Prestoration: Using species in restoration that will persist now and into the future

Brad Butterfield[1*], Stella Copeland[1,2], Seth Munson[1,2], Carla Roybal[1], Troy Wood[1,2], John Bradford[1,2]

1. Merriam-Powell Center for Environmental Research, NAU

2. USGS Southwest Biological Science Center, Flagstaff, AZ

*Biodiversity Research and INformatics (BRAIN) Lab, NAU

Restoration Objectives

- From the National Seed Strategy:
  - “**Action 2.1.2** Develop predictive models of climate change effects on target restoration species … using 20-year or mid-century climate models.“
- Which species are going to be useful for restoration under climate change?

Can we "Prestore"?

- For which species does a site represent suitable habitat now *and* in the future?
- How far into the future?
- Use restoration grass species on the CP as a case study

Research Questions

- At what time horizons is prestoration likely to be possible with the current list of target grass species for the CP?
- How many “new” species need to be added to this list in order to make up for habitat losses of current target CP grasses?
- What are the characteristics of these “new” species, and where will they need to come from?

Methods: CPNPI Priority List

- 24 species targeted in the CPNPI 5-year strategy plan (2009)

Legend for Plant Communities: **ARTR**: big sagebrush, **BB**: blackbrush, **DS**: desert shrub, **GW**: greasewood, **MB**: mountain brush, **PJ**: pinyon pine-juniper, **PP**: ponderosa pine, **SDS**: salt desert shrub, **Sands**: sandy soils, **SG**: shortgrass prairie, **TG**: tallgrass prairie

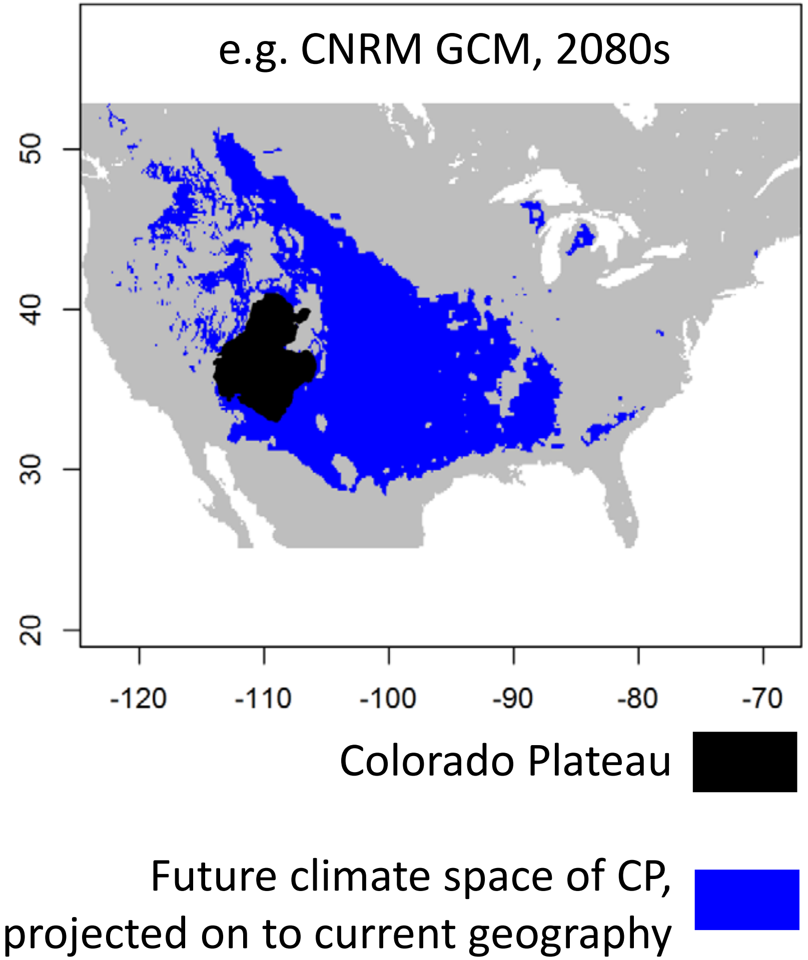
Common Name	Scientific Name	Plant Communities
Indian ricegrass	Achnatherum hymenoides	Sands, ARTR, SDS
Needle grama	Bouteloua aristidoides	BB, DS, PJ
Six weeks grama	Bouteloua barbata	DS
Side oats grama	Bouteloua curtipendula	SDS, DS, SG, ARTR, PJ, PP
Blue grama	Bouteloua gracilis	DS, SG, SDS, ARTR, PJ, PP
Mountain brome	Bromus marginatus	
Buffalograss	Buchloe dactyloides	SG
Bottlebrush, squirreltail	Elymus elymoides	DS, GW, SDS, ARTR, PJ, PP, MB
Slender wheatgrass	Elymus trachycaulus	ARTR, PJ, MB, DS
Needle and thread	Hesperostipa comata	Sands, DS, ARTR, PJ, MB
Galleta grass	Hilaria jamesii	SDS, BB, DS, PJ, GW
Junegrass	Koeleria macratha	ARTR, PJ, MB, DS
Scratchgrass	Muhlenbergia asperifolia	SDS, ARTR, PJ
False buffalograss	Munroa squarrosa	DS, SDS, ARTR, PJ, SG
Switchgrass	Panicum virgatum	SG, TG, PJ, Meadows
Western wheatgrass	Pascopyrum smithii	ARTR, DS, PJ, MB
Muttongrass	Poa fendleriana	ARTR, DS, PJ, MB
Sandberg's bluegrass	Poa secunda secunda	DS, GW, ARTR, PJ, MB, SDS
Bluebunch wheatgrass	Pseudoroegneria spicata	ARTR, DS, PJ, MB, PP
Little bluestem	Schizachyrium scoparium	SG, DS, PJ, PP, TG
Alkali sacaton	Sporobolus airoides	SDS, GW
Spike dropseed	Sporobolus contractus	DS, PJ
Sand dropseed	Sporobolus cryptandrus	PJ, Sands, ARTR
Six week fescue	Vulpia octoflora	SDS, BB, PJ, ARTR, GW, SG

