Modeling Invasive Species Considering Climate to Inform Management Activities

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USGS Fort Collins Science Center

With help from many others!

U.S. Department of the Interior
U.S. Geological Survey


Figure





Photo: The Nature Co


Where is it now?

Lots of location data!

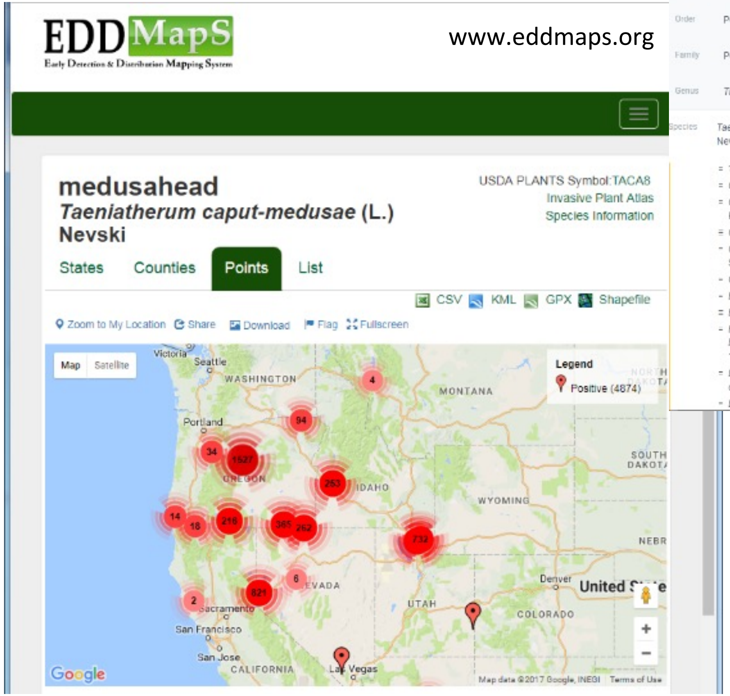
On-line and government repositories.

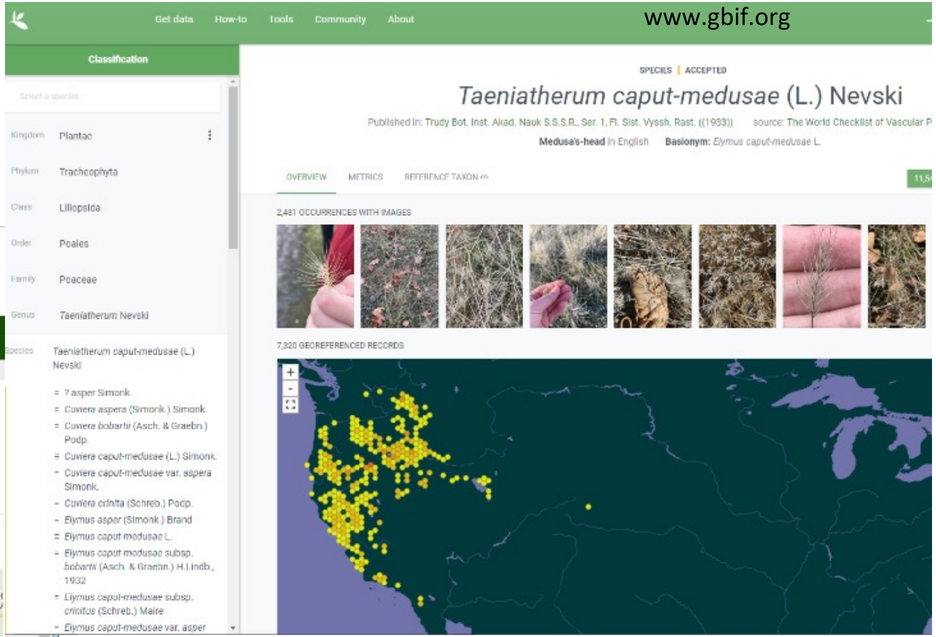
Calflora

NATIONAL SYSTEM OF PUBLIC LANDS
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

NATIONAL PARK SERVICE

USGS





EDDMapS find • map • track

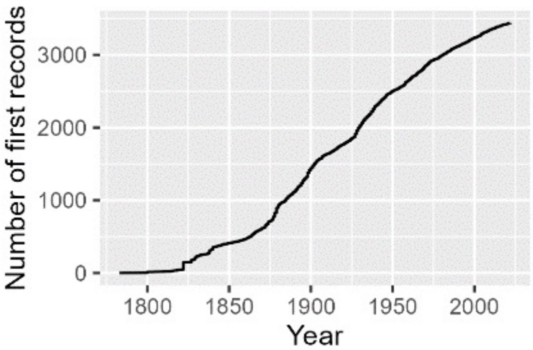
GBIF

iMapInvasives

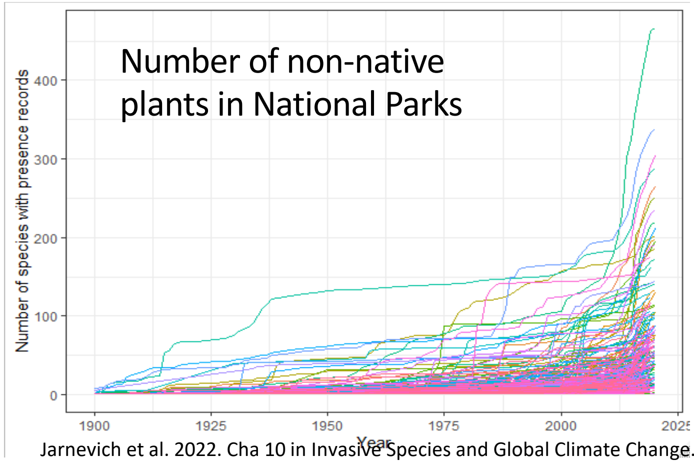
Weed mapping, monitoring plots, museum data, citizen scientists, etc.

Invasive species are arriving and spreading

- Distributions often are not stable.
- US-RIIS includes ~4000 introduced (non-native), established (reproducing) vascular plant species (Simpson et al. 2022) .
- People don't look for invasive plants everywhere.
- Where should we look for what species?



Williams et al. 2024. USGS data release.



Jarnevich et al. 2022. Cha 10 in Invasive Species and Global Climate Change. CABI.

USGS

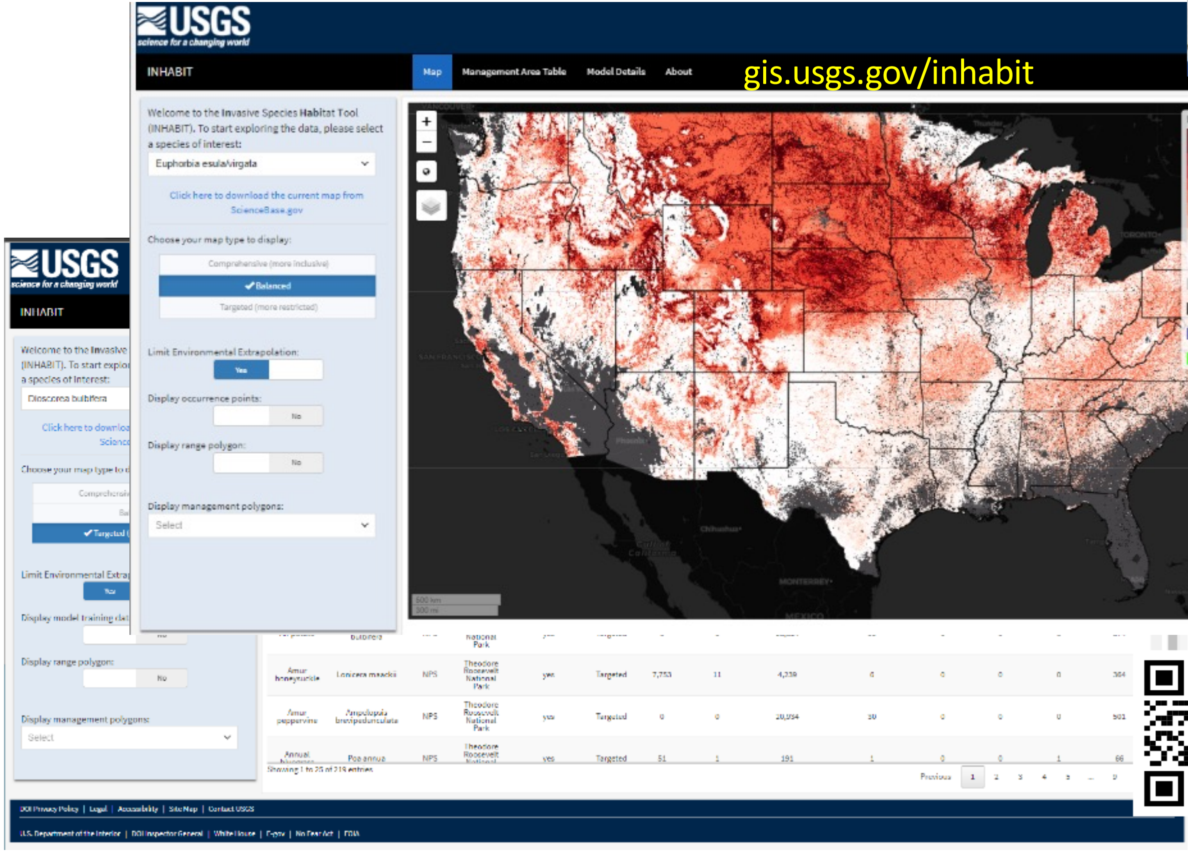
How do we forecast risk?

USGS

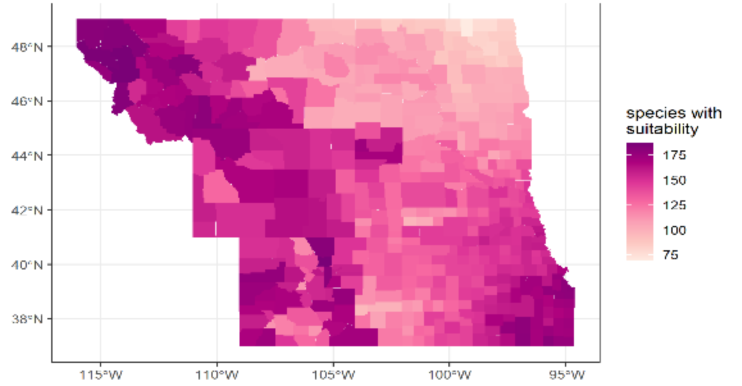
Invasive Species Habitat Tool (INHABIT)

Where might species be found?

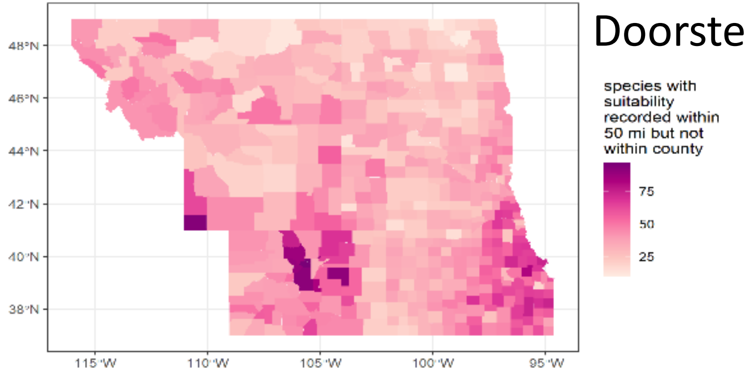
- Habitat suitability models for 221(259 soon) manager selected terrestrial plants for CONUS.
- Co-produced with management agencies to serve map products and tabular summaries across species for management units.
- Ranked risk summaries across species for a unit, integrate suitability predictions with known occurrences.

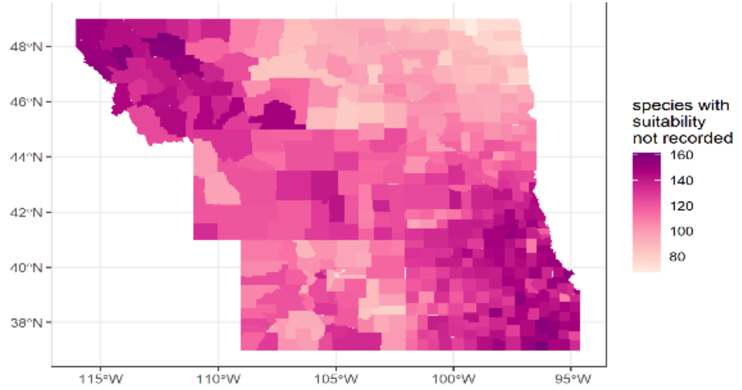


Watch Lists

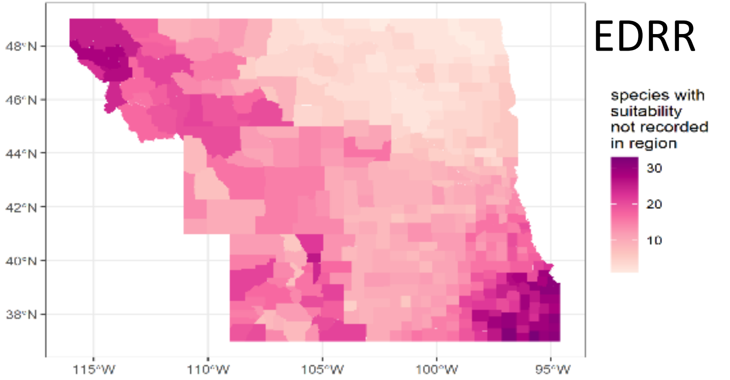


Doorstep





EDRR



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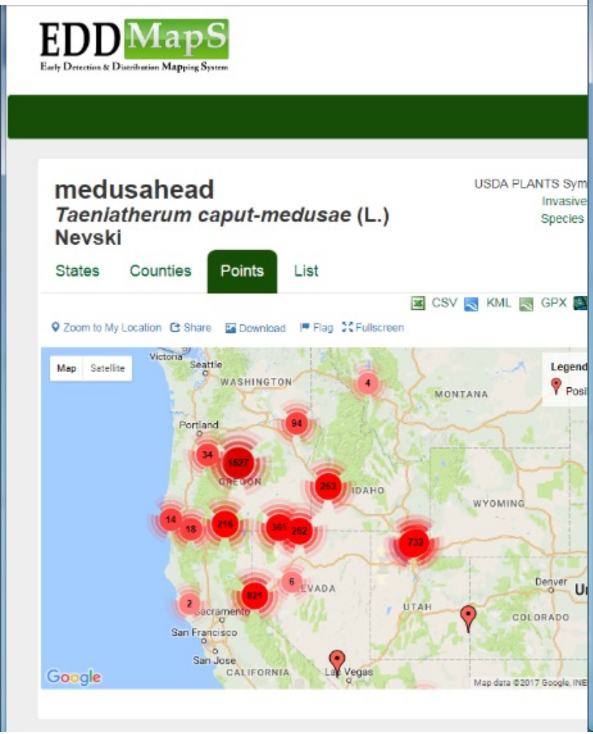
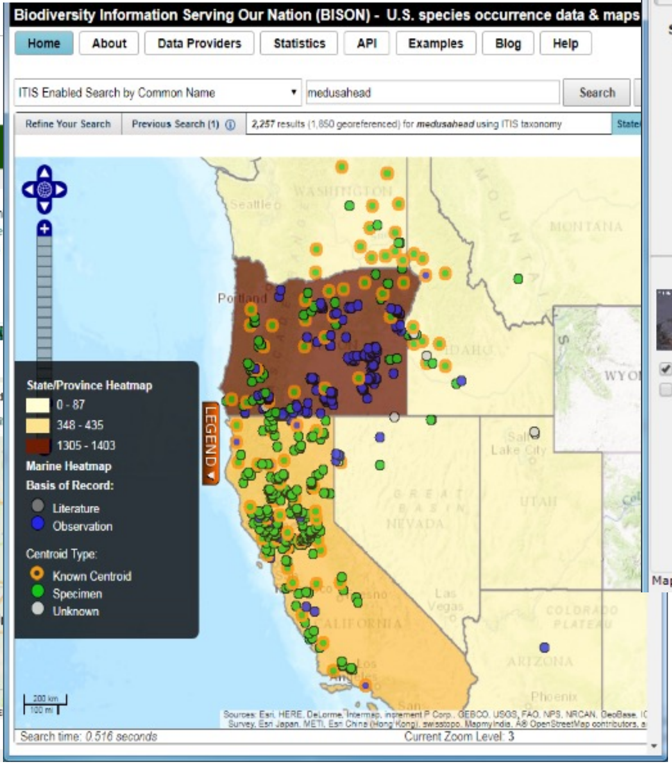
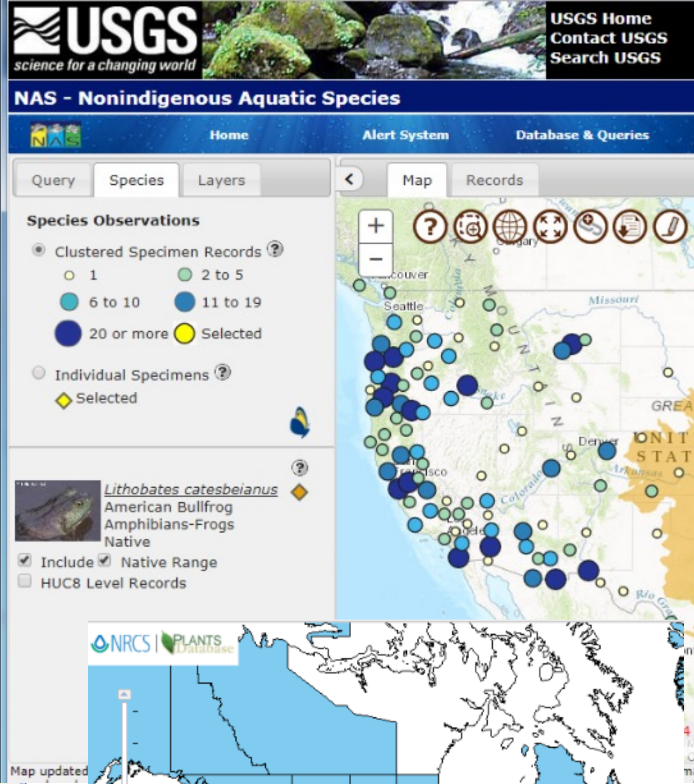
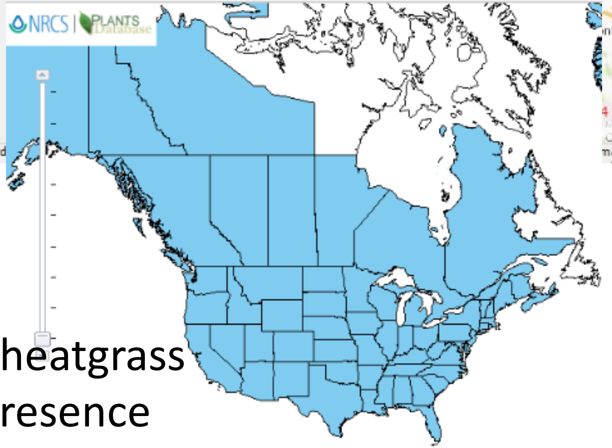
Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

