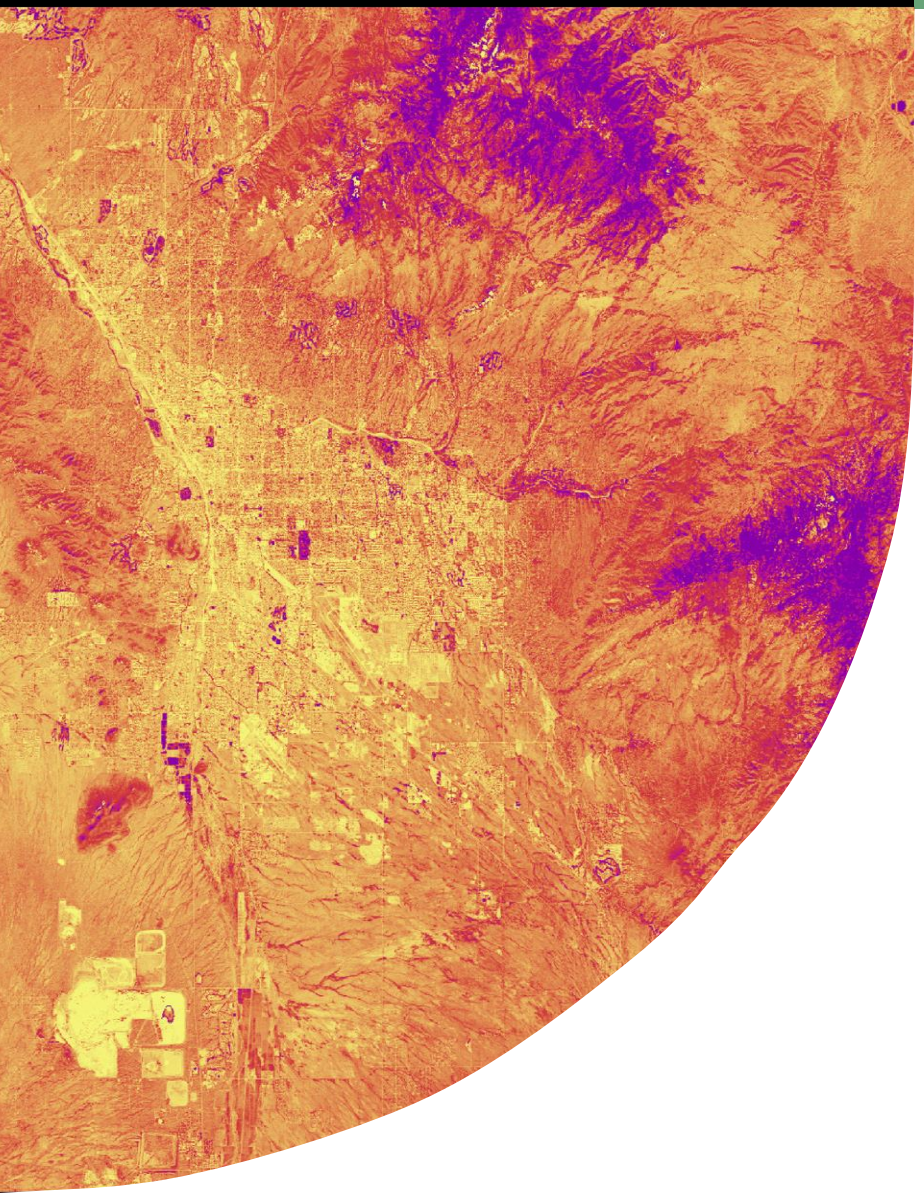
National Aeronautics and Space Administration



Sonoran Desert Ecological Conservation

Identifying and Mapping Category 1 Invasive Species in the Sonoran Desert in Southern Arizona Using Harmonized Landsat and Sentinel Data

Emma Gashi, Ghazaleh Alikaram, Davin Rich, Quinton Smith (Analytical Mechanics Associates)

Idaho – Pocatello | Spring 2025

The Sonoran Desert

"The Green Desert" - The world's most biodiverse desert

- Unique **rainfall** pattern
- Elevation gradient: ~sea level – 10,000 ft
- Microclimates