Methods: Climate Scenarios

- 10 general circulation models (GCMs)
  - Statistically downscaled to 15x15km resolution
- 2 emissions scenarios (RCP4.5 and RCP8.5)
  - Only presenting results for RCP8.5 (sadly, our current global trajectory)
    - 4.5 results are similar, but with a plateau in emissions and associated losses of suitable habitat after mid-century
- 9 decades
  - 2010s-2090s

Methods: Identifying Potential New Species

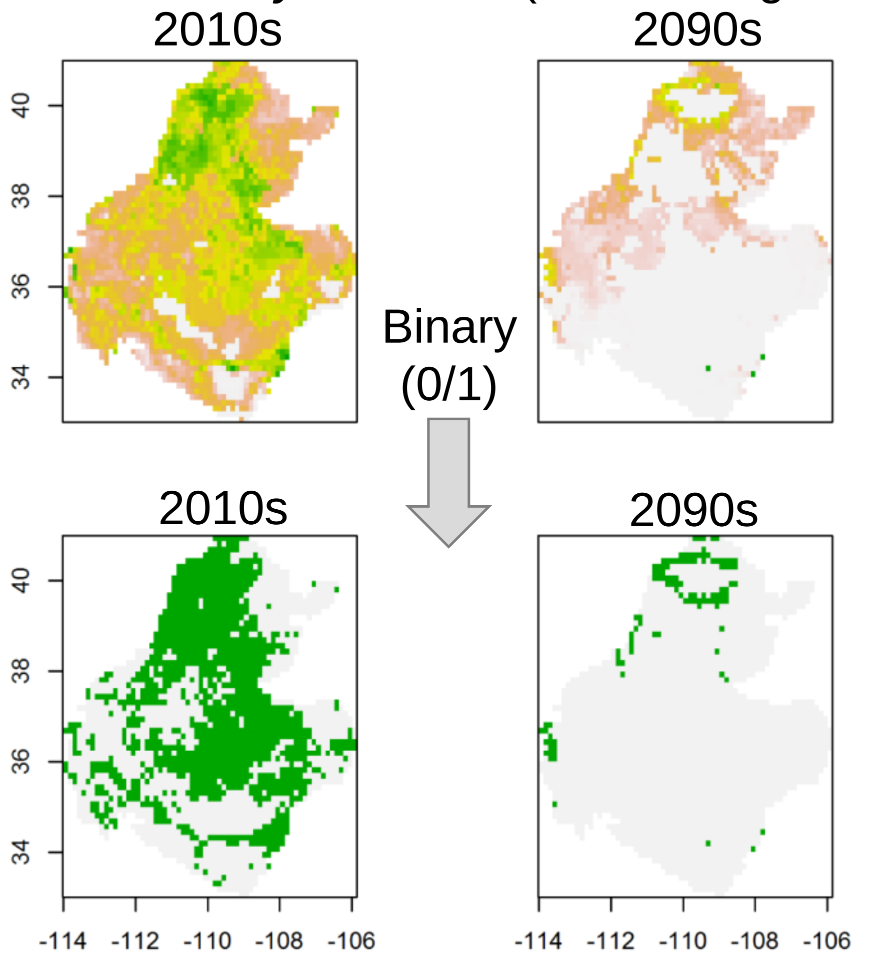
- Identify predicted climate conditions of CP in the future using multiple scenarios
- Project those conditions on to *current* geographic space
- Identify species in that geographic space using the Global Biodiversity Information Facility (GBIF)
- Take top 48 species in terms of number of occurrences found across all climate scenarios



Methods: Climate Niche Modeling

- 7 Climate variables
  - MAT, MAP
  - Seasonality
  - Combos of precip and temp
- MaxEnt ensembles from multiple runs
- Apply species-specific binary thresholds to create maps of predicted suitable/unsuitable habitat at present and in future

Achnatherum hymenoides (Indian ricegrass)

