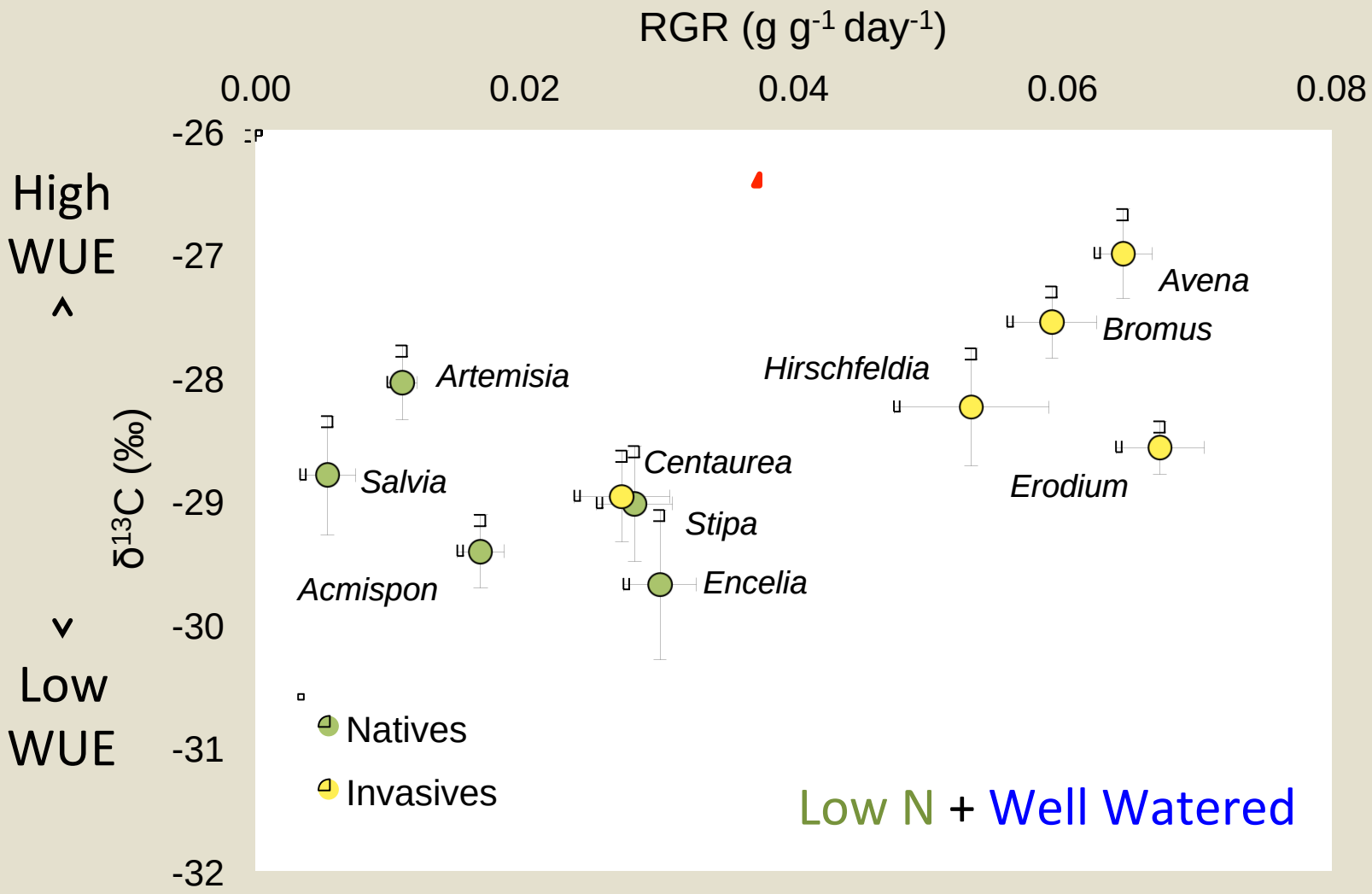