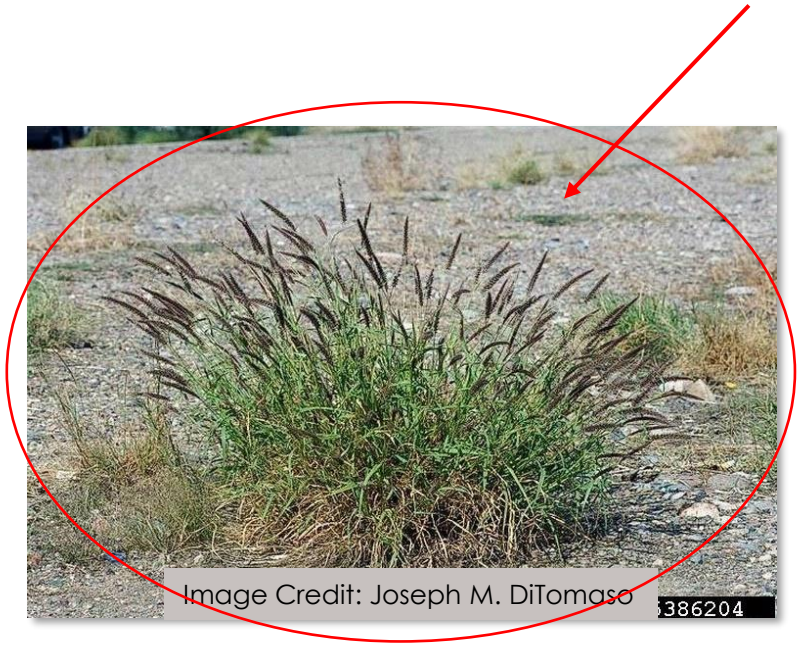
Inhabitants

- **500+** animal species, **2,000+** plant species
- Known for: **The Saguaro Cactus**, famous symbol of the Southwest

Anthropogenic Stressors

- Climate change
- Human Development
- Invasive Species

Category 1 Invasive Species



Buffelgrass

Cenchrus ciliaris

Fountain grass

Cenchrus setaceus

Stinknet

Oncosiphon piluliferum

Background

- **Buffelgrass** (*Cenchrus ciliaris*), is an invasive perennial grass species from Africa
- Originally introduced for cattle forage and erosion control, it rapidly **outcompetes native vegetation** in the Southwestern United States.
- It increases the **risk of wildfires** and has the potential to **rapidly transform** the desert landscape.