Emphasis on non-native presence









Cheatgrass presence

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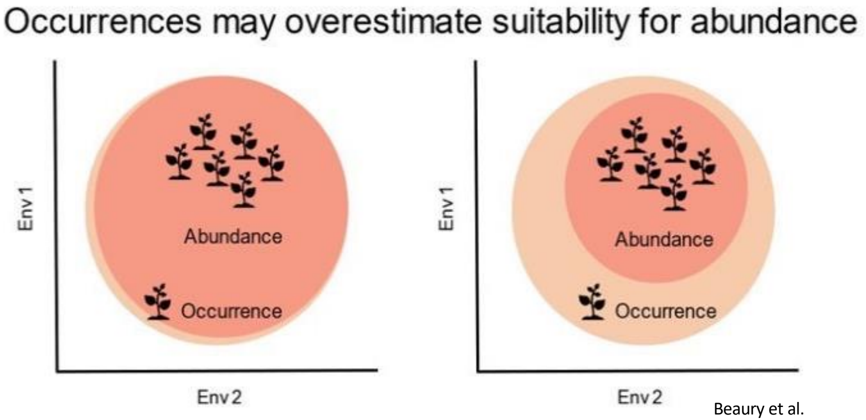
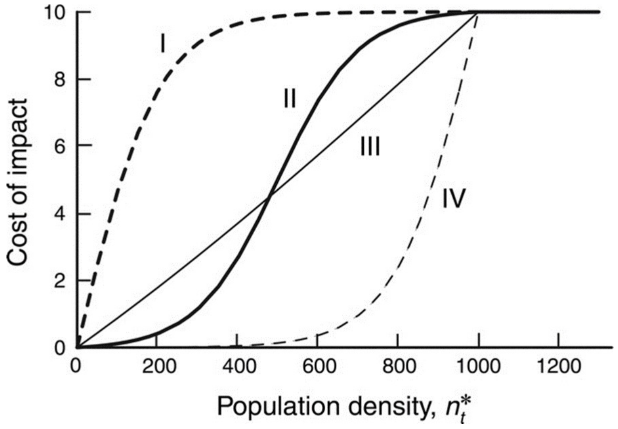
But we care about where things are abundant.



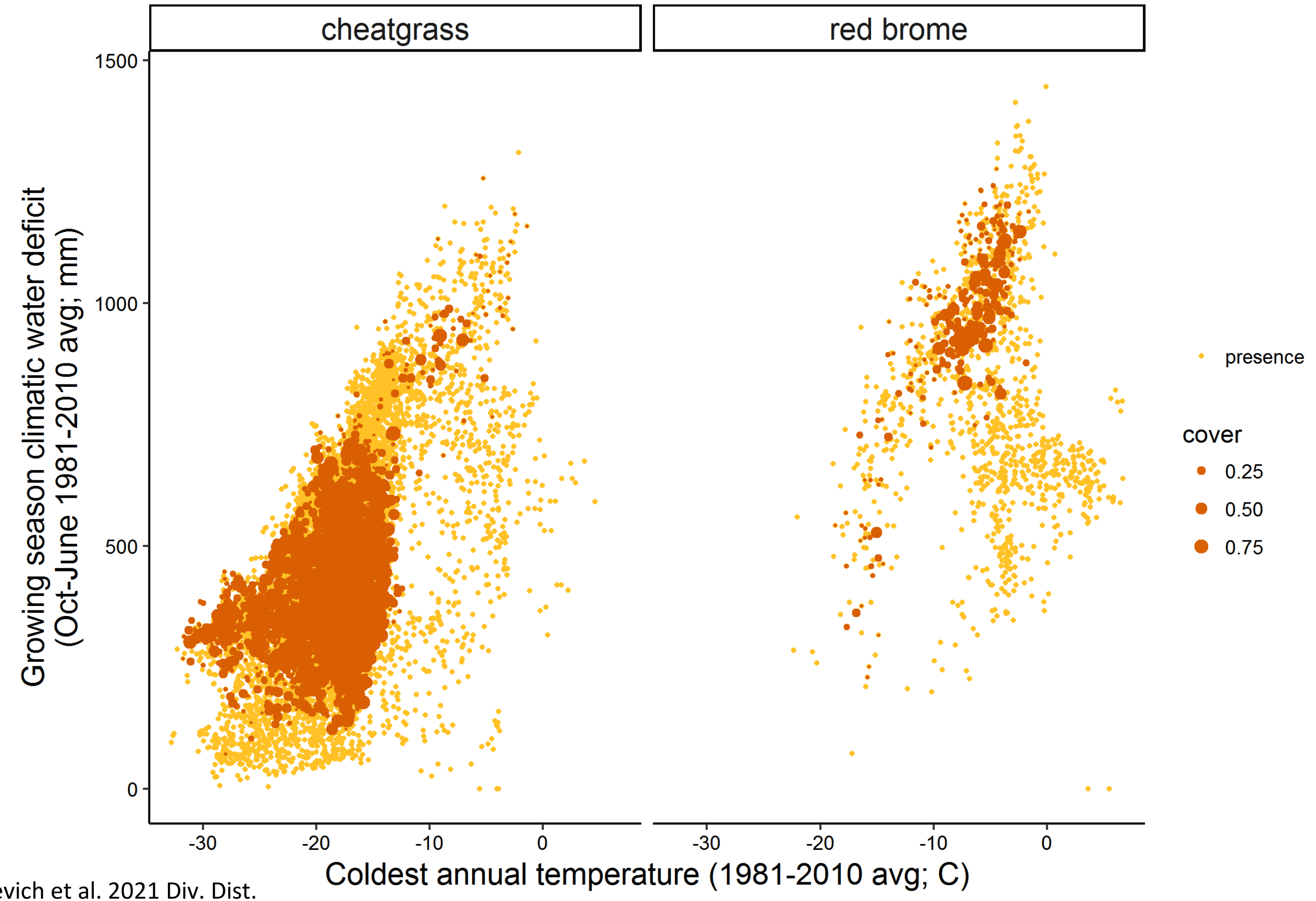
Beaury et al. 2023, Bio Invasions

Photos by C. Jarnevich



Yokomizo et al. 2009, Ecol App 19: 376-386

Abundance in climate space



Jarnevich et al. 2021 Div. Dist.

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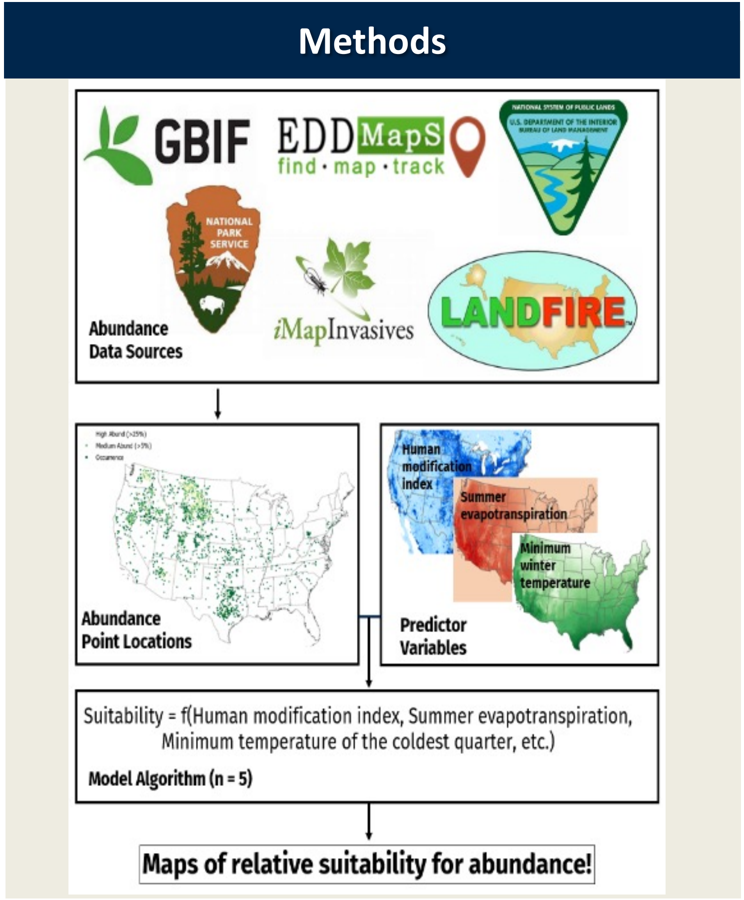
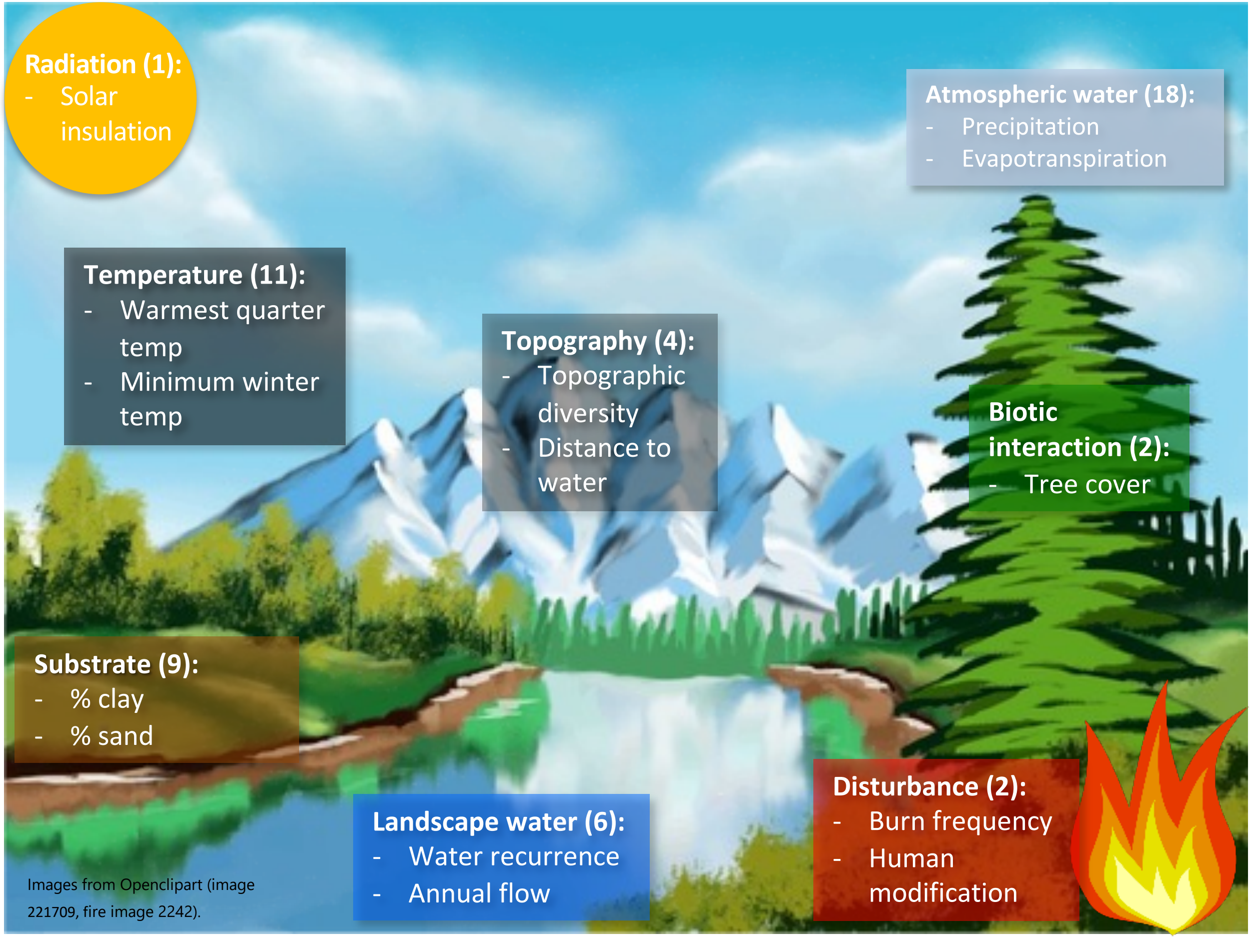
INHABIT

- Aggregated data
- Occurrence = wherever the plant is found
- Medium abundance = >5% cover
  - 217 species
- High abundance = >25% cover
  - 189 species

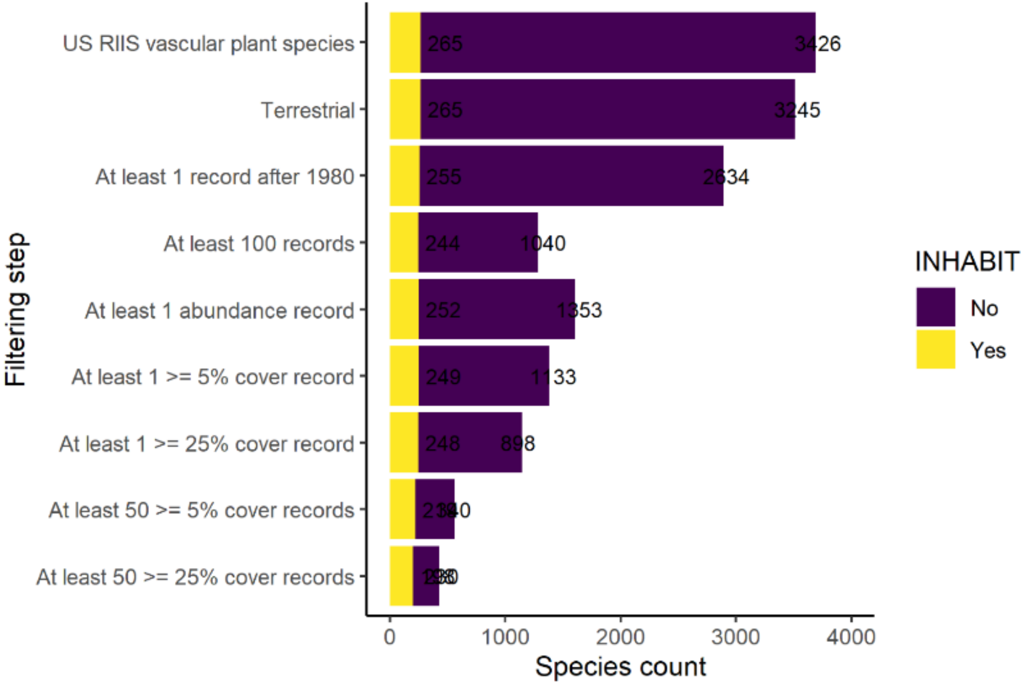


Environmental Data (53 Predictors)



Images from Openclipart (image 221709, fire image 2242).

How many species do we model?

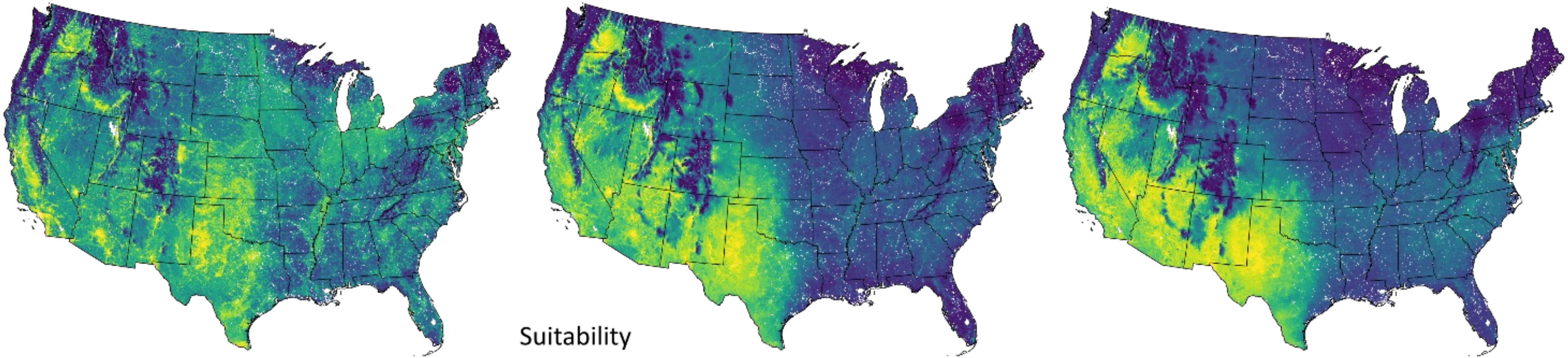


Visualization of abundance maps

Continuous output for occurrence, medium abundance, and high abundance maps for *Tribulus terrestris* (puncture vine)

Relative suitability for:

Occurrence | >5% cover | >25% cover



Suitability

High

Low

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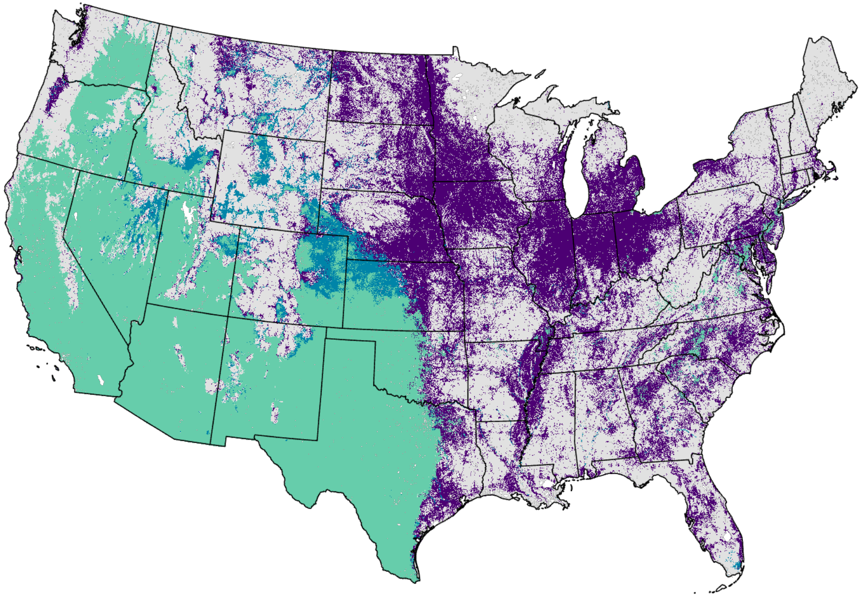
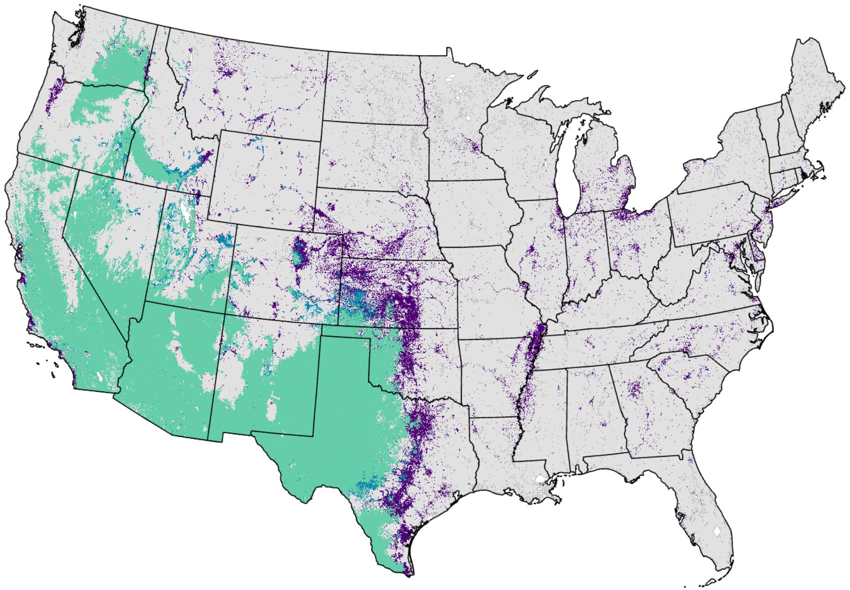
Combined thresholded models – Puncture vine (*Tribulus terrestris*)

1% threshold (Comprehensive/inclusive)
counties with suitability: 3109, 1894, 1813



10% threshold (Targeted/restrictive)
counties with suitability: 3059, 648, 545



- Suitability for high abundance
- Suitability for abundance
- Suitability for occurrence
- Low/no suitability

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Analysis of Environmental Predictor Variables

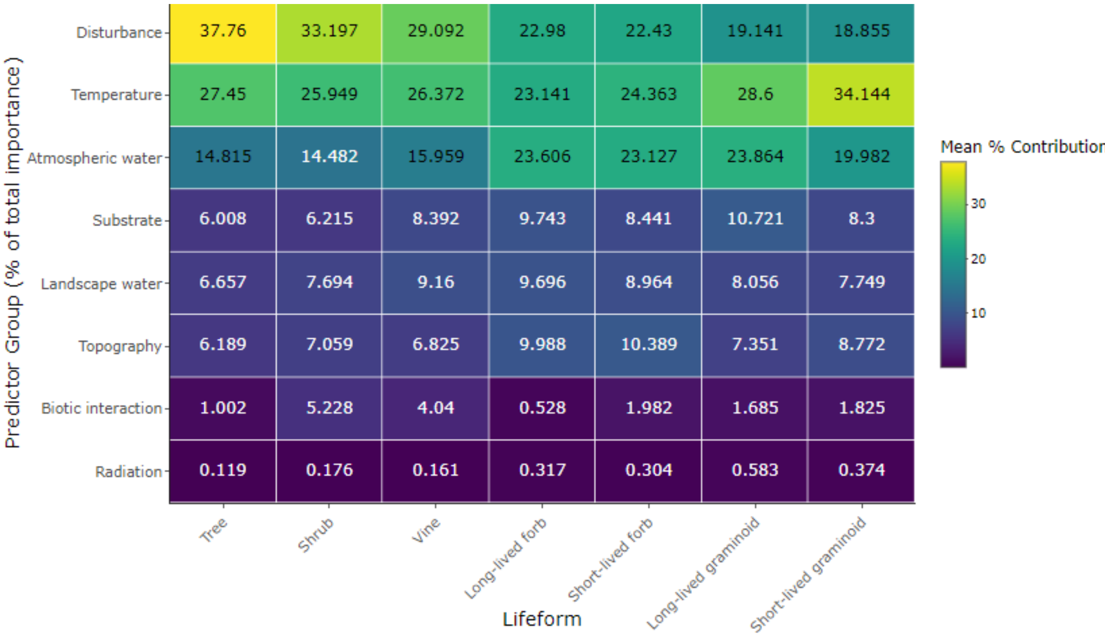
USGS
Keana Shadwell

USGS
Demetra Williams

- Top performing individual predictors: human modification & minimum winter temperature

- Most influential predictor groups: disturbance, temperature, atmospheric water

- Lifeforms don't really differ in predictor group contribution of importance



Williams, D., K Shadwell, et al. In review. Div. Dist.

What are the forecasting limitations?

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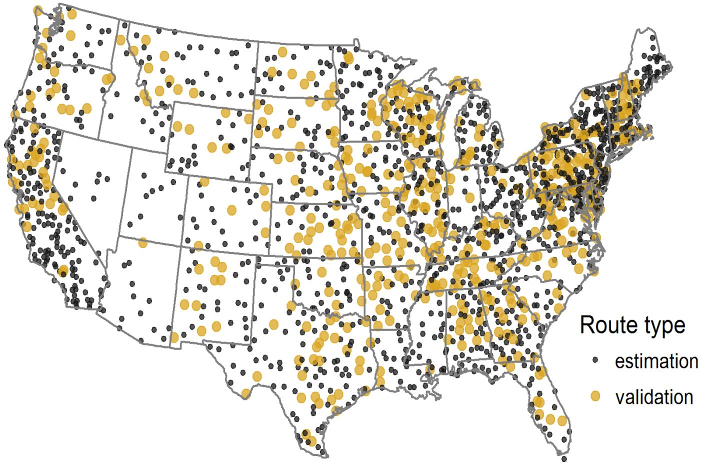
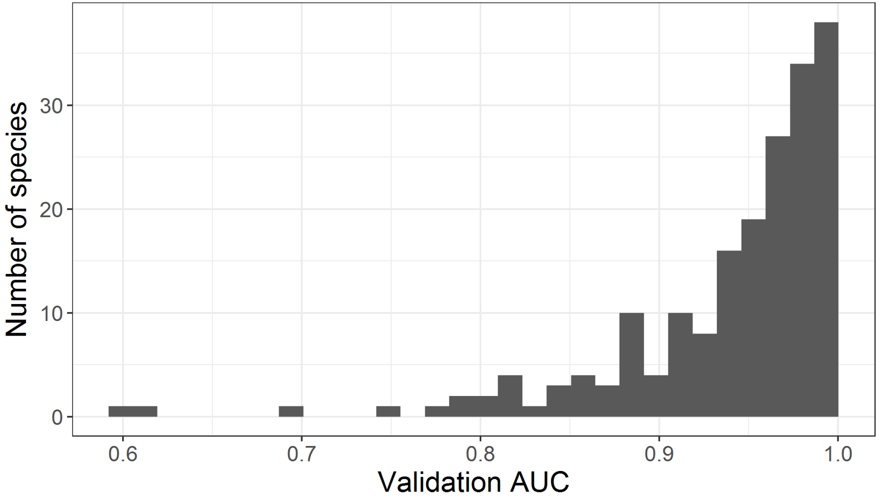
Breeding bird survey data

Sofaer et al. *2018*, Global Ecology and Biogeography

- Model training data: 1970s
- Model testing data: 2010s
- Climate and habitat predictors





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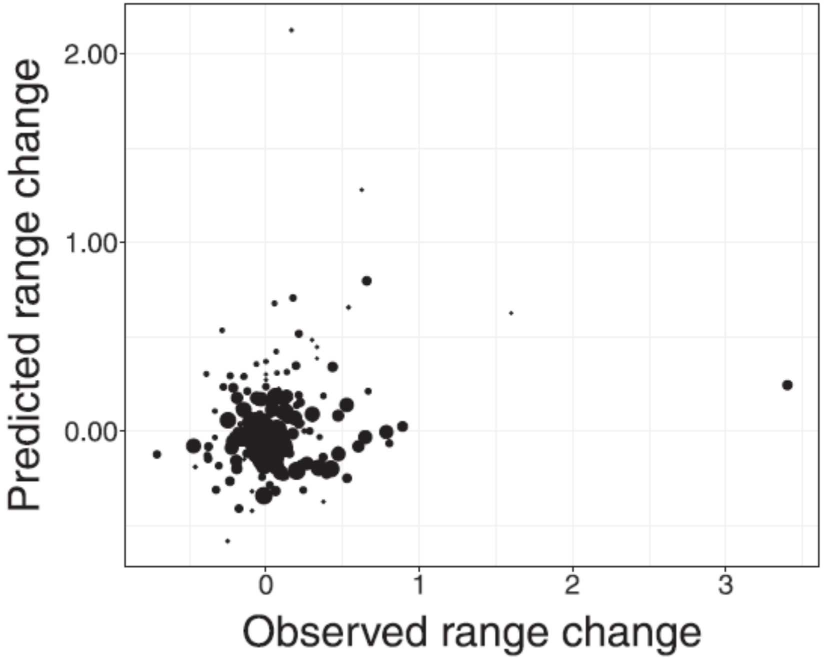
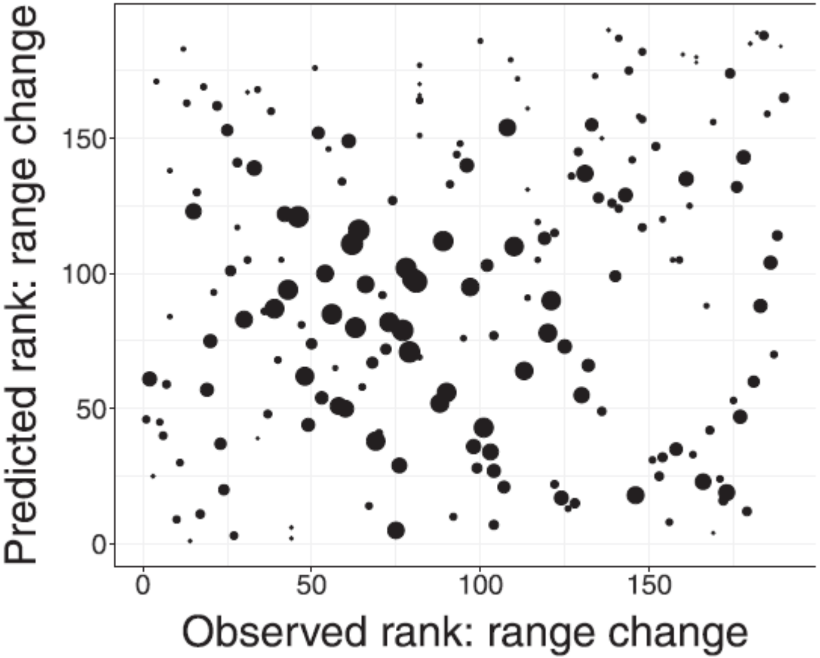
Change in range size was not reliable





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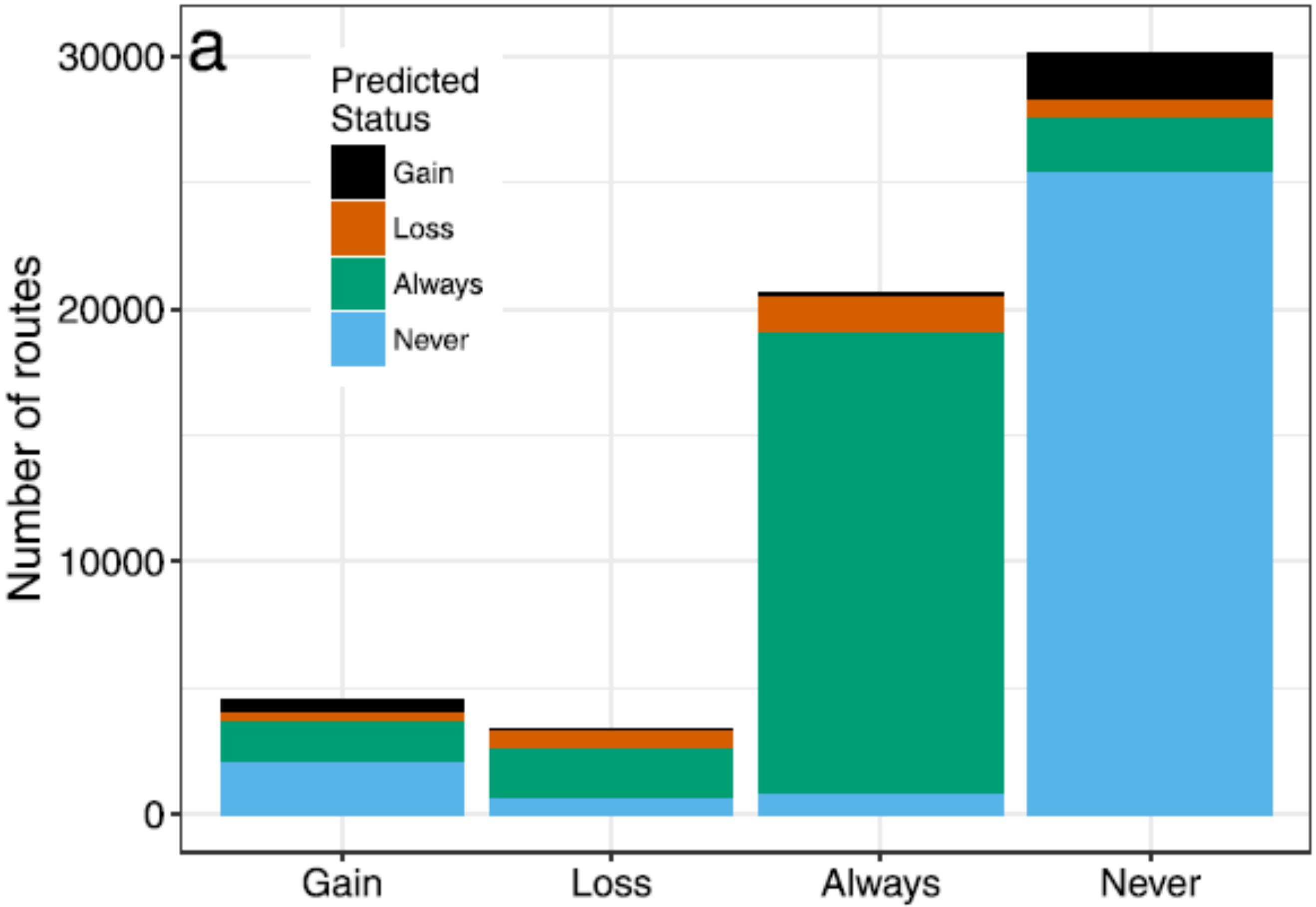
Sofaer et al. 2018. Global Ecology and Biogeography

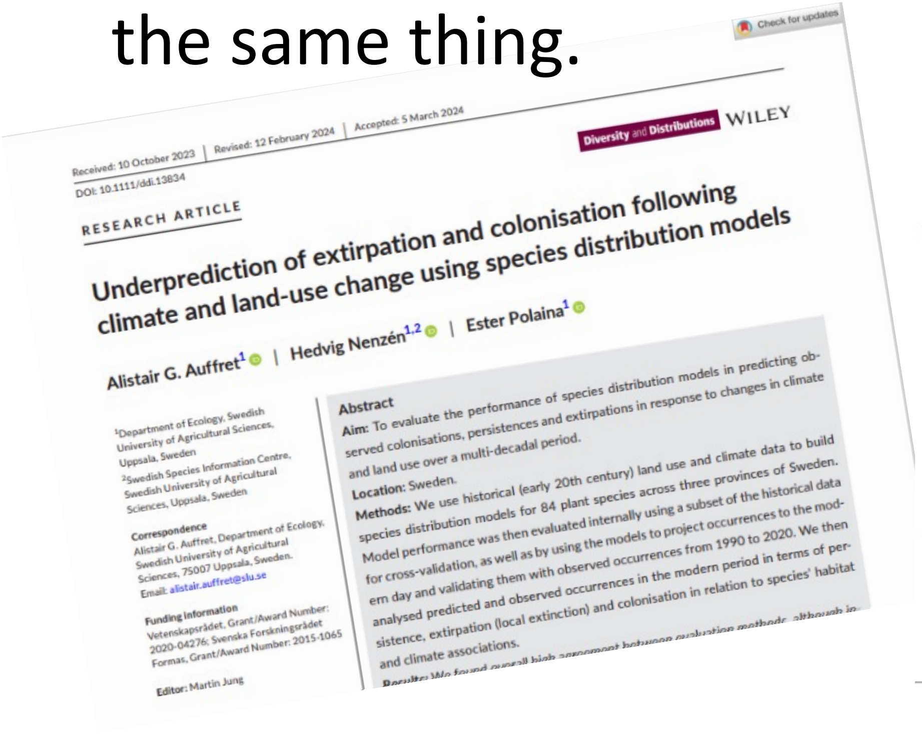
Poor prediction where change occurred



Sofaer et al. 2018. Global Ecology and Biogeography

USGS

Others have found the same thing.