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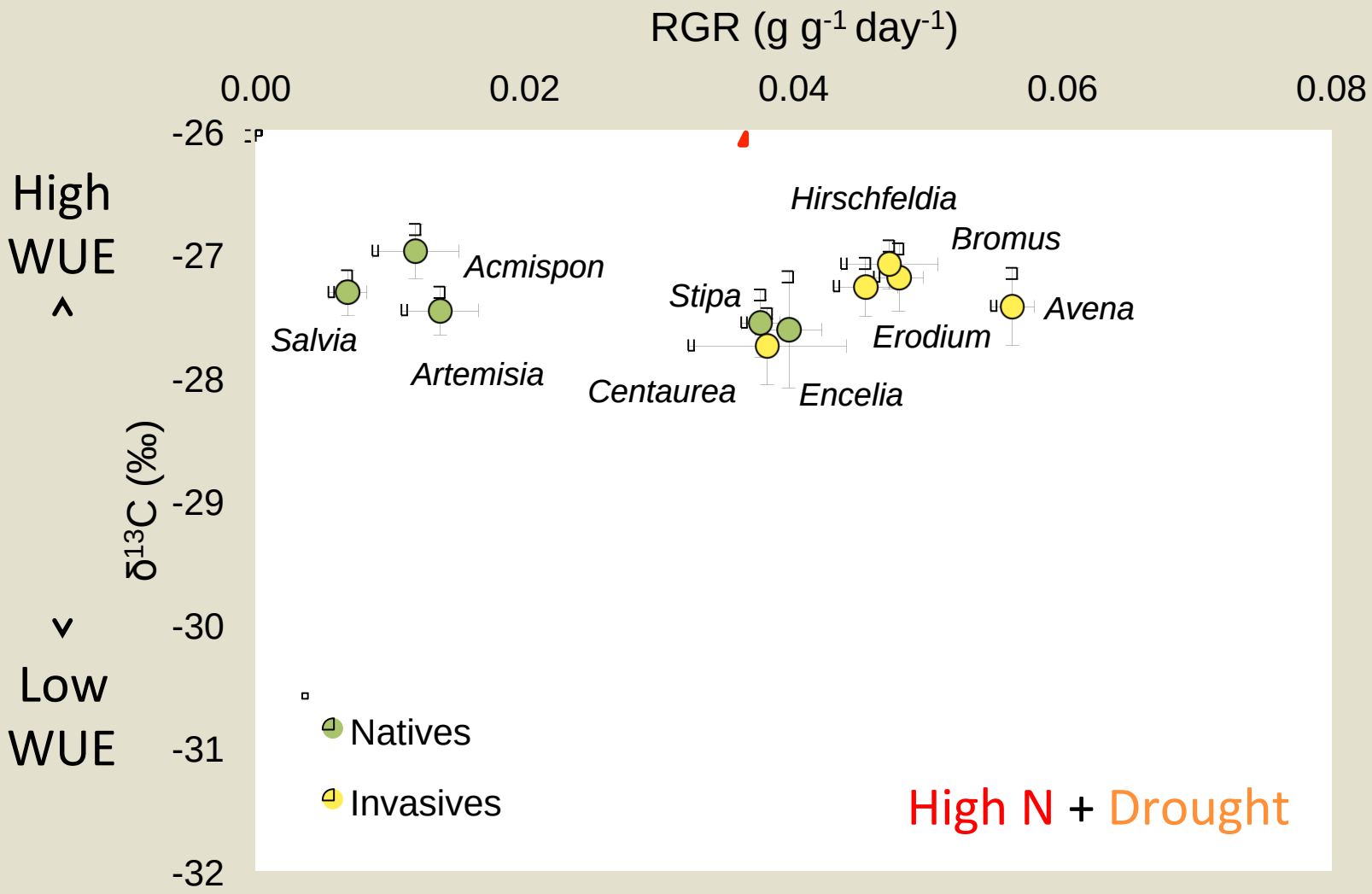