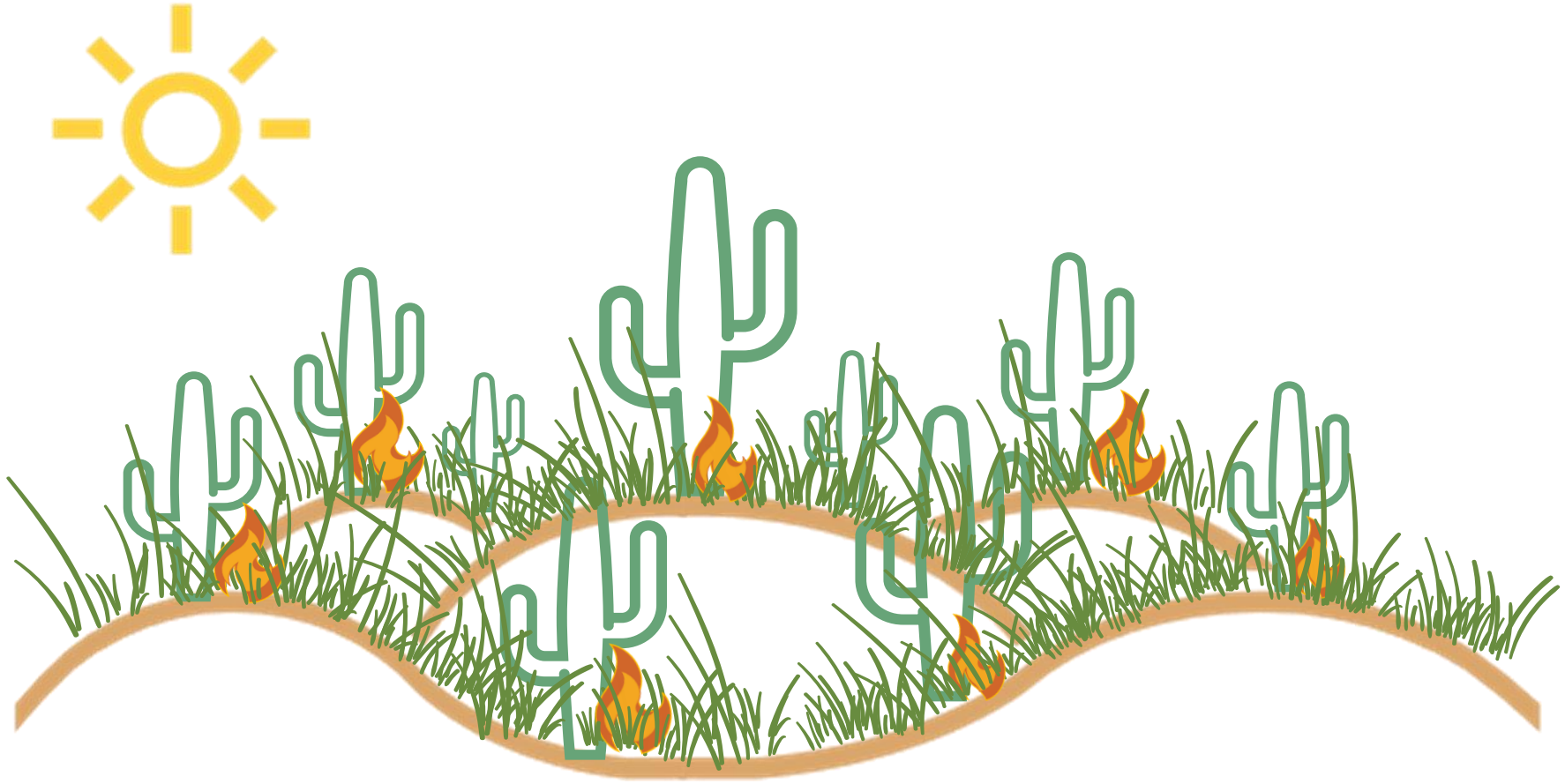
Before buffelgrass

Image credit: Saguaro National Park

After buffelgrass

Image credit: Saguaro National Park

Community Concerns



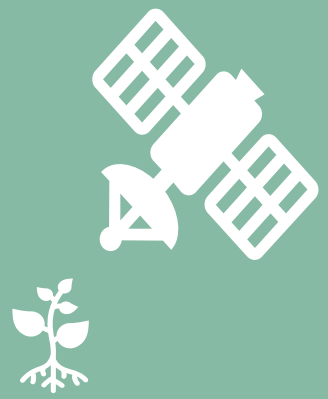
Buffelgrass creates a positive feedback loop for wildfires

Project Partners

- National Park Service
  - Saguaro National Park
  - Tumacácori National Historical Park
- United States Fish & Wildlife Service
  - Arizona National Wildlife Refuges