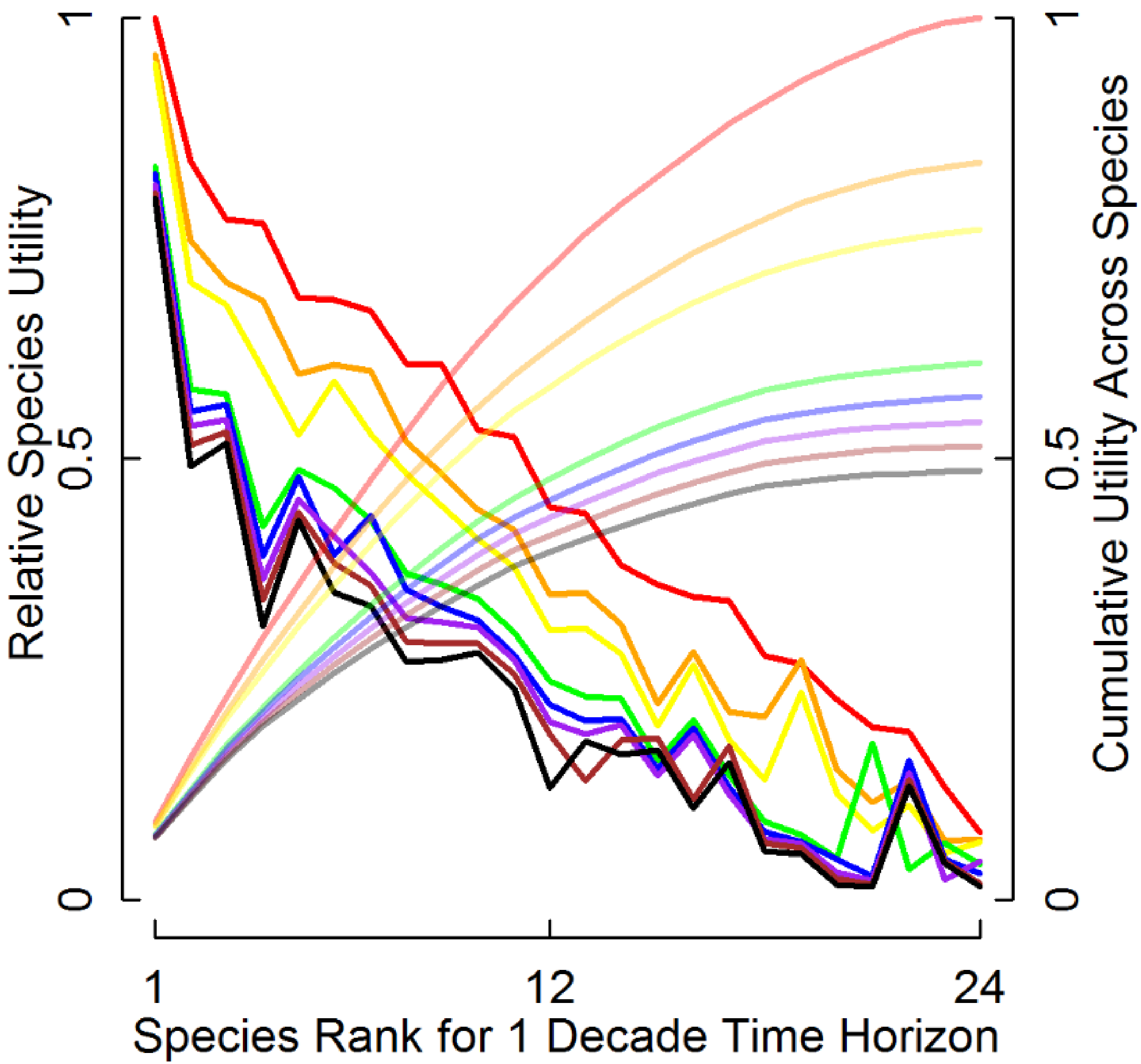


Methods: Prestoration Potential

- In each pixel, identify:
  - For which CP target species does that space represent suitable habitat now and 1, 2 … 8 decades into future
  - Loss of suitable species with increasing time horizons
  - Climatic correlates of species utility
- Given loss of suitable species with increasing time horizons, determine:
  - Which new species could be substituted for current target CP species
  - How many new species from the pool of 48 are required regionally to make up for losses of target CP species suitability

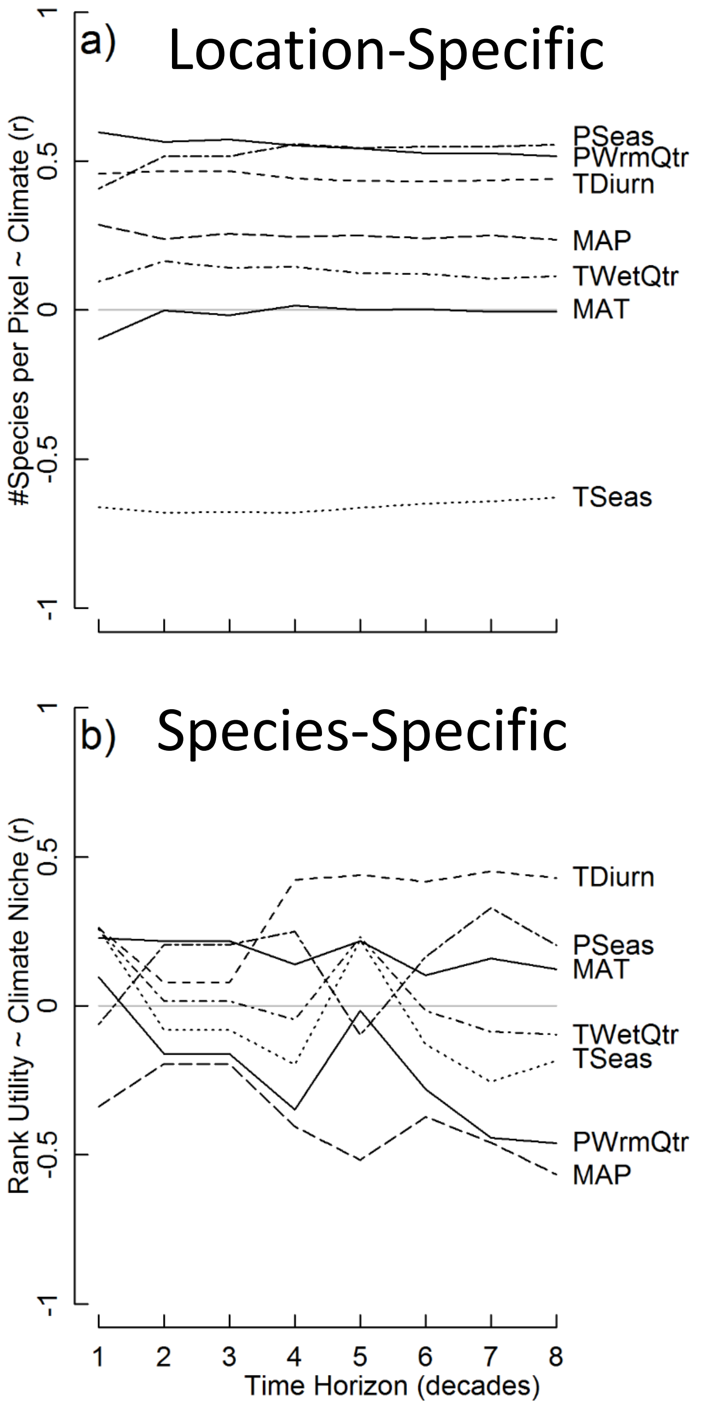
Current Species Utility

- Species relative rankings of utility – in terms of prestorable area – remain relatively constant with increasing time horizons
- Loss of ~40% of prestorable area by mid-century (~50% by end of century)