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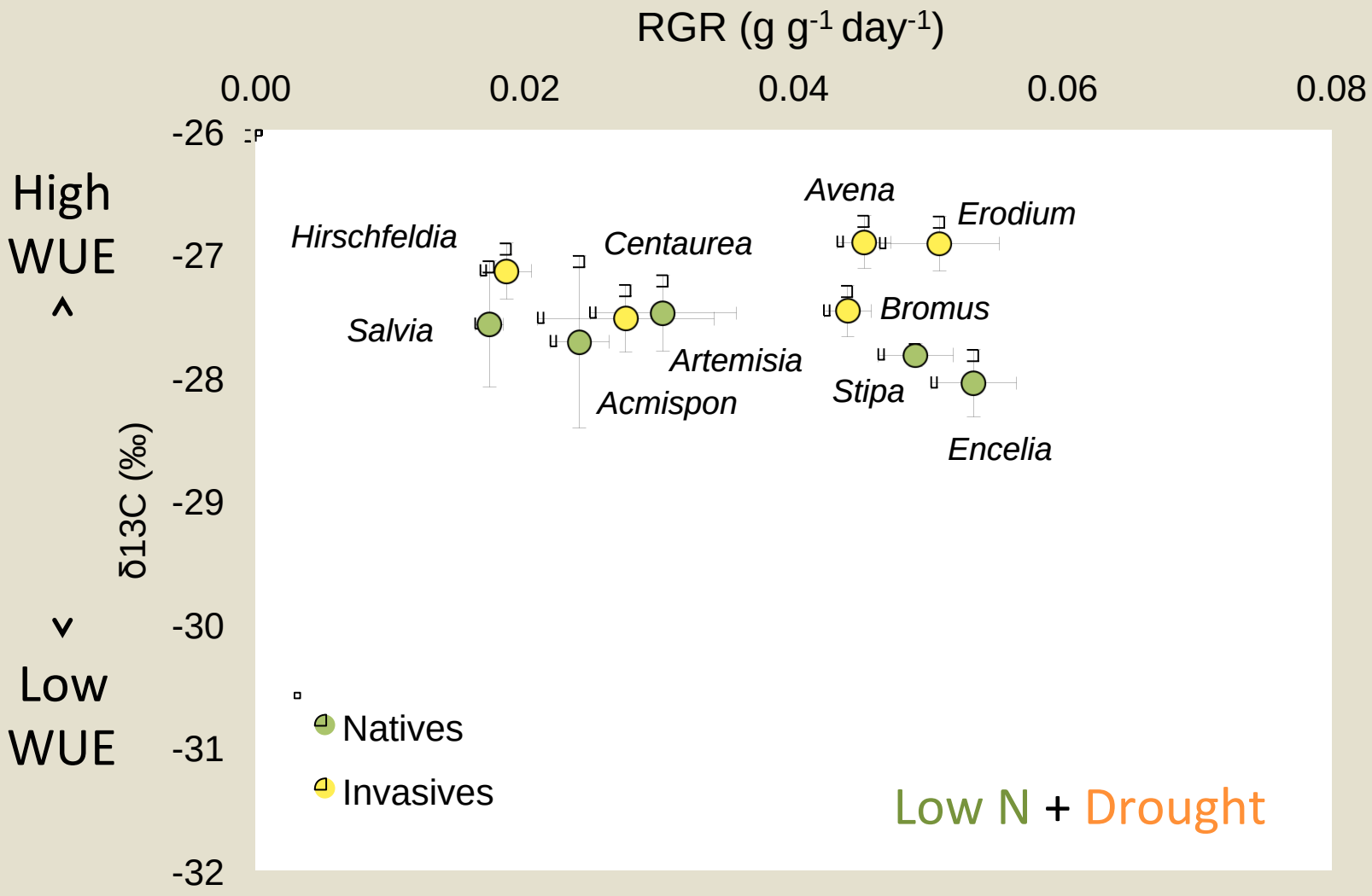

Conclusions

Plant winners, losers and cheaters under global change

- Invasive annuals accrue greater biomass than seedlings of native perennials, especially under high N (winners)
- Natives may respond positively to N, but in the presence of invasives, they are most successful under low resource conditions (but still losers)
- Water and N availability alters RGR and WUE in both native and invasive plant species
- Under high resource availability invasives exhibit “forbidden trait combinations” of high RGR and WUE (cheaters)
- High RGR and WUE in invasive species may contribute to their success under projected global change

Acknowledgements

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Air Resources Division

Santa Monica Mountains
National Recreation Area

Dr. Irina Irvine
Staff & Interns

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