Check for updates

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Diversity and Distributions WILEY

RESEARCH ARTICLE

Underprediction of extirpation and colonisation following climate and land-use change using species distribution models

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[2]Swedish Species Information Centre, Swedish University of Agricultural Sciences, Uppsala, Sweden

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Editor: Martin Jung

Abstract

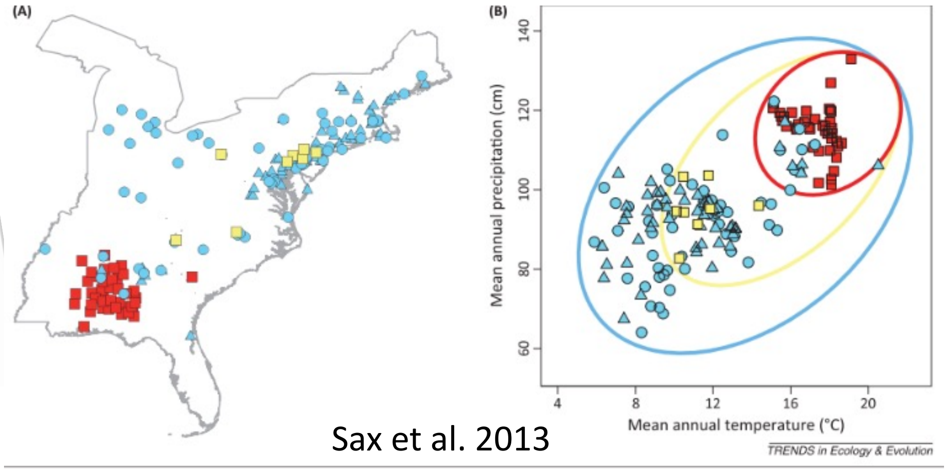
Aim: To evaluate the performance of species distribution models in predicting observed colonisations, persistences and extirpations in response to changes in climate and land use over a multi-decadal period.

Location: Sweden.

Methods: We use historical (early 20th century) land use and climate data to build species distribution models for 84 plant species across three provinces of Sweden. Model performance was then evaluated internally using a subset of the historical data for cross-validation, as well as by using the models to project occurrences to the modern day and validating them with observed occurrences from 1990 to 2020. We then analysed predicted and observed occurrences in the modern period in terms of persistence, extirpation (local extinction) and colonisation in relation to species' habitat and climate associations.

What restricts a species' range?

Red = native range
Yellow = naturalized or adventive
Blue = botanic garden/ commercially sold



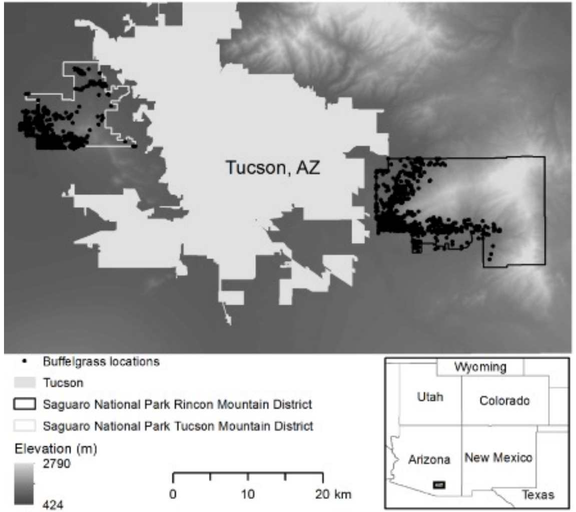
Sax et al. 2013

USGS

What can we do?

Buffelgrass in Saguaro National Park

- African C4 perennial bunchgrass
- Globally invasive
- Potentially alter fire regime
  - Continuous fuel for fire
  - Ecosystem not fire adapted



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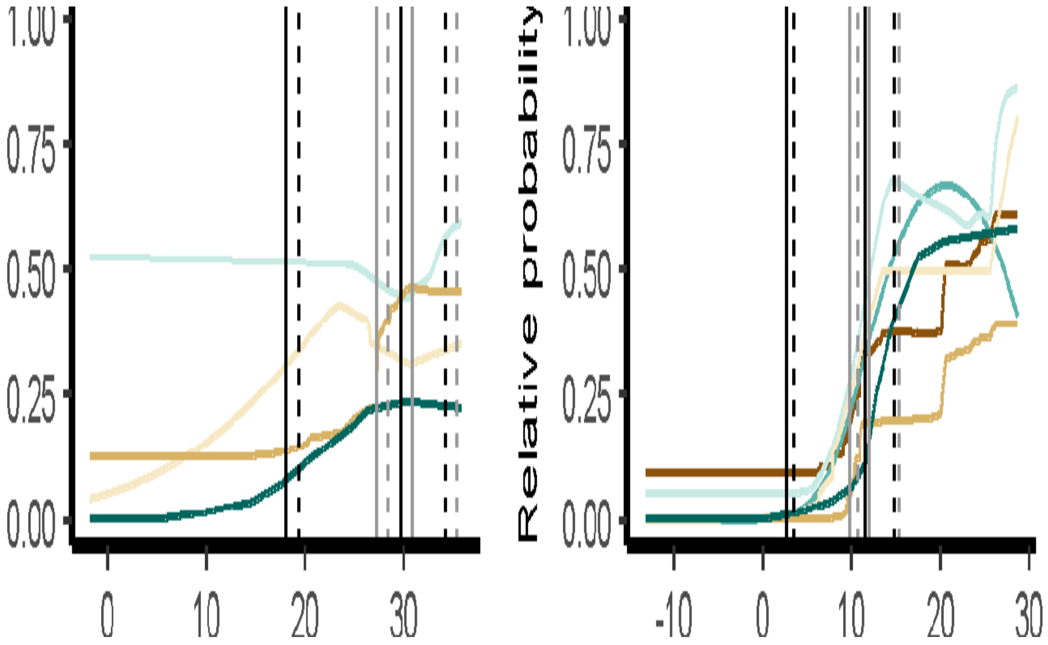
Climate context: changing suitability?

- SNP conditions with global response curves
- Solid: 1981-2010 conditions
- Dotted: 2055 based on 15 GCMs for RCP 8.5



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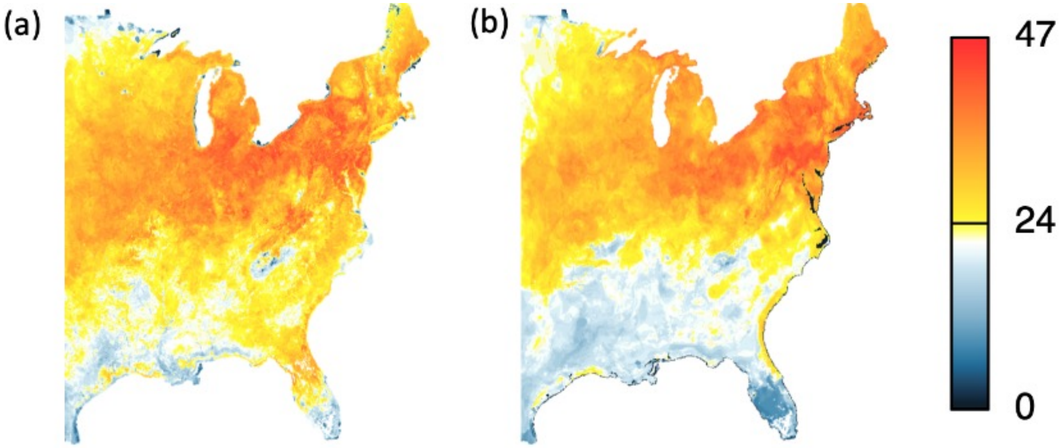
Shifting invasives

Number of species with abundance suitability

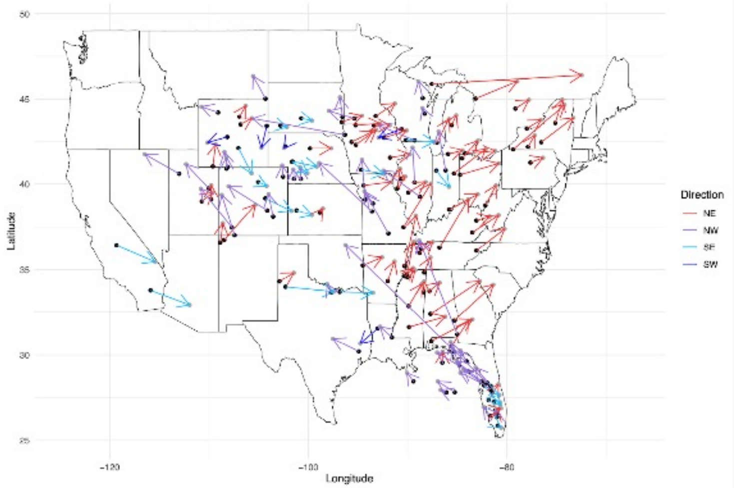
(of 138 species using US locations)



Western species are coming!

Shifts in predicted range centroids

(Current to +2C)



NECASC
Northeast Climate Adaptation Science Center

Annette Evans

USGS

Preliminary Information-Subject to Revision.
Not for Citation or Distribution.

Aquatic Invasive Species Modeling

Developing predictor layers for the Nation


Asian Swamp Eel, USGS


Phragmites, USDA


Quagga Mussel, EPA/Buffalo State

Grace Henderson (USGS FORT)
Catherine Jarnevich (USGS FORT)
Wesley Daniel (USGS WARC)
Ian Pfingsten (USGS WARC)
Peder Engelstad (CSU in cooperation with USGS FORT)

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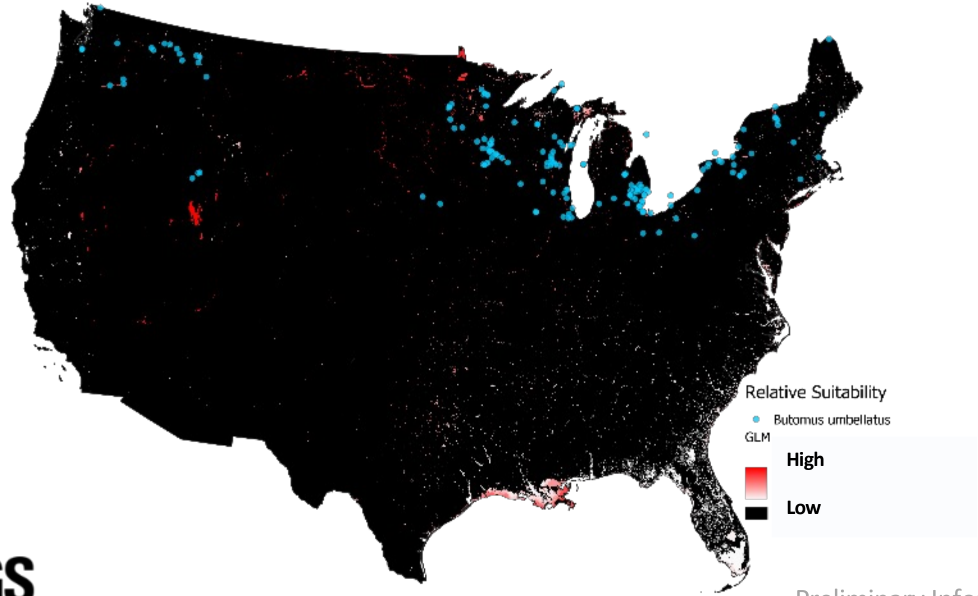
AQUA-INHABIT

- Fit models for lakes and for steams
- Apply to future climate and land use

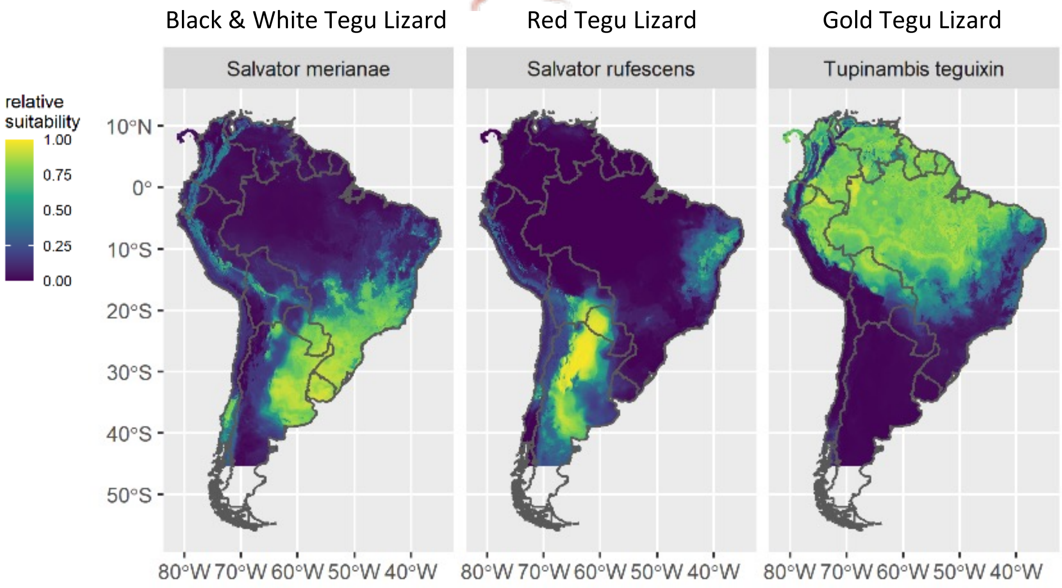


An example: Implications for invasion threat from climate change and tegu Lizards

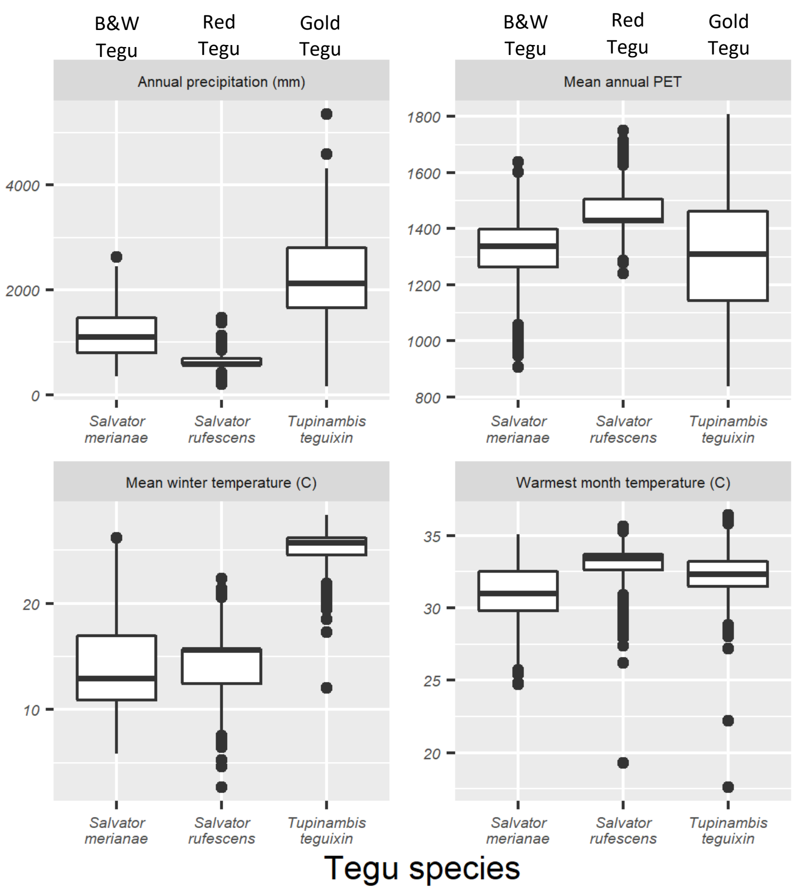
- Work with Amy A. Yackel Adams, Amanda M. Kissel, Andrea F. Currylow
- Extending previous modeling work, comparing with thermal studies, over-winter study, and extended range documentation.

Amanda Kissel

Three Tegu species appear to occupy distinct geographic and climatic niches



Climate variables



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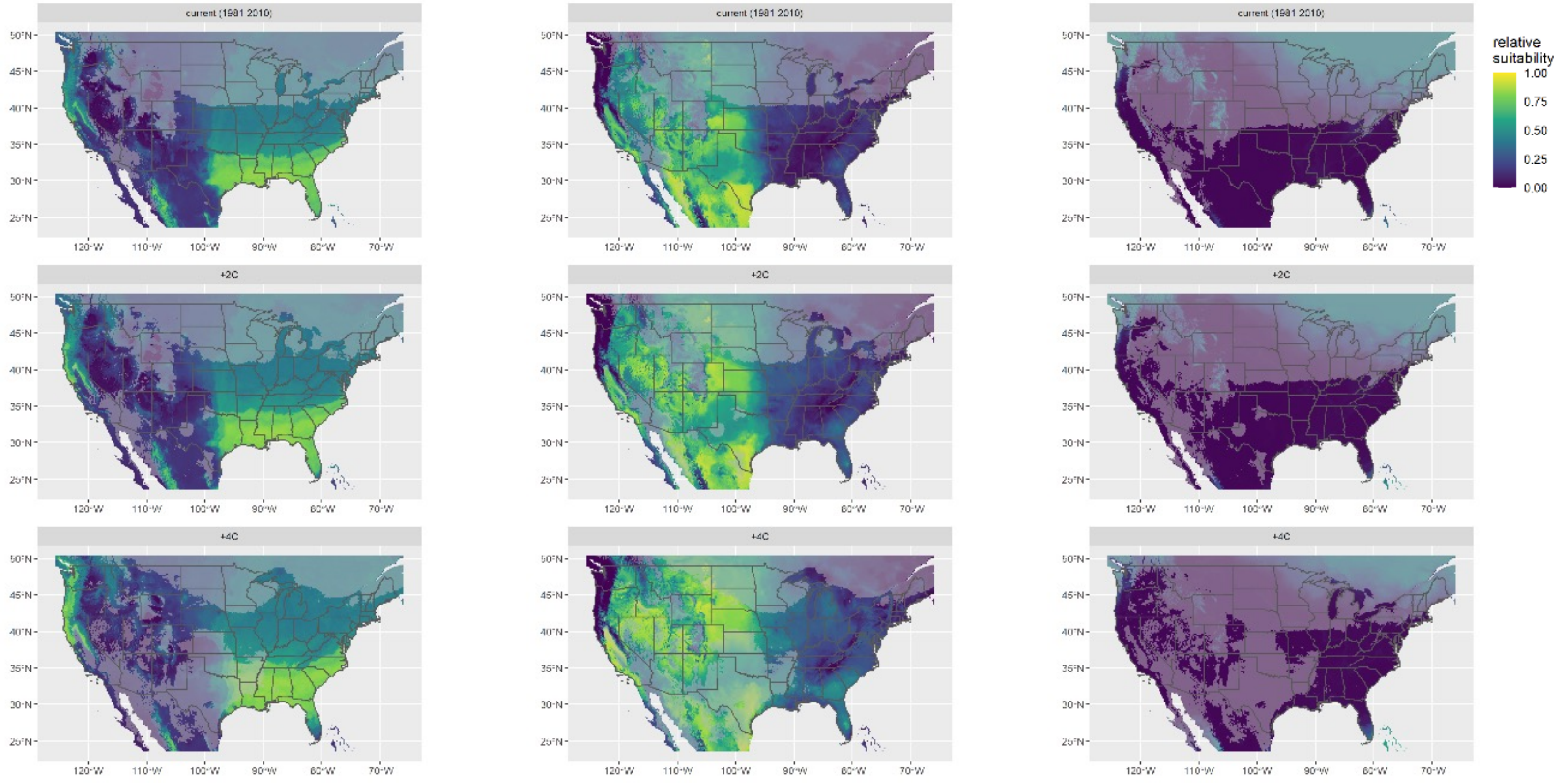
Species Distribution Models for North America