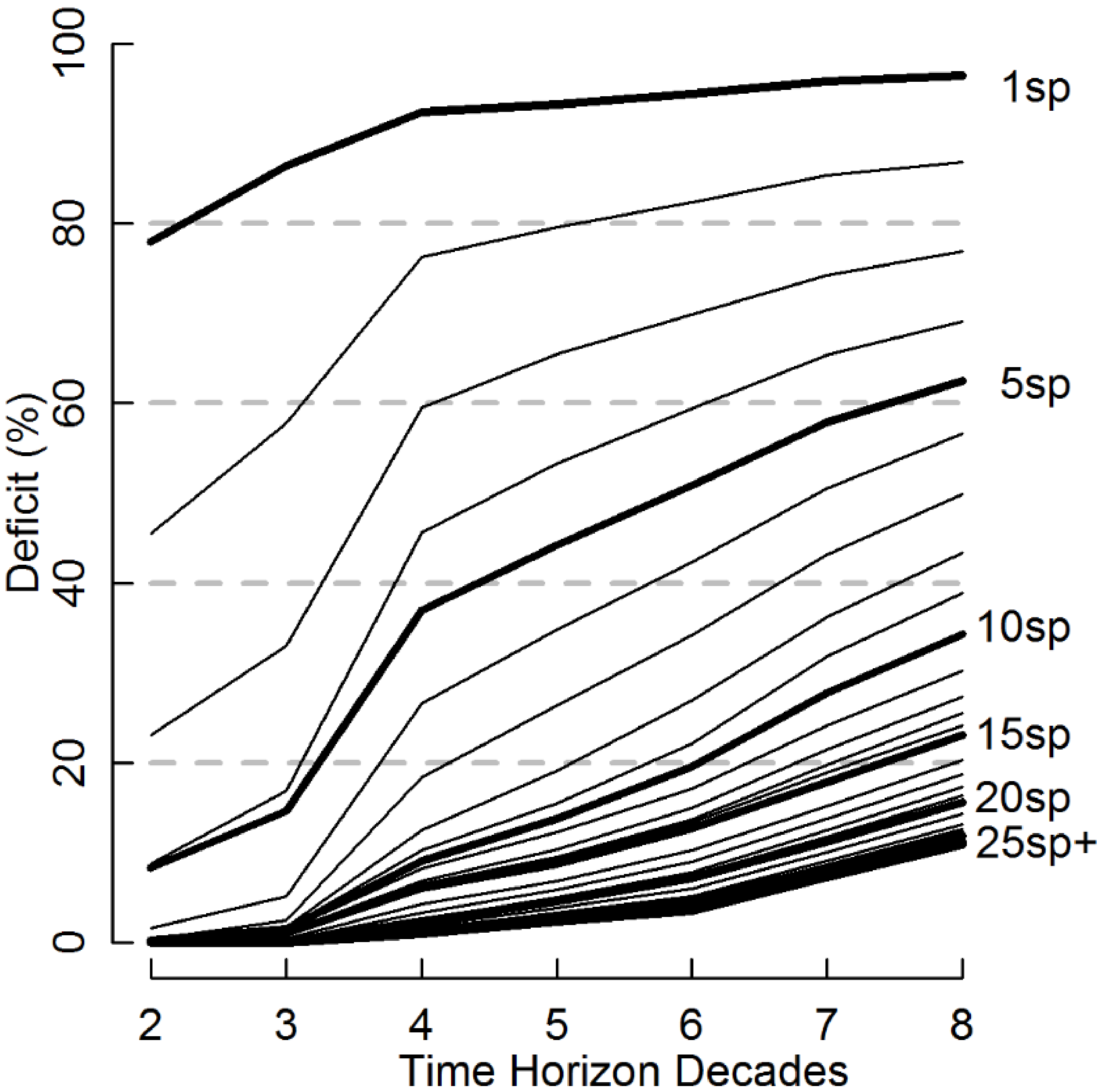
Utility as a Function of Climate Niche

- Location-specific: Prestoration potential greatest in habitats with a wet warm season, high diurnal temperature fluctuations but low seasonal temperature fluctuations (monsoonal habitats with high VPD)
- Species-specific: Prestoration potential greatest for species from dry environments with high diurnal temperature fluctuations (arid-adapted species)