- United States Geological Survey
  - Western Geographical Science Center

Objectives

Use vegetation indices and phenology data products to identify buffelgrass green-up



Vegetation Distribution Time Series

Map areas most susceptible to buffelgrass infestations

Buffelgrass Habitat Suitability Model

Image credit: Bob Wick

Study Area

Pima and Santa Cruz Counties, Arizona

Size

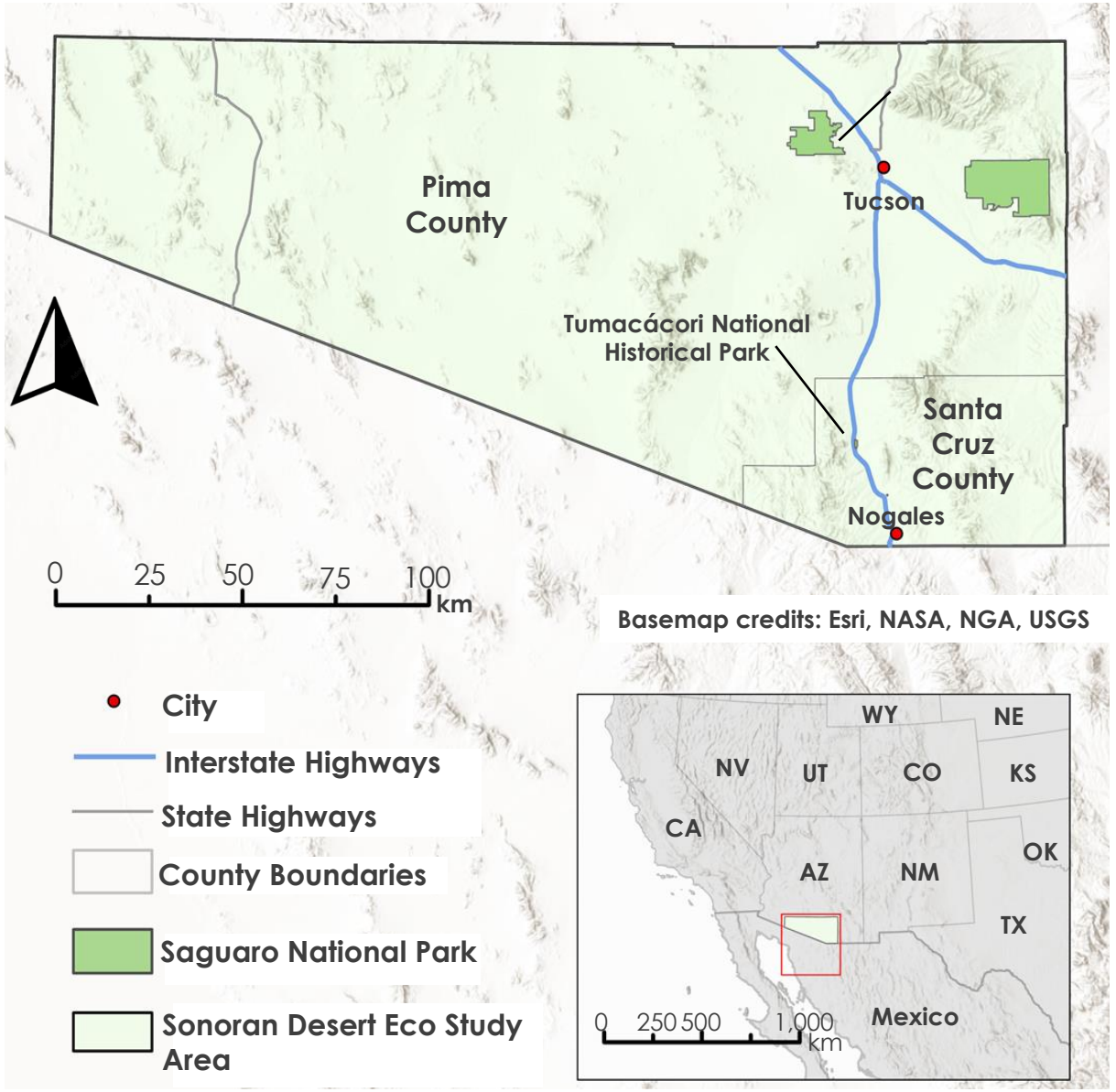
- 27,004 km² of the Sonoran Desert.