	Black & White Tegu Lizard	Red Tegu Lizard	Gold Tegu Lizard
	Salvator merianae	*Salvator rufescens*	*Tupinambis teguixin*

Current

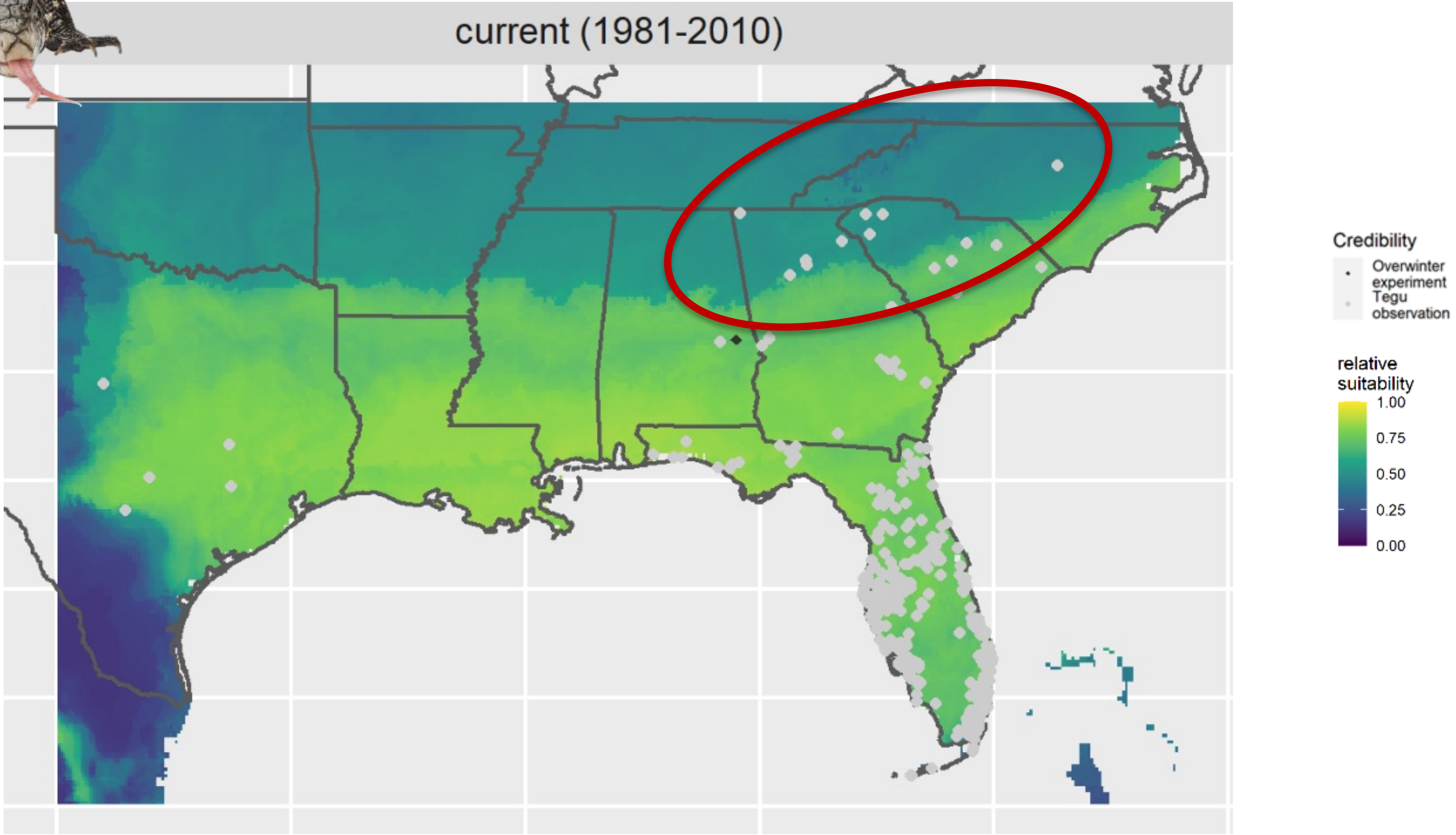
+ 2°C

+ 4°C



Preliminary Information-Subject to Revision. Not for Citation or Distribution

Black and White Tegu sightings with current climate conditions



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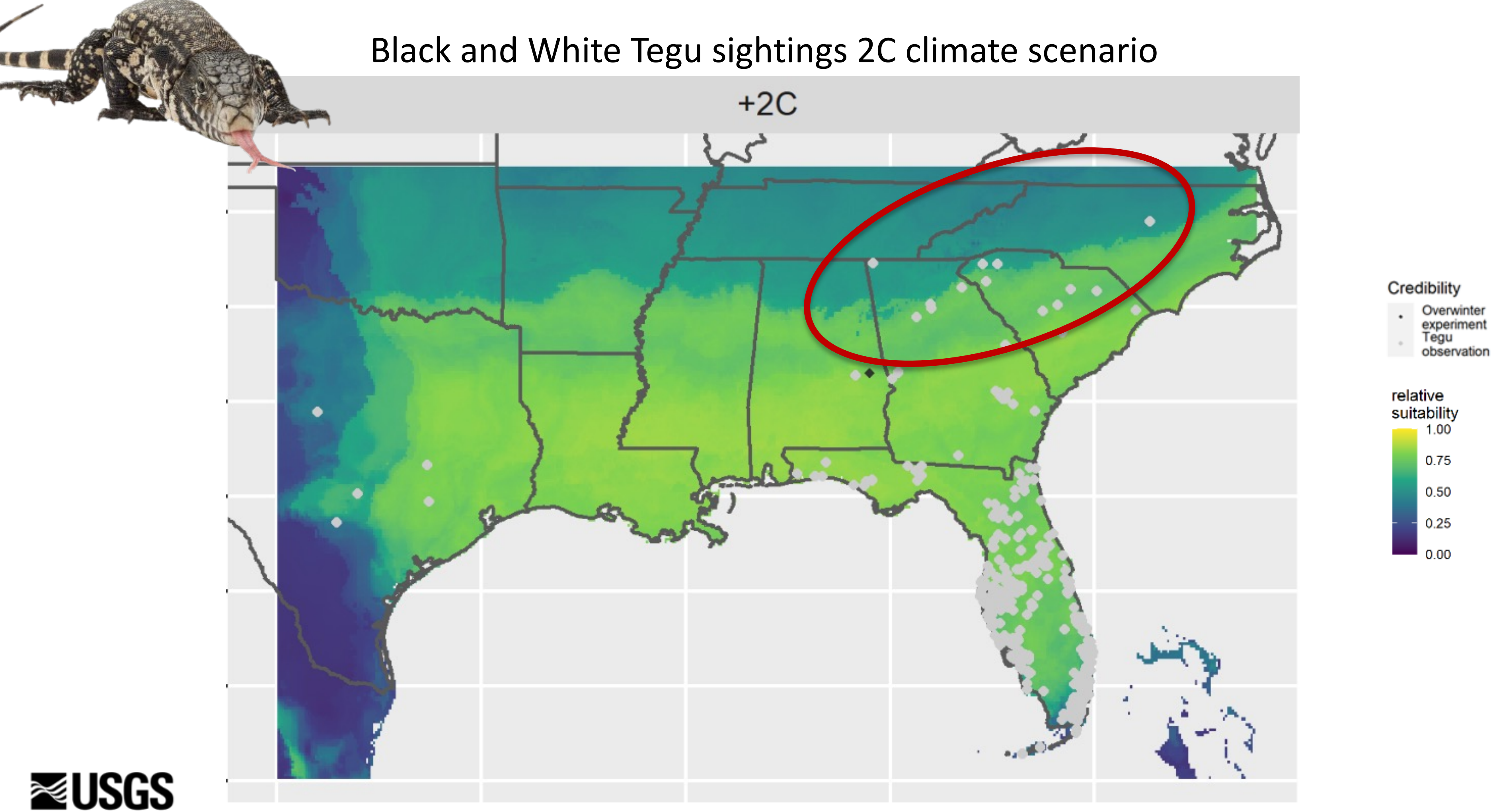
Black and White Tegu sightings 2C climate scenario



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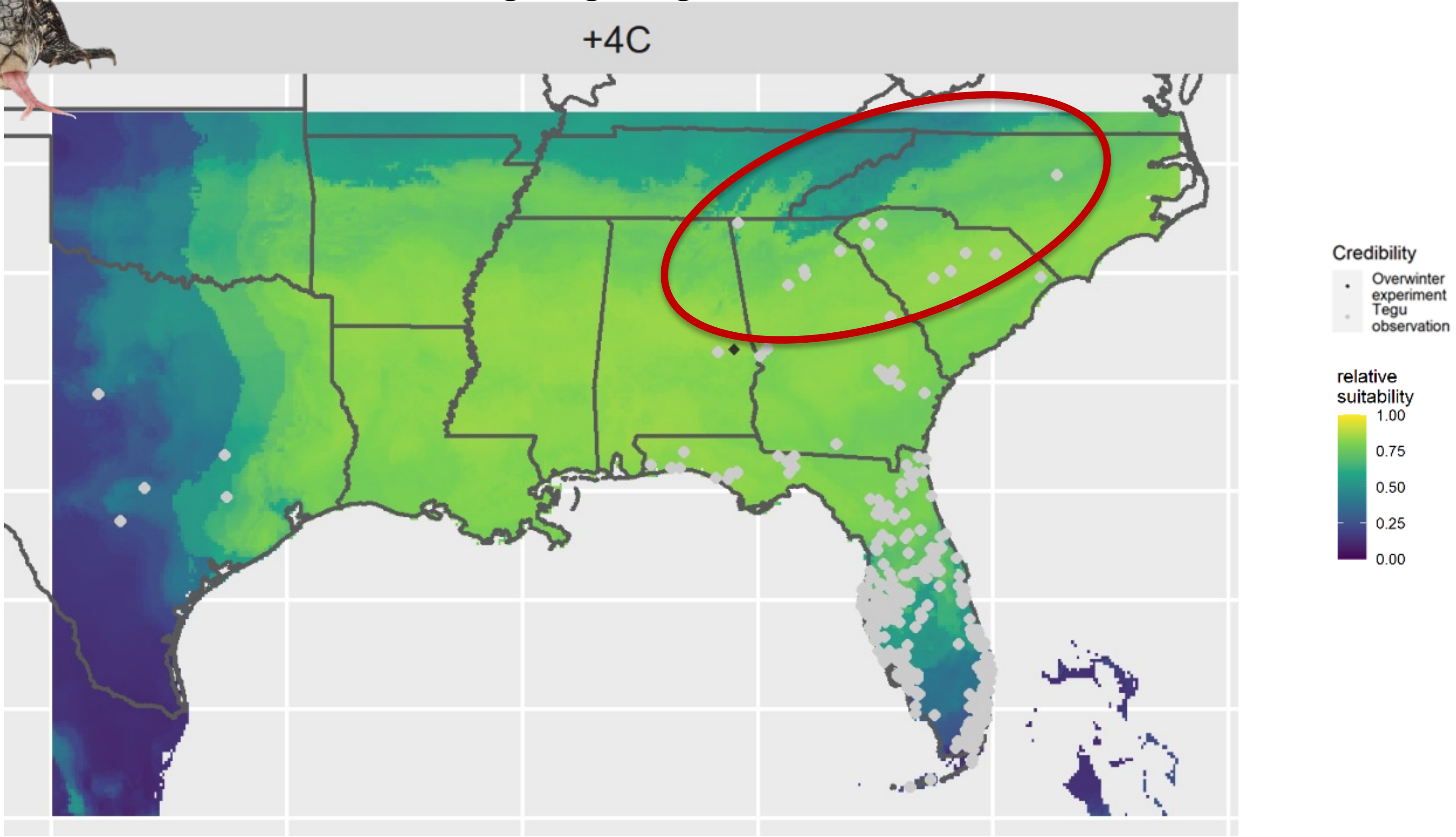
Black and White Tegu sightings 4C climate scenario



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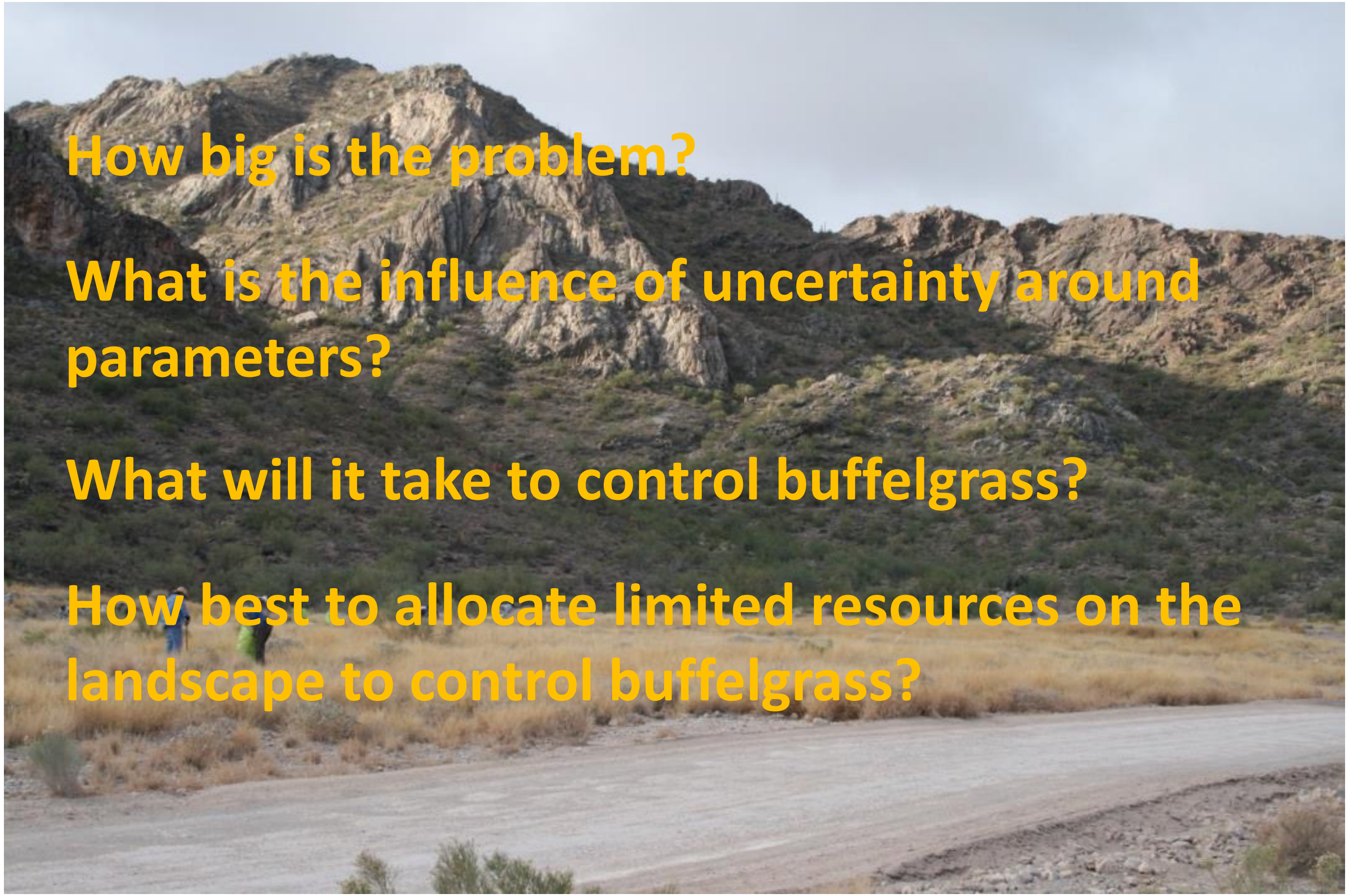
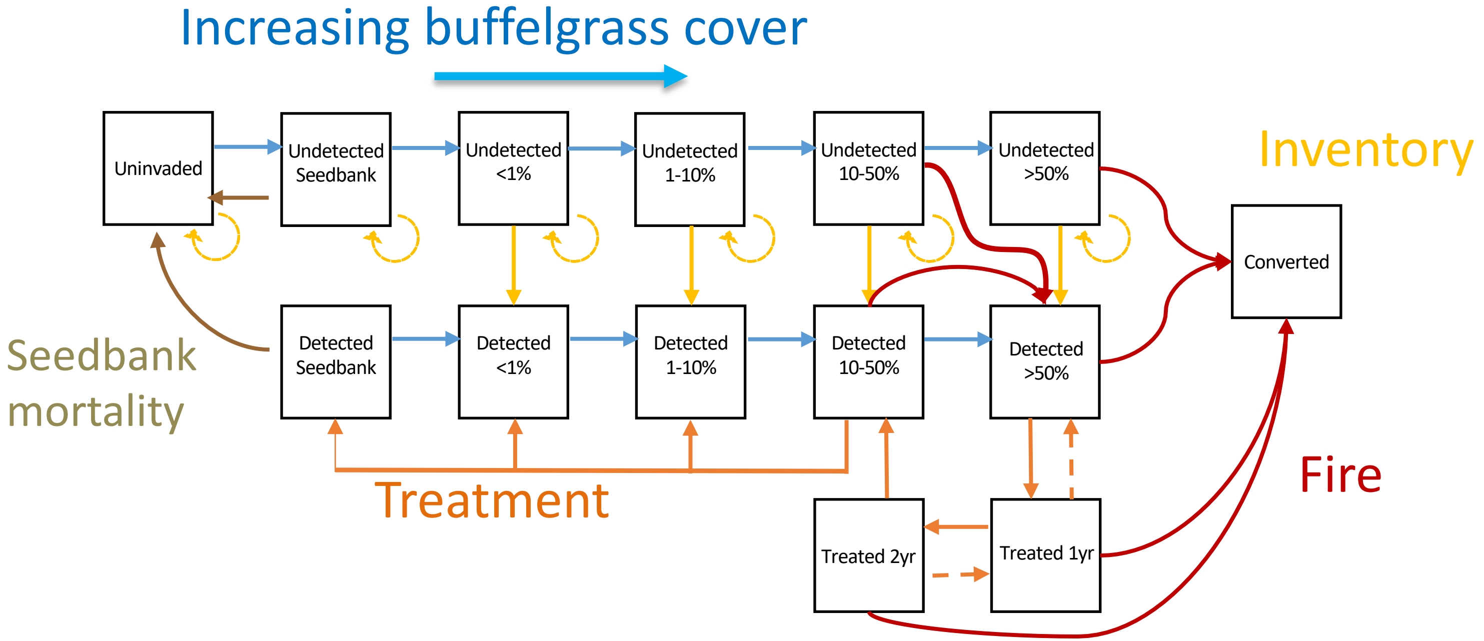
Tegu conclusions

- Areas where Tegu suitability was predicted to be high from Jarnevich et al. (2018) are indeed suitable
- Important to consider all three species for risk assessment because of climatic distinctions between the species
  - True physiological differences or competitive exclusion?
- B&W Tegu ability to thermoregulate facilitates advance northward
  - Reptiles that can self-thermoregulate (like endotherms) likely to be ‘better’ invaders (e.g., Burmese python)
- Suitability in South Florida for B&W Tegu declines but increases for the other 2 Tegu species
- Some SE states have passed regulations banning B&W Tegus but climate change scenarios an increase of areas at risk (i.e., North [B&W] and West [Red Tegu])

USGS


How big is the problem?
What is the influence of uncertainty around parameters?
What will it take to control buffelgrass?
How best to allocate limited resources on the landscape to control buffelgrass?