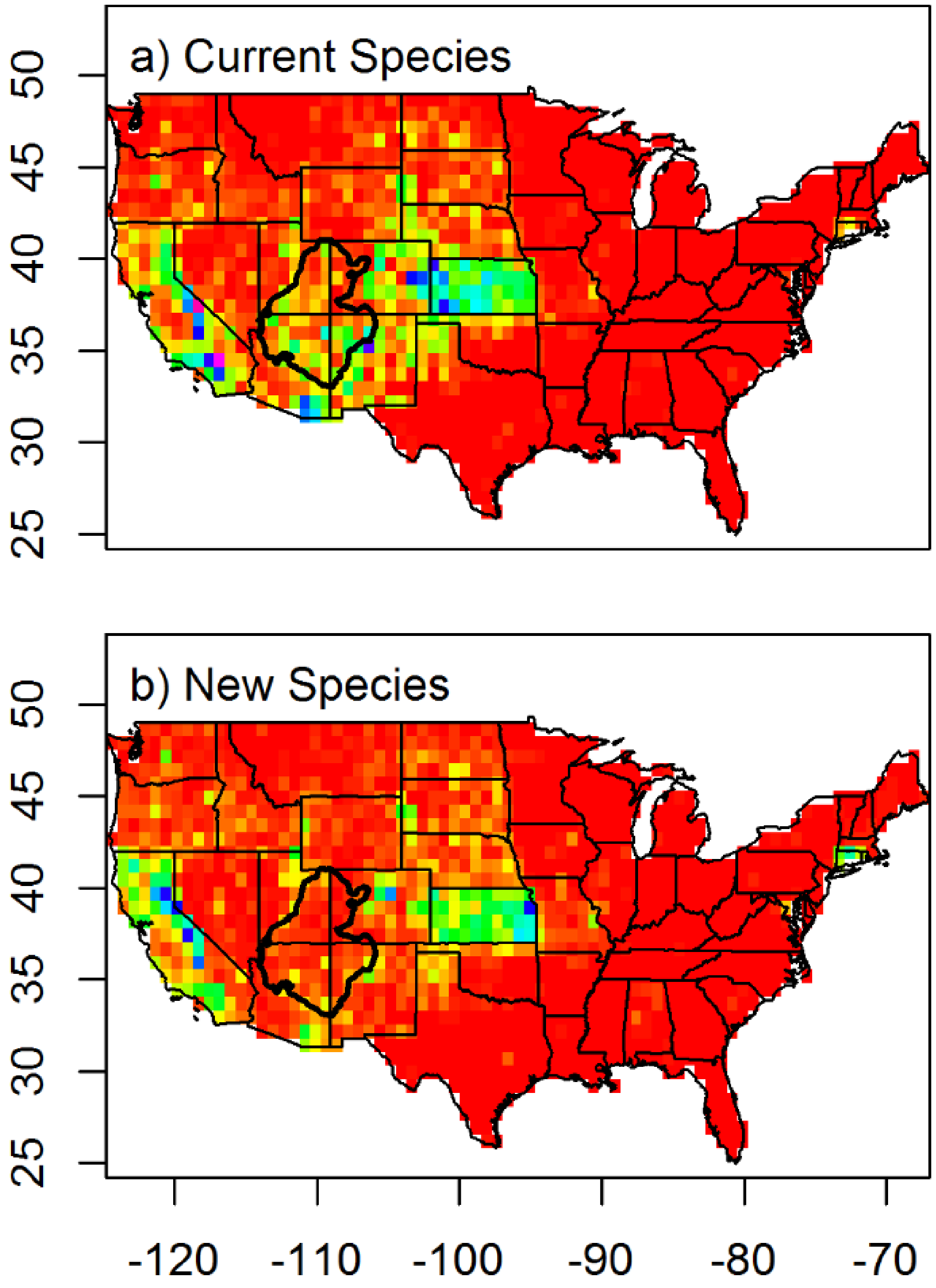
Utility of New Species

- 6 “new” species could make up for nearly all of the lost suitable habitat for the current target species list at a 2-3 decade time horizon
- Still only ~ dozen could make up for most losses by mid-century



Geographic Distribution

- Most already occur on the CP, just not super common
- Tend to come from somewhat hotter environments (correlation with climate niche *r* = 0.40, *P* = 0.004)



Conclusions

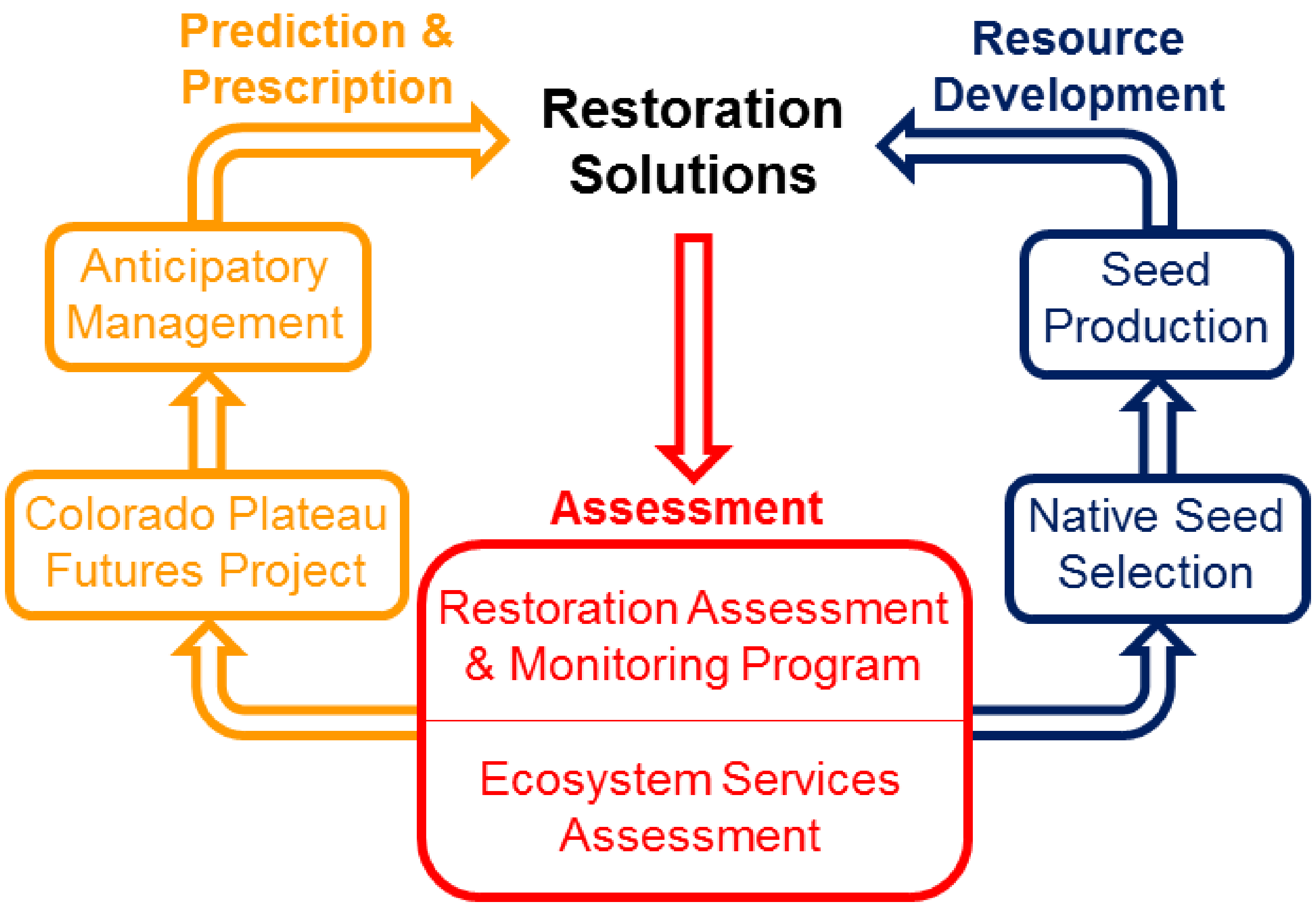
- Current list of target species does a decent job of predicted suitability for the future, considering that climate change wasn't an explicit driving factor in their selection
- Utility is predictable based on climate of a site and climate niche of a species, though certainty in these estimates is variable
- "New" species to add would only increase the priority list by ~50%
- Communication among managers of adjacent ecoregions could help supply the necessary diversity of seed resources to deal with climate change