Home to

- National Parks and Monuments
- Tohono O'odham Nation Reservation
- City of Tucson

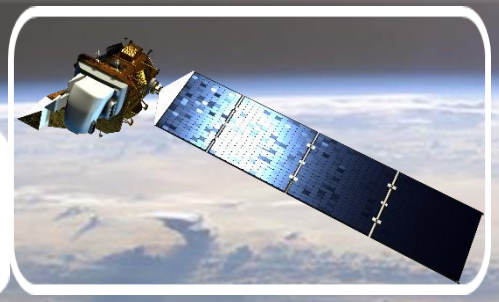
Study Period

- January 2016 – December 2024



Earth Observations

Landsat 8
Operational Land Manager (OLI) Sensor



Sentinel-2
Multi-Spectral Instrument (MSI)

Normalized Difference Vegetation Index (NDVI)

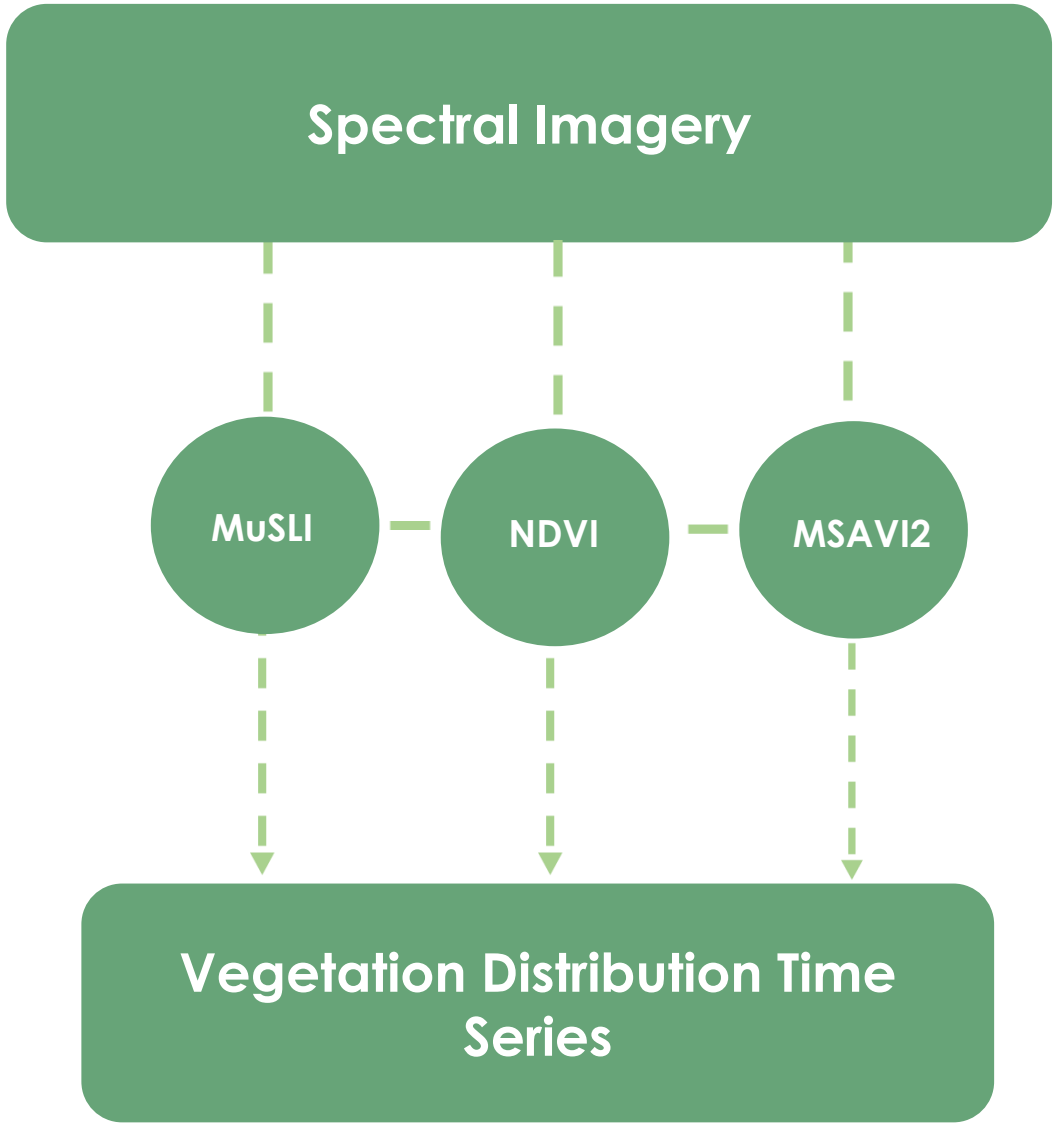
Harmonized Landsat and Sentinel-2 (HLS)

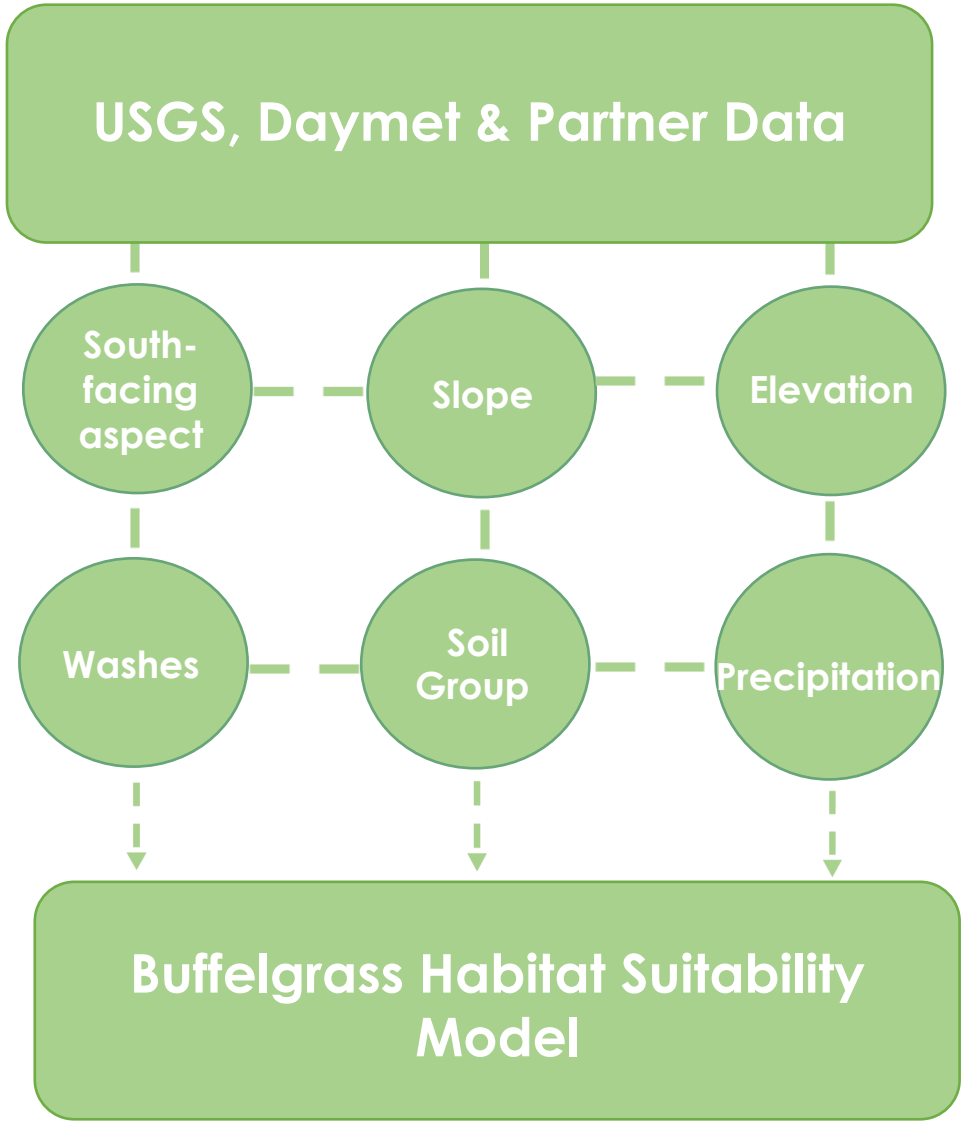
Second Modified Soil Adjusted Vegetation Index (MSAVI2)