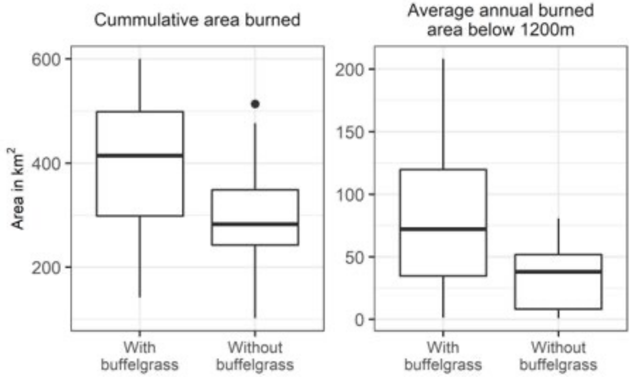
State and Transition Simulation Model

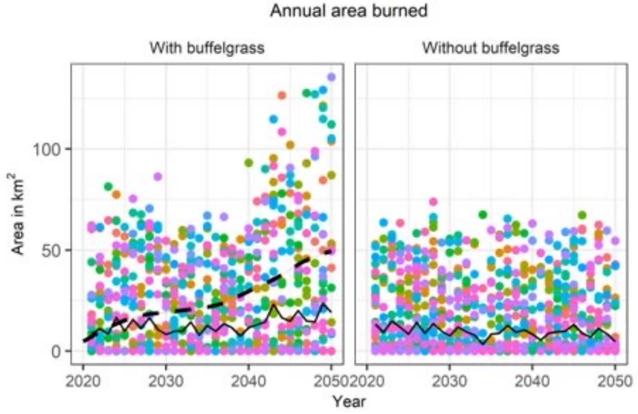


Jarnevich et al. 2022 Biol. Cons.

*Dashed lines denote treatment or detection failures

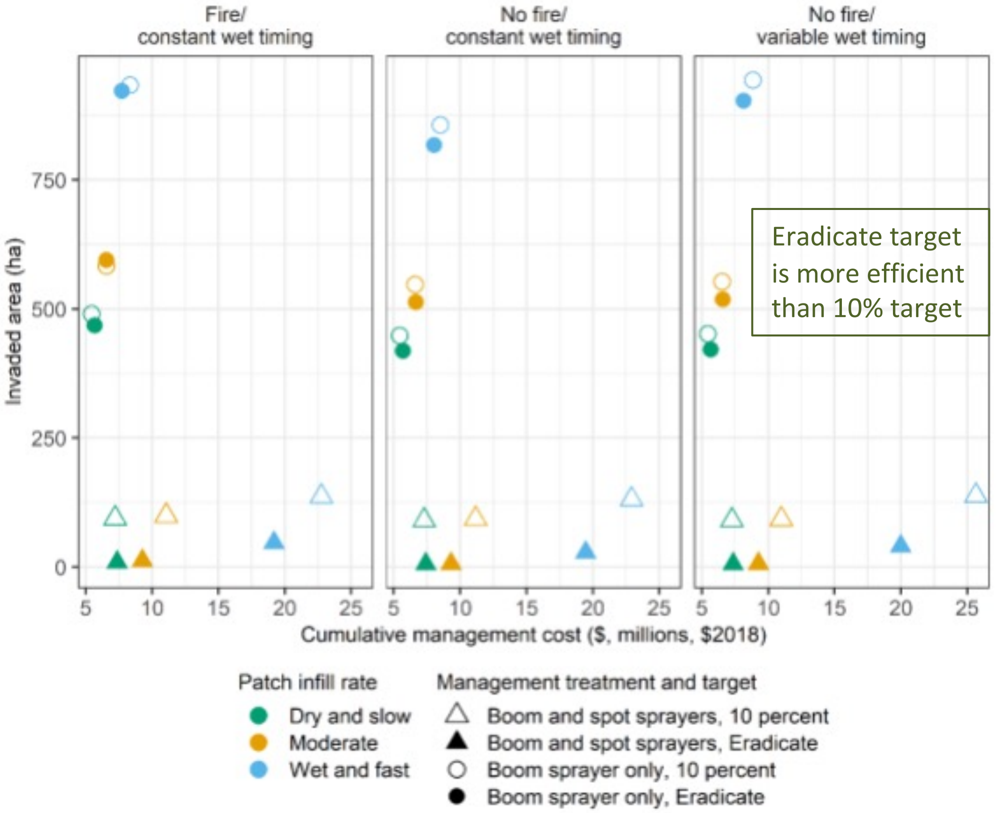
Fire regime alterations:
Santa Catalina Mountains





Wilder et al. 2021 FEVO

How to allocate resources?



Jarnevich et al. 2022 Biol. Cons.

USGS

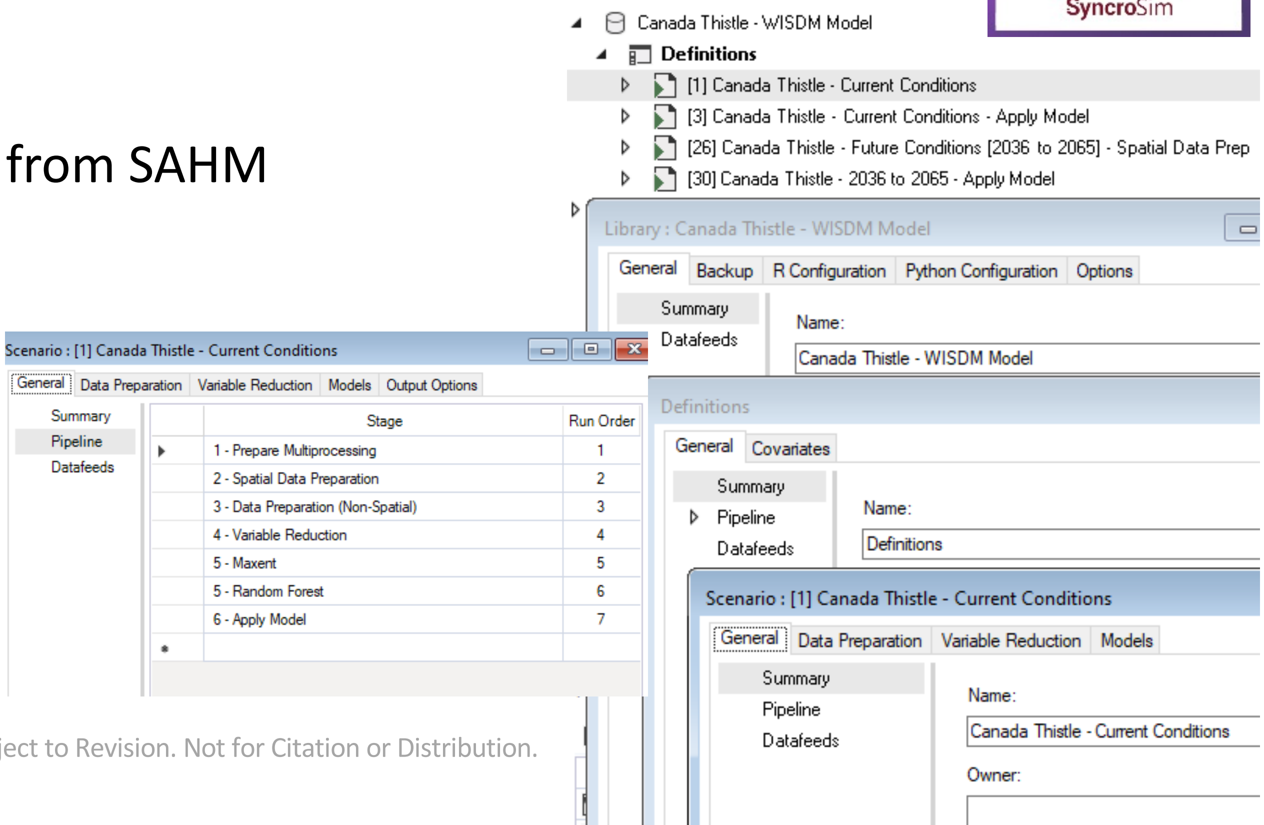
WISDM: Workbench for Integrated Species Distribution Modeling

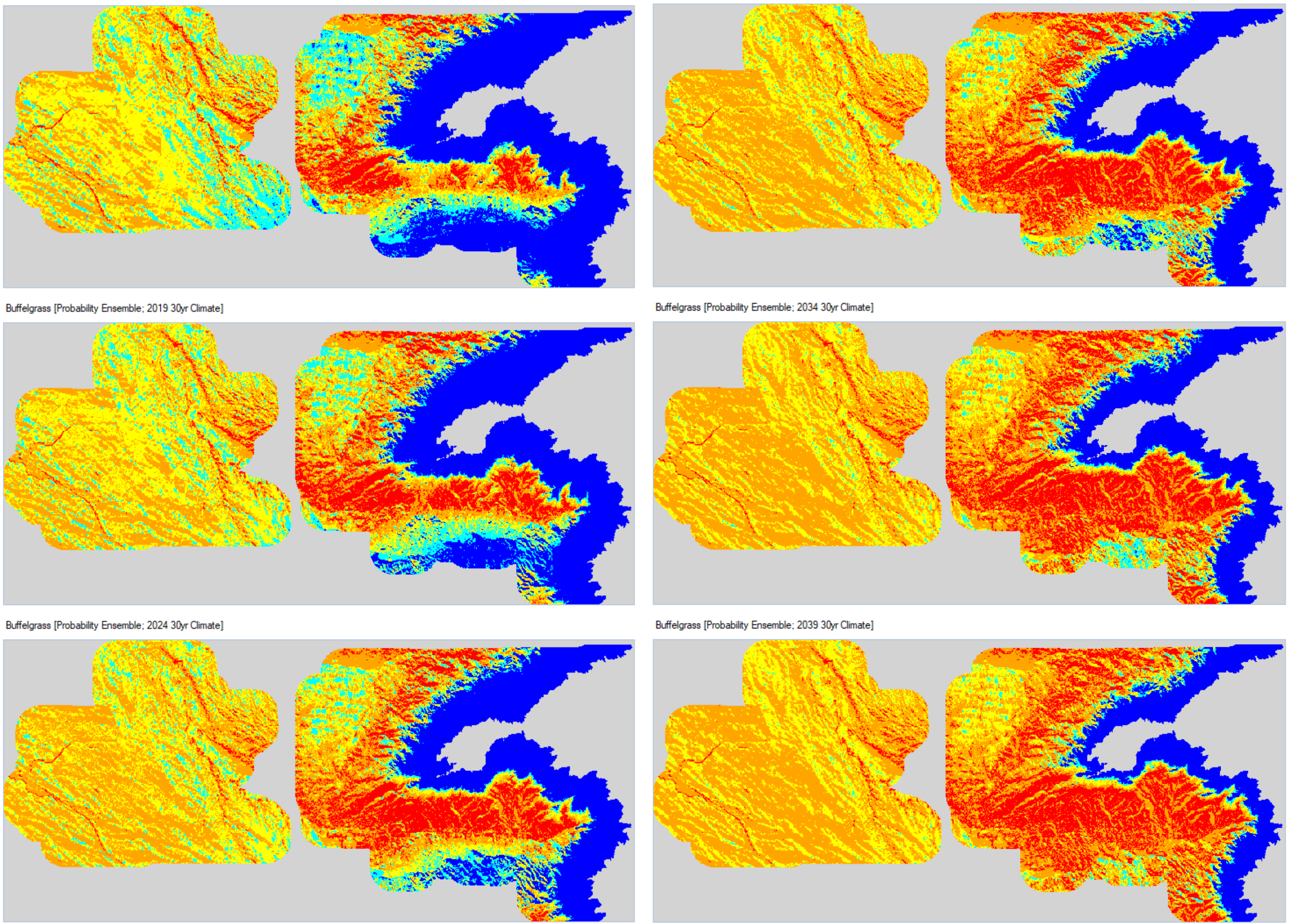
- Seed establishment is based on underlying suitability, which is constant.
- New package to automatically interact with ST-SIM

Partnership between Apex RMS, USFS, and USGS.

WISDM

- Started development within SyncroSim in 2021
- Updating modules from SAHM
- Beta version
  - Data preparation
  - Variable reduction
  - Model algorithms
  - Outputs
  - Visualization





WISDM SyncroSim

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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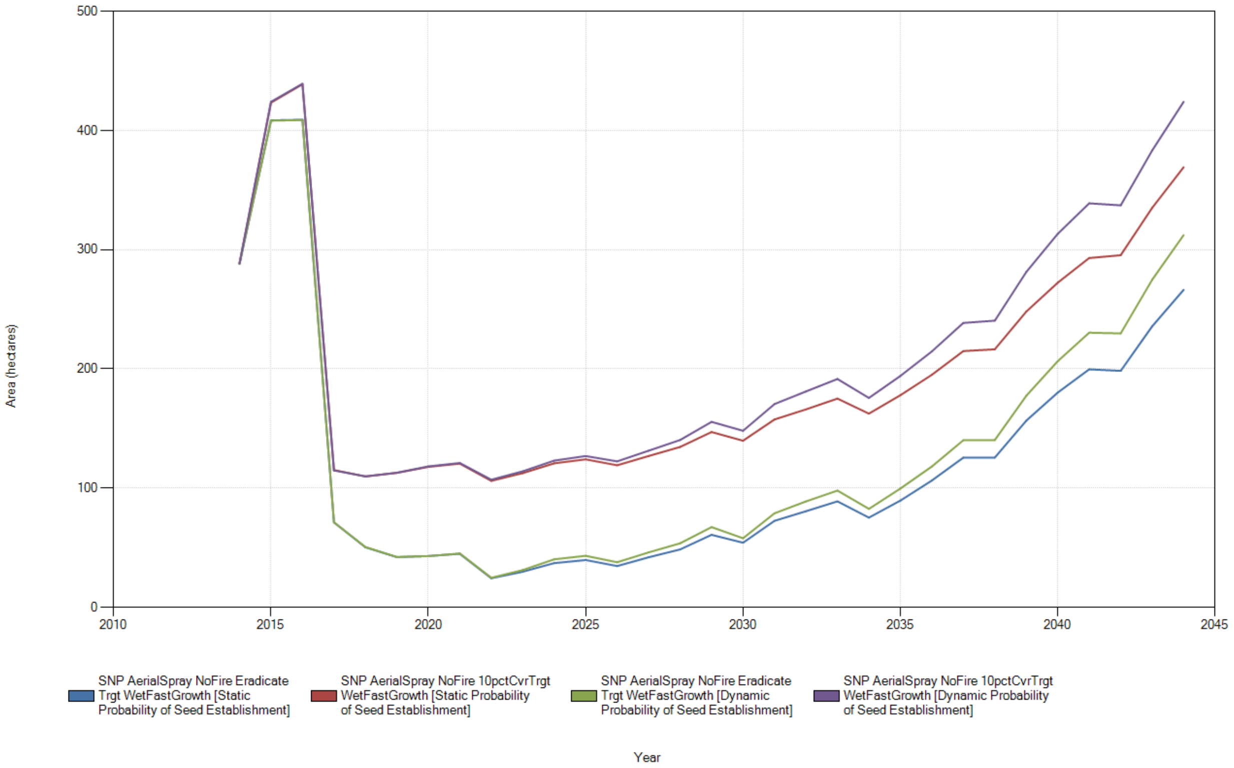
Predicted invaded area increases – Will this influence outcomes?