Caveats

- This does not account for:
  - local adaptation/intraspecific variation
  - target ecosystem services associated with different species
  - soils, disturbance, etc.
- These limitations speak to broader discussions we've been having over the last two days

Restoration Solutions in a Changing World

- Collaborations between Merriam-Powell Center for Environmental Research (NAU) and USGS Southwest Biological Science Center
- Dr. John Bradford
- Dr. Seth Munson
- Dr. Troy Wood

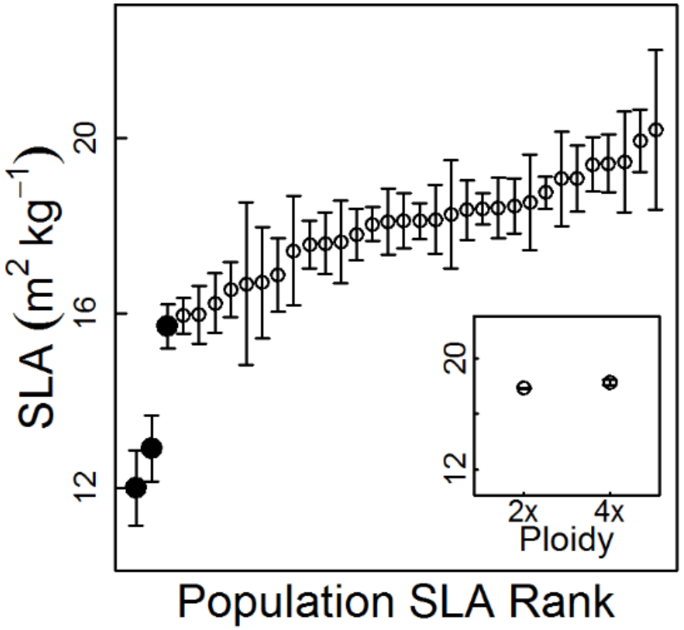


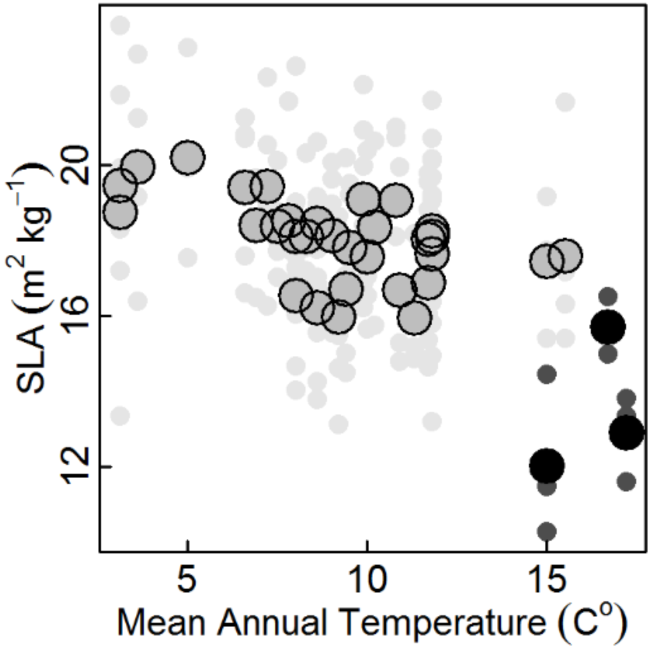
Functional Traits: Translating Environmental Variation into Ecosystem Services

- Functional diversity: A compromise between "local is best" and "one size fits all"
- Focus on functional traits: organismal characteristics that predict responses to, and effects on, the environment (Lavorel and Garnier 2002)

Functional Approach

- In *Bouteloua gracilis*, specific leaf area (SLA) is:
  - Significantly (broad-sense) heritable (i.e. genetically constrained)
  - Correlated with population source annual temperature
- Current cultivars are functionally pretty different from natural populations
- Could select seed sources based on their functional trait values and match them to climate and ecosystem service objectives
- Focus on functional diversity within species