Multi-Source Land Imaging (MuSLI)
Land Surface Phenology

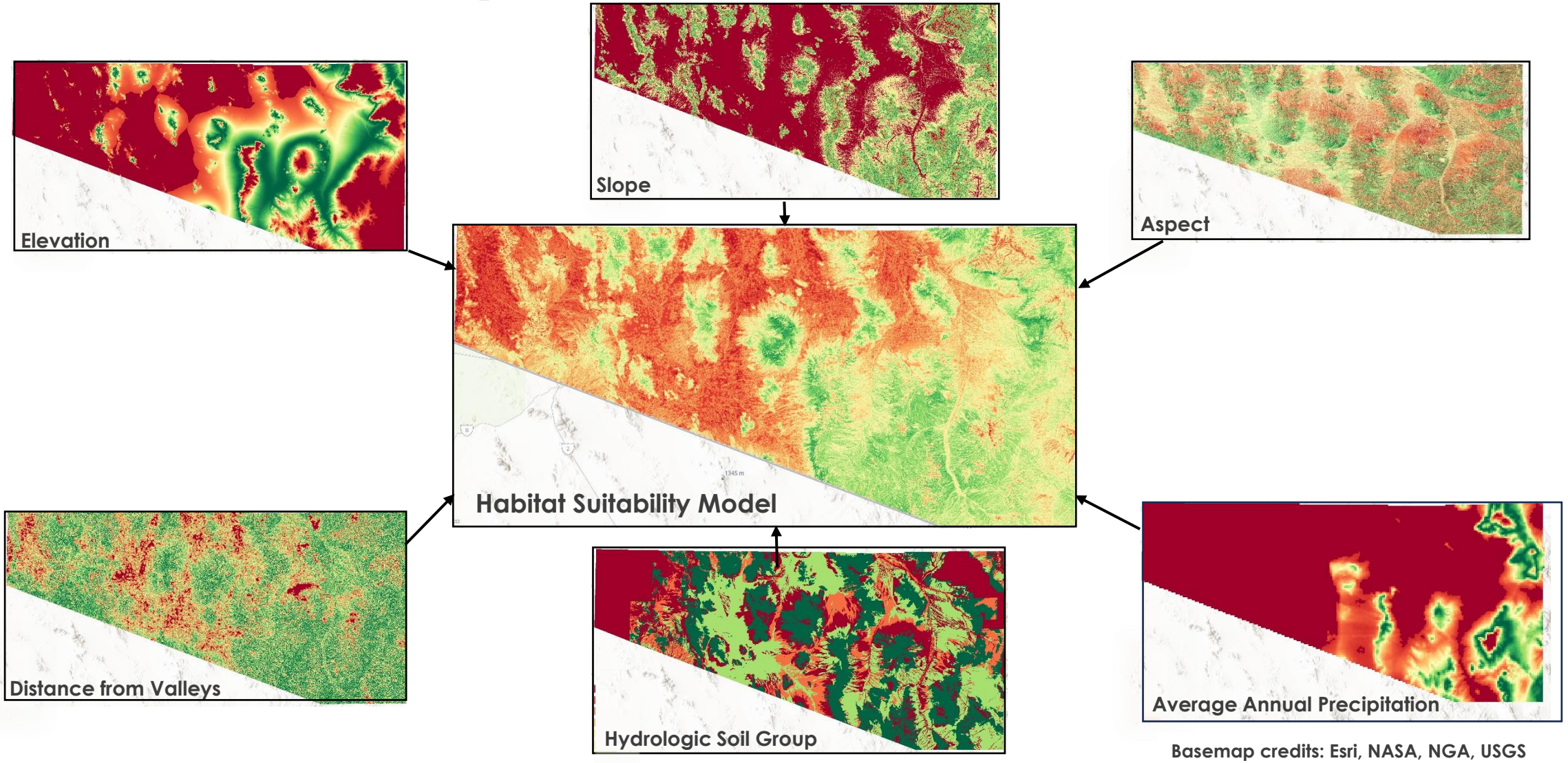
Image Credits: NASA, Rama

Methods


Spectral Imagery
MuSLI
NDVI
MSAVI2
Vegetation Distribution Time Series

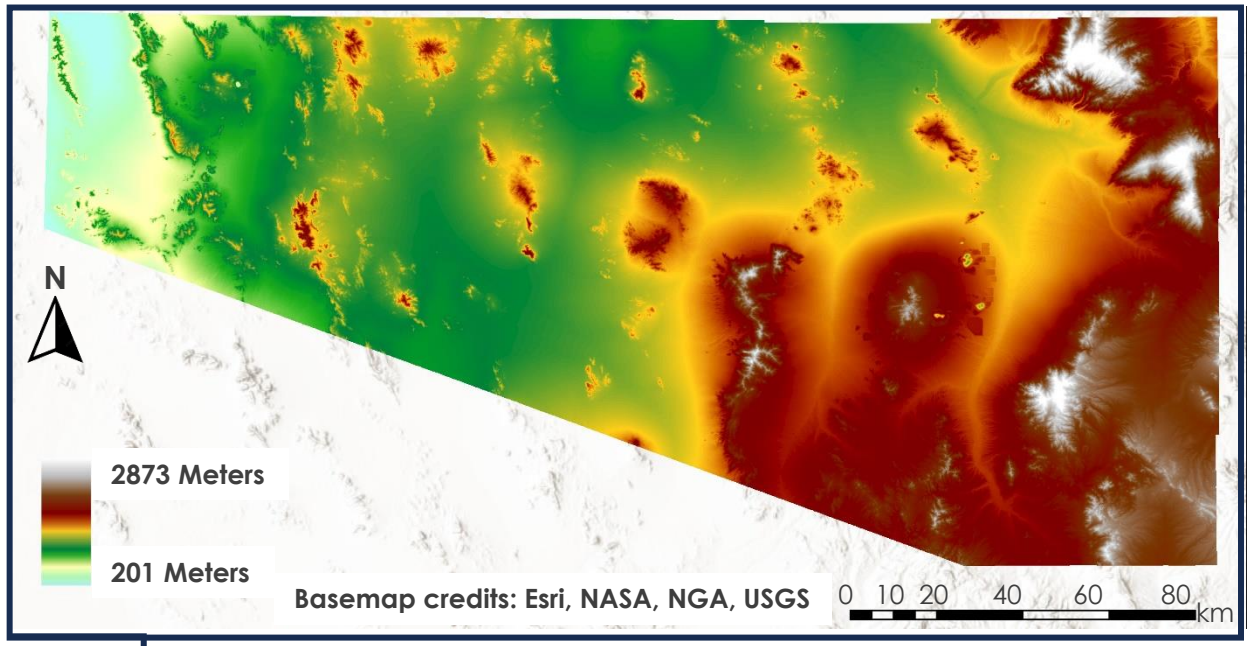

USGS, Daymet & Partner Data
South-facing aspect
Slope
Elevation
Washes
Soil Group
Precipitation
Buffelgrass Habitat Suitability Model