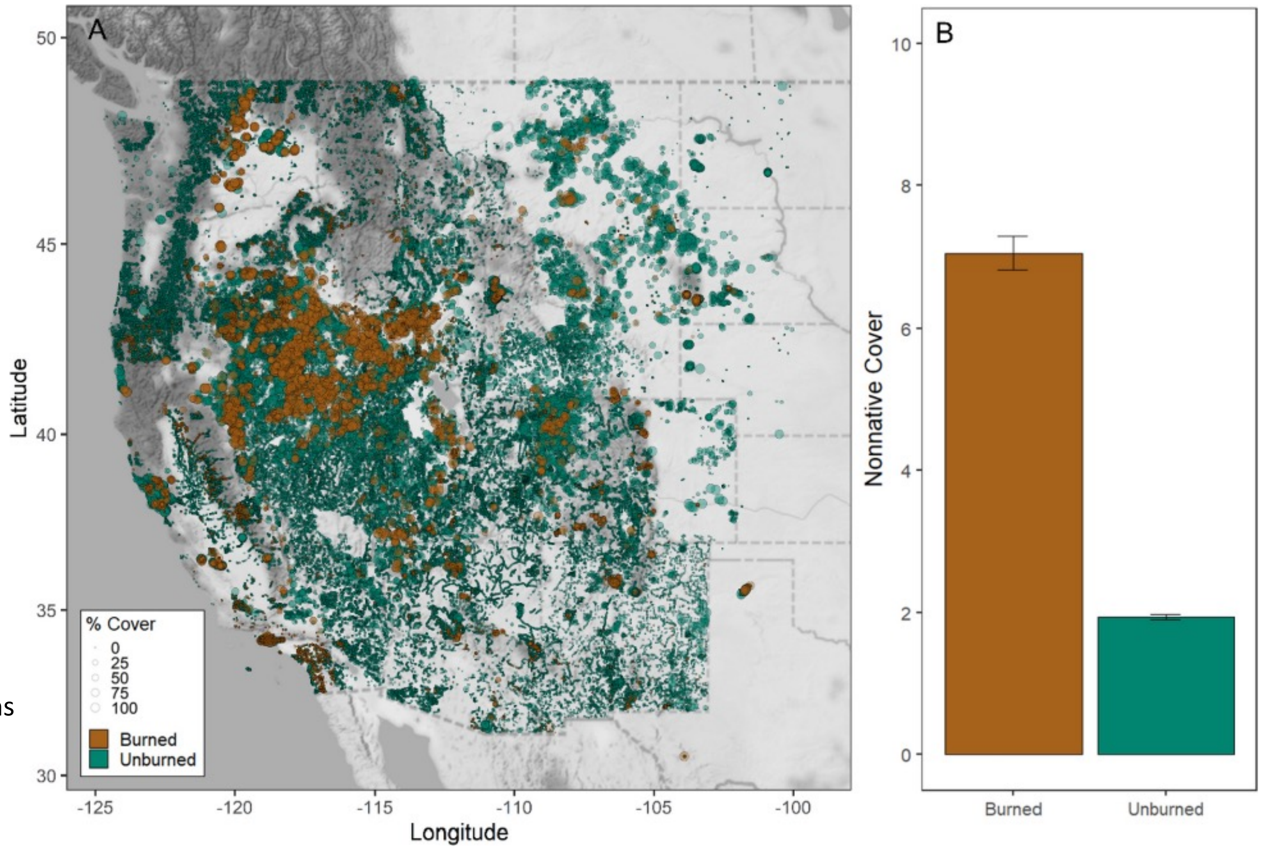


USGS

How do we prioritize?

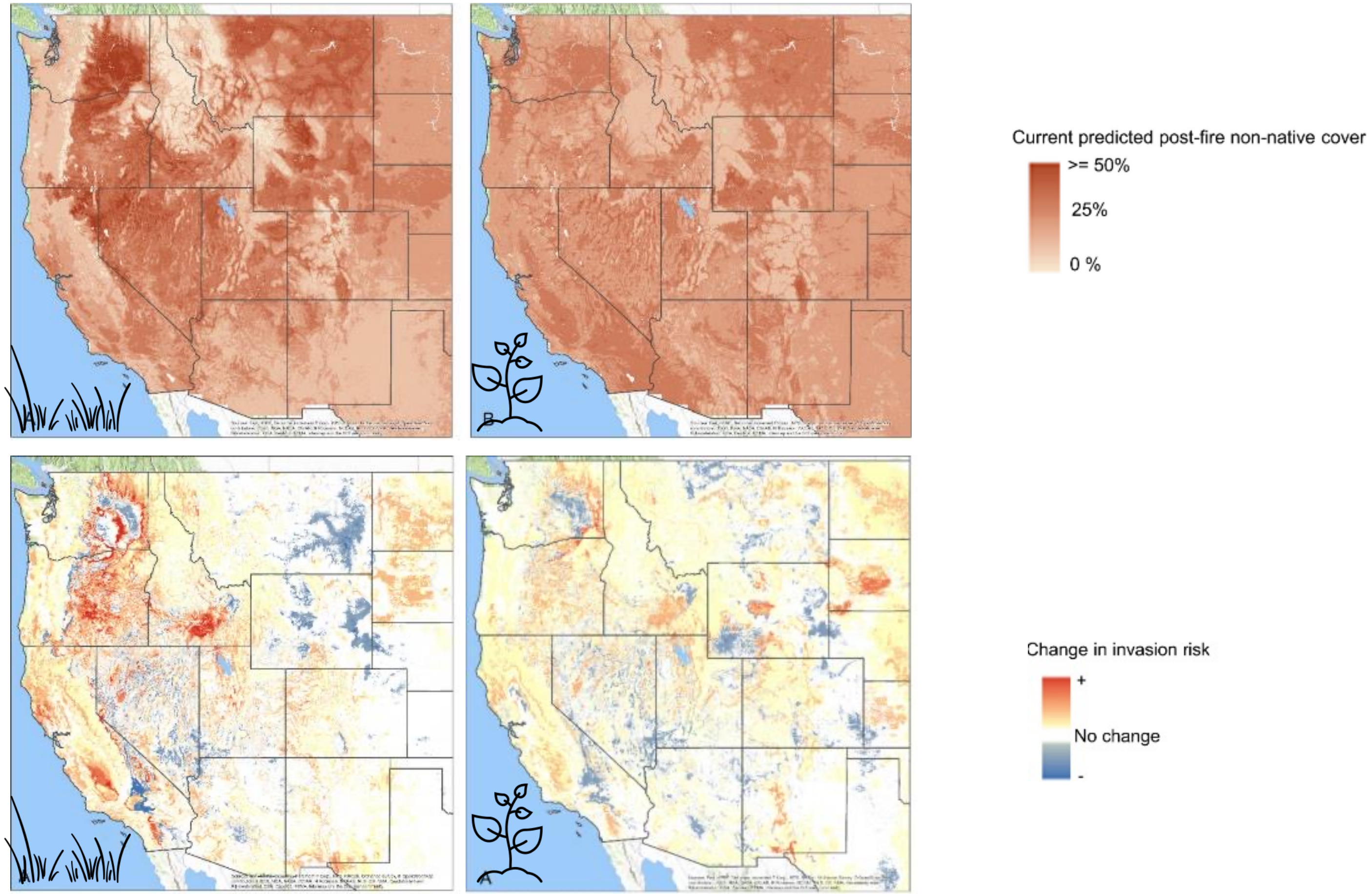
Post fire non-native plant abundance

- Aggregated 26,729 vegetation plots
- Short lived forbs and C3 grasses had significantly higher cover after fire.
- Climate variables were the most important in predicting their post-fire cover.



Prevey et al. 2024 Biol. Invasions

USGS



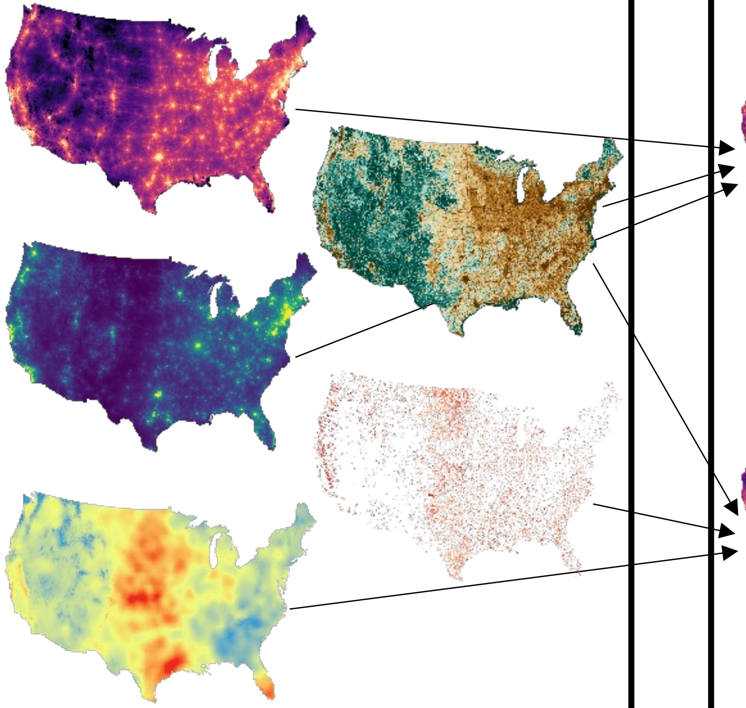
Prevey et al. 2024,
Biol. Invasions

1.

- **Human Impact**
- **Disturbance**
- **Nonnative Species Richness**
- **Climate Change Projections**
- **High Priority Sites**

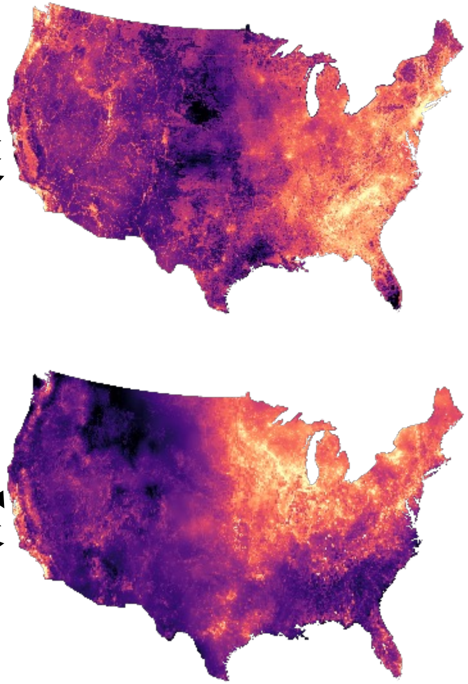
Identify management priorities

2.



Generate data layers

3.



Create user-specific site prioritization maps

	Data Layer	Data Source
Human Impact / Disturbance	Remoteness	U.S. Census, TIGER, NTD, NED
	Landscape Condition	NatureServe
	Burn Frequency	MTBS
	LandTrendr: Year of Disturbance	Landsat, Google Earth Engine
	LandTrendr: Magnitude of Disturbance	
	LandTrendr: Duration of Disturbance	
	LandTrendr: Pre-Disturbance Greenness	
Nonnative Species Richness	Amphibians	GBIF, EDDMaps, NAS, SPCIS, iMapInvasives
	Fish	
	Invertebrates	
	Mammals	
	Mollusks	
	Plants	
	Reptiles	
Climate Change: Projected Magnitude of Change	Mean Annual Temperature	ClimateNA
	Mean Annual Precipitation	
	Mean Temperature of Coldest Month	
	Summer Heat Moisture Index	
High Priority Resources	Imperiled Species Richness	NatureServe
	User-Supplied Layers	

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science for a changing world

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Site Prioritization Tool

Map | Data Layers | About

Area of Interest

Rocky Mountain National Park

Layer Selection

3 options selected

Mean Annual Temperature (high):

-1 0.3 1

-1 -0.8 -0.6 -0.4 -0.2 0 0.1 0.2 0.4 0.6 0.8 1

Remoteness:

-1 1

-1 -0.8 -0.6 -0.4 -0.2 0 0.1 0.2 0.4 0.6 0.8 1

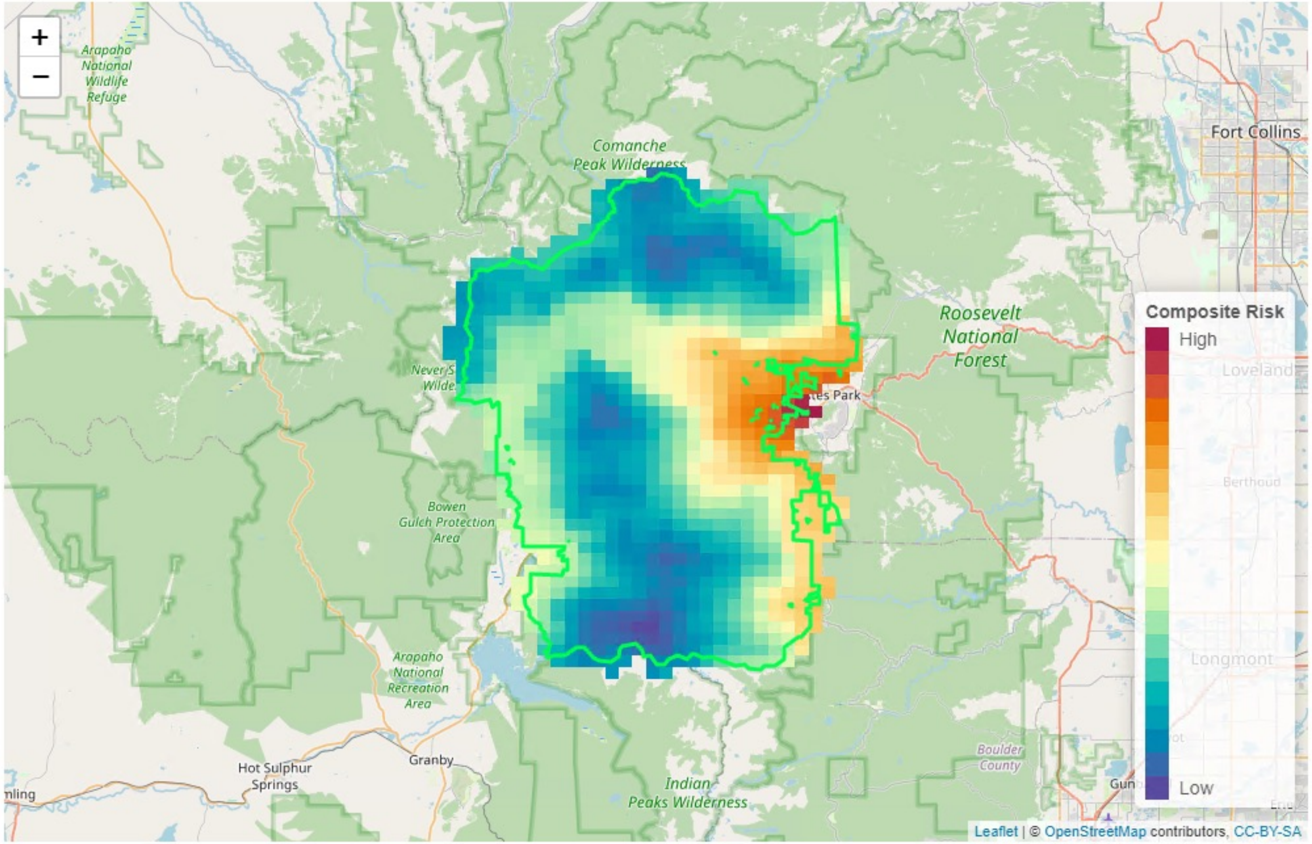
Nonnative Plants Richness:

-1 0.8 1

-1 -0.8 -0.6 -0.4 -0.2 0 0.1 0.2 0.4 0.6 0.8 1

Calculate

Download



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Where are species now?

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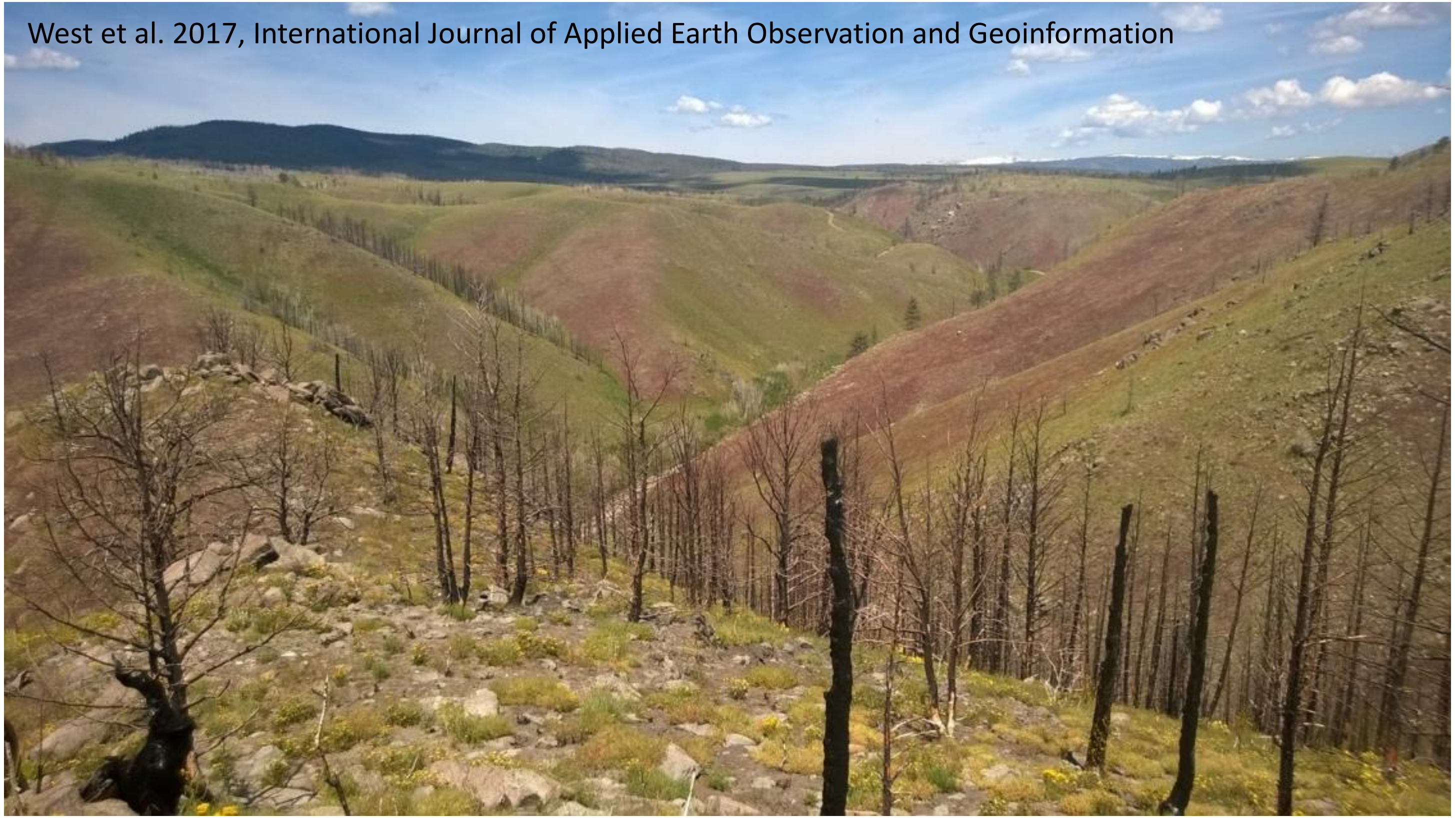
Primary objective: Create a highly accurate map of cheatgrass cover that can be used for targeted management