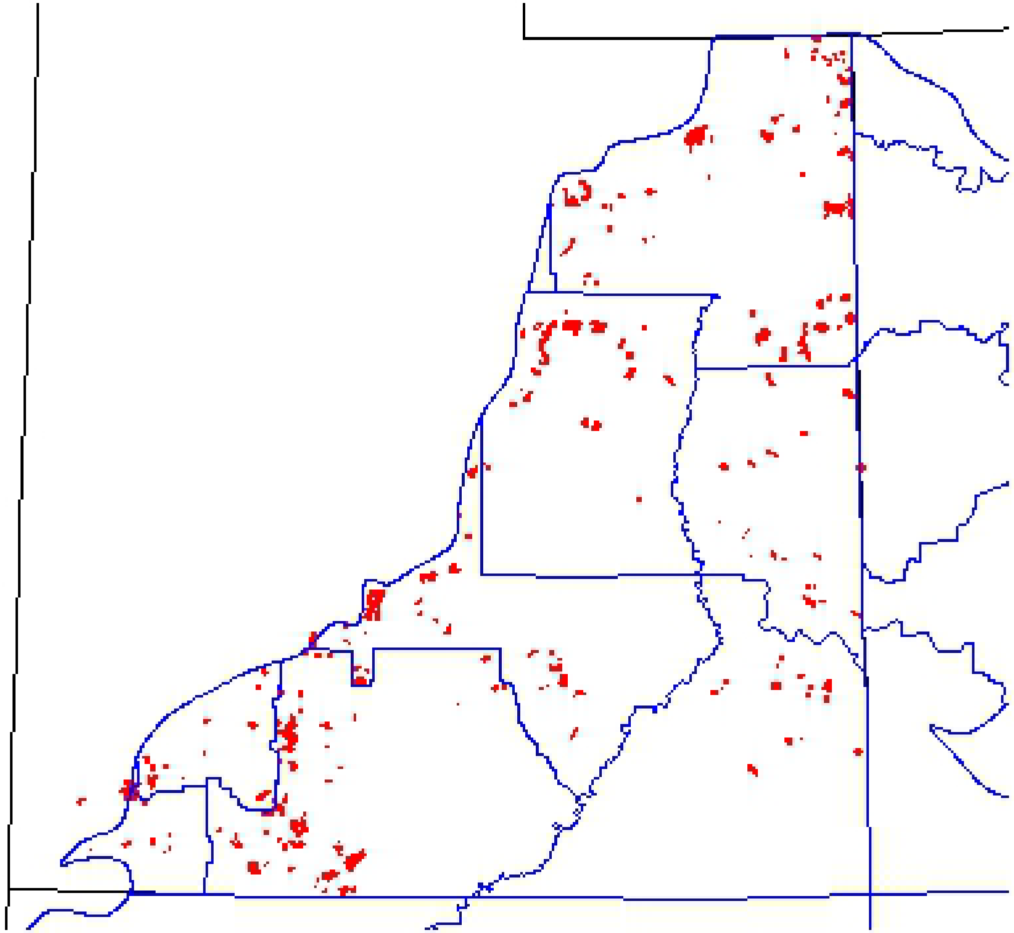
Butterfield & Wood 2015 *Plant Ecology*

Functional Approach

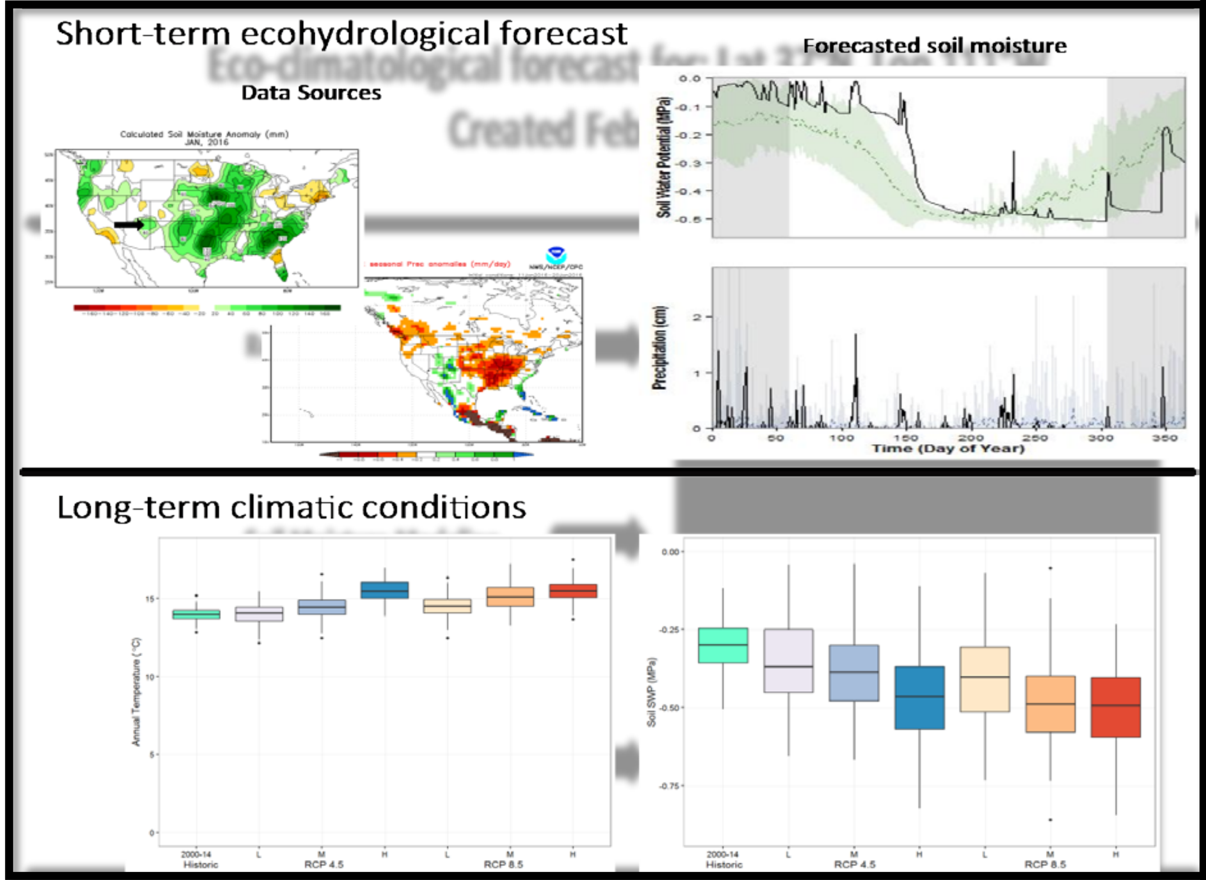
- Need to know which functional traits are heritable, and which are more plastic
- Do heritable functional traits exhibit consistent environmental correlations across species?
- Carla Roybal is answering this question through:
  - Meta-analysis of grass common garden studies globally
  - Greenhouse experiment focused on CP and GB species, particularly root traits

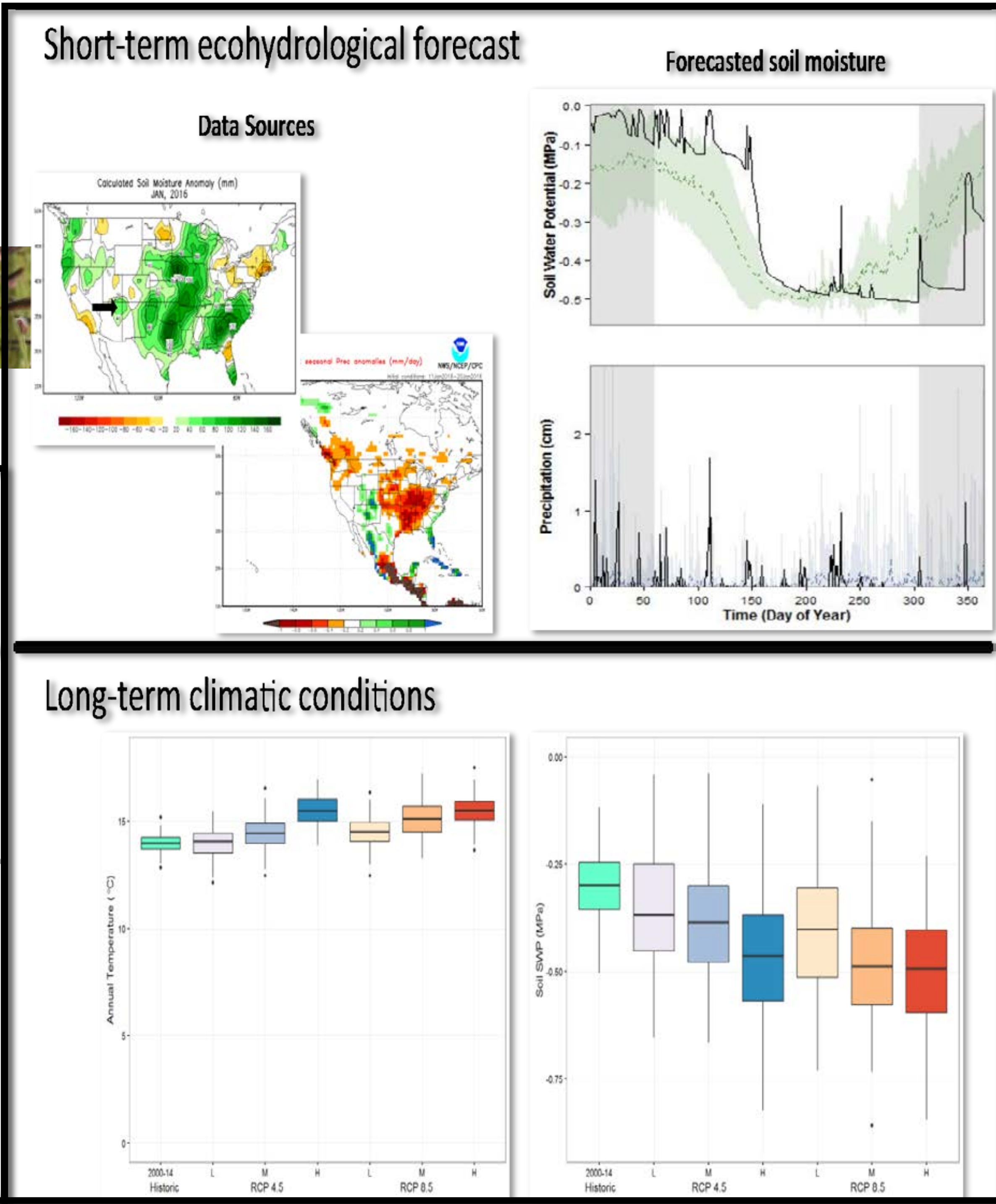
Ecosystem Service Assessments to Quantify Restoration Success

- Ecosystem service assessments of WRI projects
  - Soil stabilization/aggregate formation
  - Forage quality/quantity
  - Wildlife habitat
  - Pollinator habitat
- Related to environment, disturbance, treatments and seed mixes



Anticipatory Management






NORTHERN
ARIZONA
UNIVERSITY
USGS
science for a changing world
Thanks!