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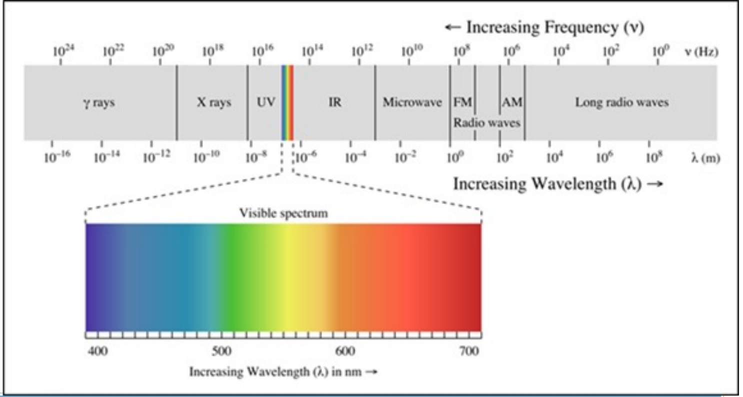
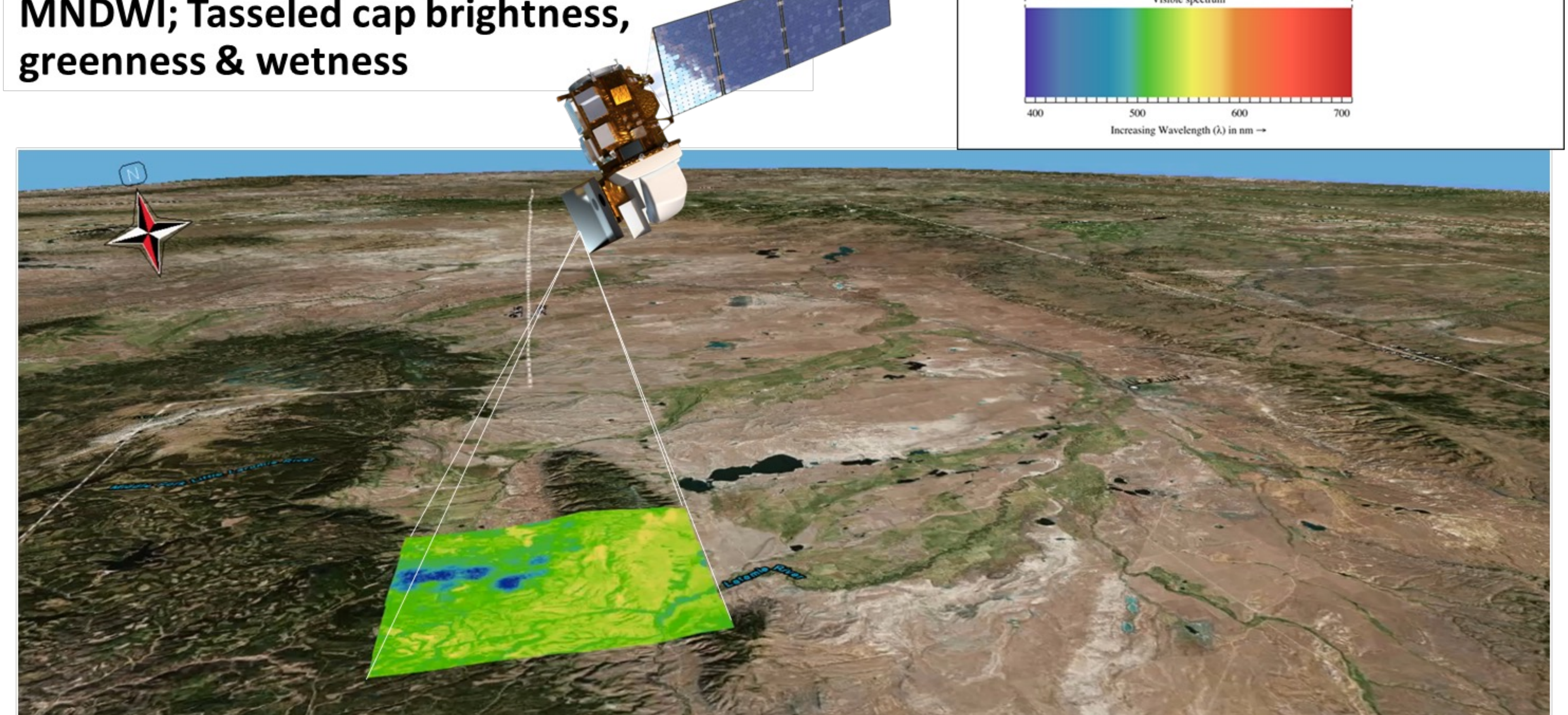
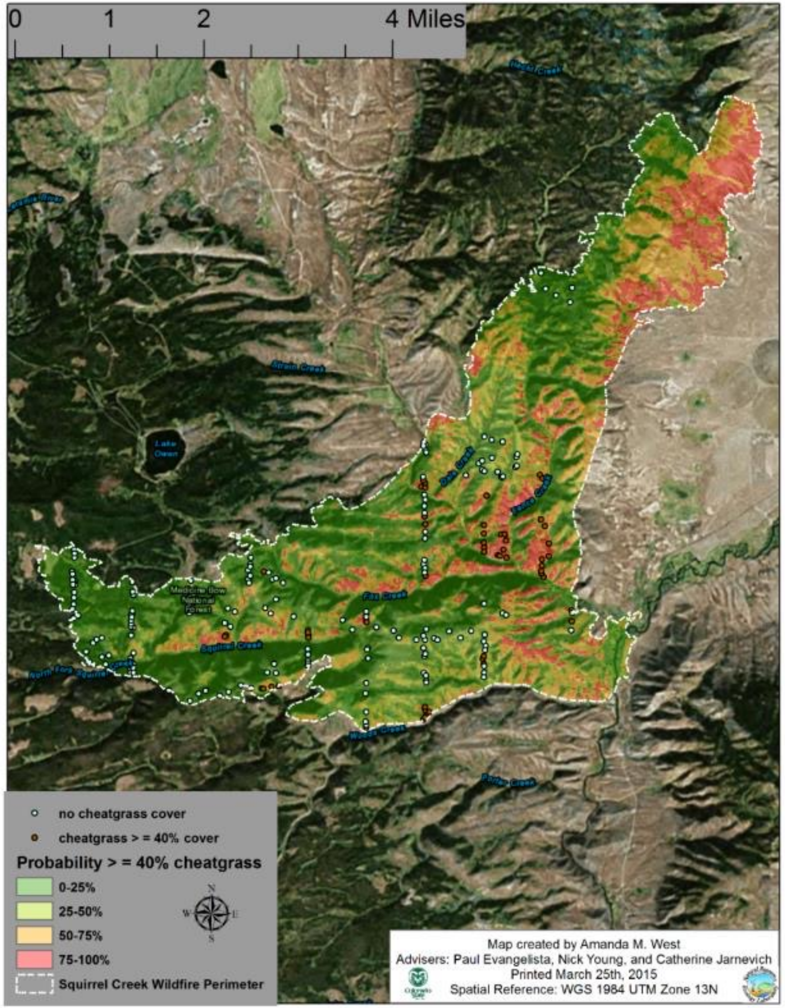
Spectral indices of reflectance and transmittance of visible & near infrared (IR) frequencies: NDVI; SAVI; EVI; NDWI; MNDWI; Tasseled cap brightness, greenness & wetness





Cheatgrass control

- Used model to obtain treatment funding
- Aerial application where >50% probability and patch size >= 2 ac



West et al. 2017, International Journal of Applied Earth Observation and Geoinformation

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Pre- (2016) and Post- (2017) treatment with Imazapic via helicopter using model

Jackie Roaque
Rangeland Management Specialist

Forest Service
Medicine Bow-Routt National Forests,
Laramie Ranger District

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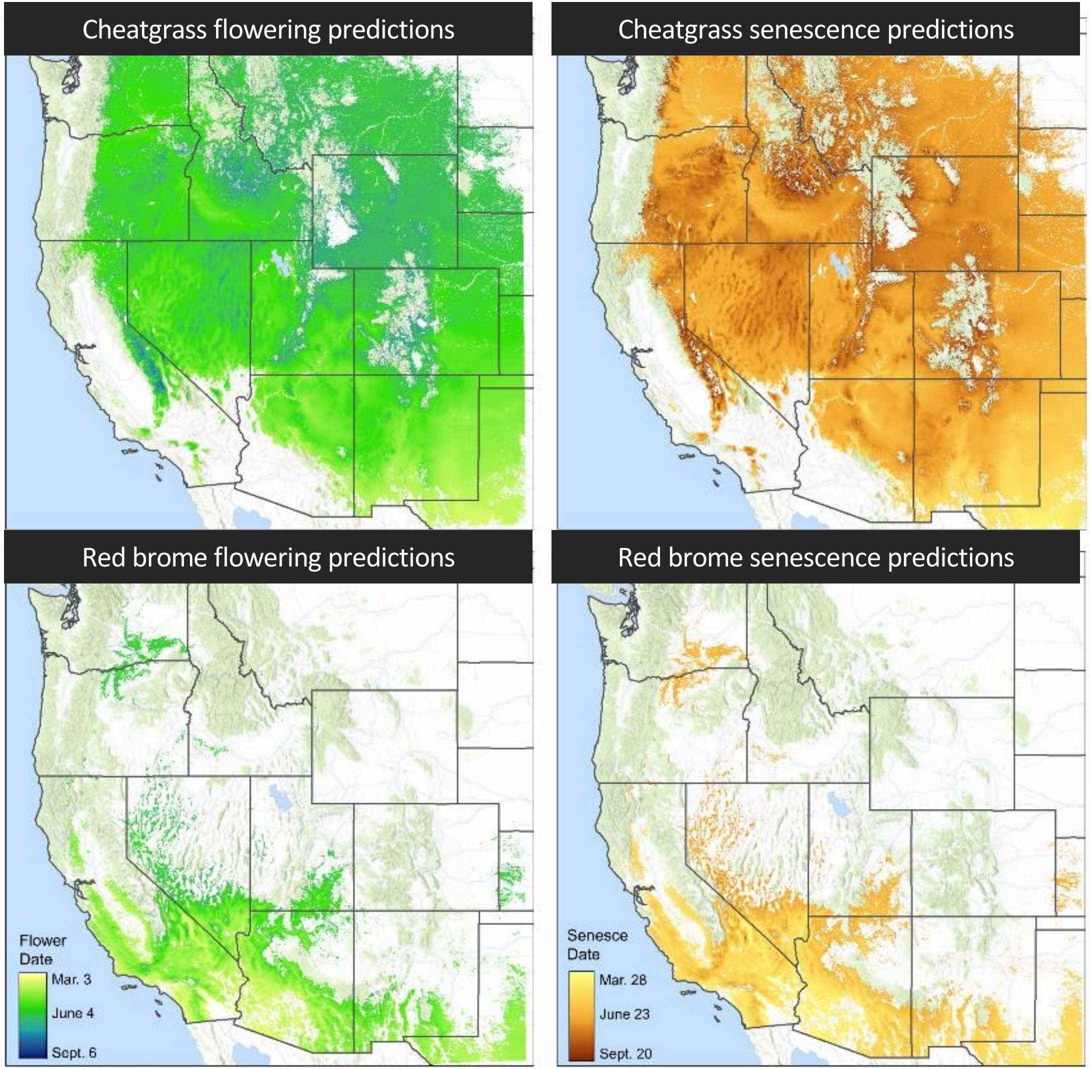
Phenology forecasting tools for management and detection of invasive grasses

Janet Prevéy

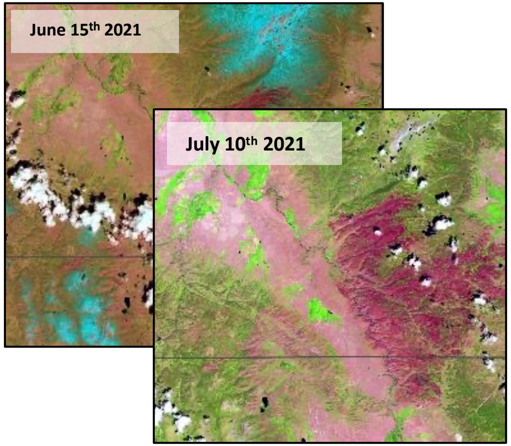
- Plant phenology is highly variable and influenced by temperature, elevation, and topography.
- We developed predictive, mechanistic phenological models to improve detection of invasive grasses across elevational gradients as the climate changes.
- Phenology models paired with species distribution/abundance maps can help managers address *when* and *where* to focus management efforts.
- **Red brome phenology forecast webtool:** https://usanpn.org/data/forecasts/Red_brome
- **Manuscript**: Prevéy, JS, et al. *In submission*. Phenology forecasting tools for detection and management of invasive annual grasses. *Ecological Applications.*



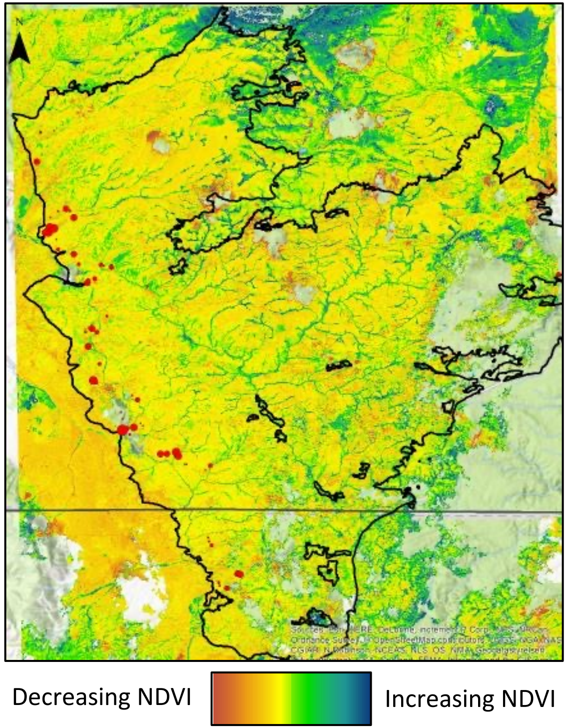
Case study: Using phenology predictions to map cheatgrass after wildfires

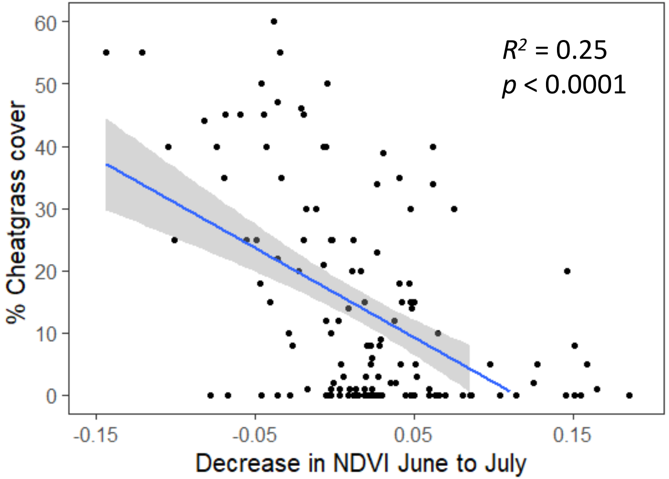
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

In collaboration with Nick Young, NREL, CSU



We differenced NDVI values from Sentinel-2 satellite imagery selected during predicted peak greenness and senescence dates to detect cheatgrass following a fire in southern Wyoming.





Changes in NDVI between peak greenness dates and senescence dates correlated with on the ground cheatgrass cover estimates of in the burned area.

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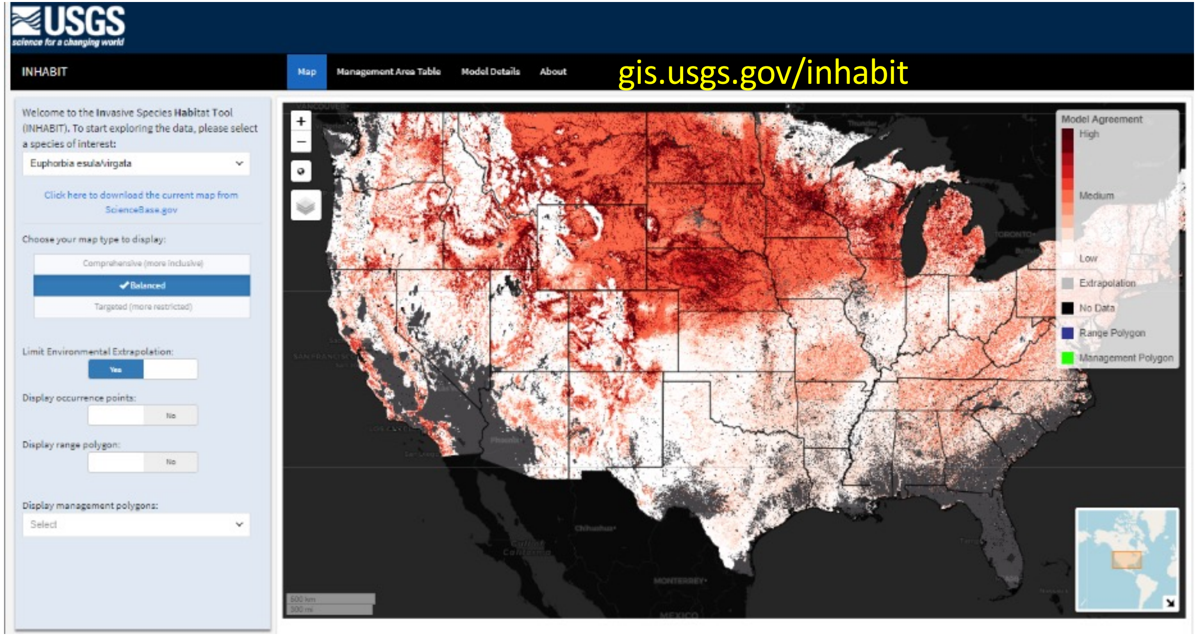
Thanks!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INHABIT
Map
Management Area Table
Model Details
About
gis.usgs.gov/inhabit
Welcome to the Invasive Species Habitat Tool (INHABIT). To start exploring the data, please select a species of interest:
Euphorbia esula/virgata
Click here to download the current map from ScienceBase.gov
Choose your map type to display:
Comprehensive (more inclusive)
Balanced
Targeted (more restricted)
Limit Environmental Extrapolation:
Yes
Display occurrence points:
No
Display range polygon:
No
Display management polygons:
Select
Model Agreement
High
Medium
Low
Extrapolation
No Data
Range Polygon
Management Polygon

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