Habitat Suitability - Workflow

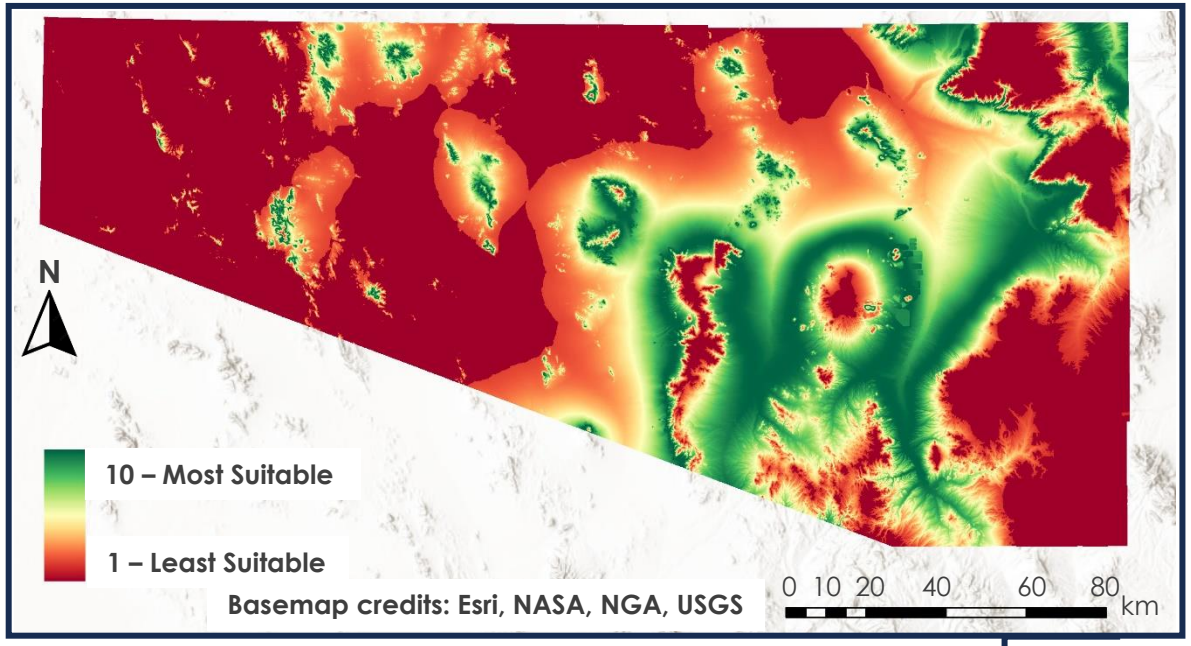


Basemap credits: Esri, NASA, NGA, USGS

Elevation

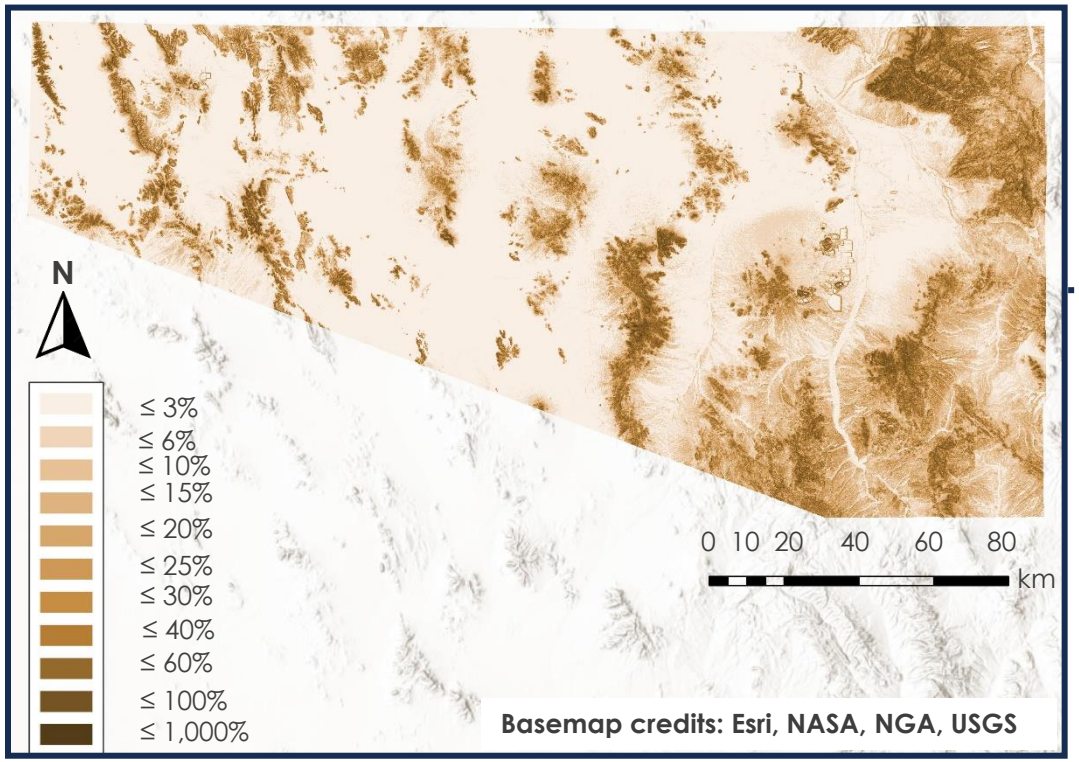


- USGS Topographic Digital Elevation Model (DEM)
- 30 x 30meter resolution



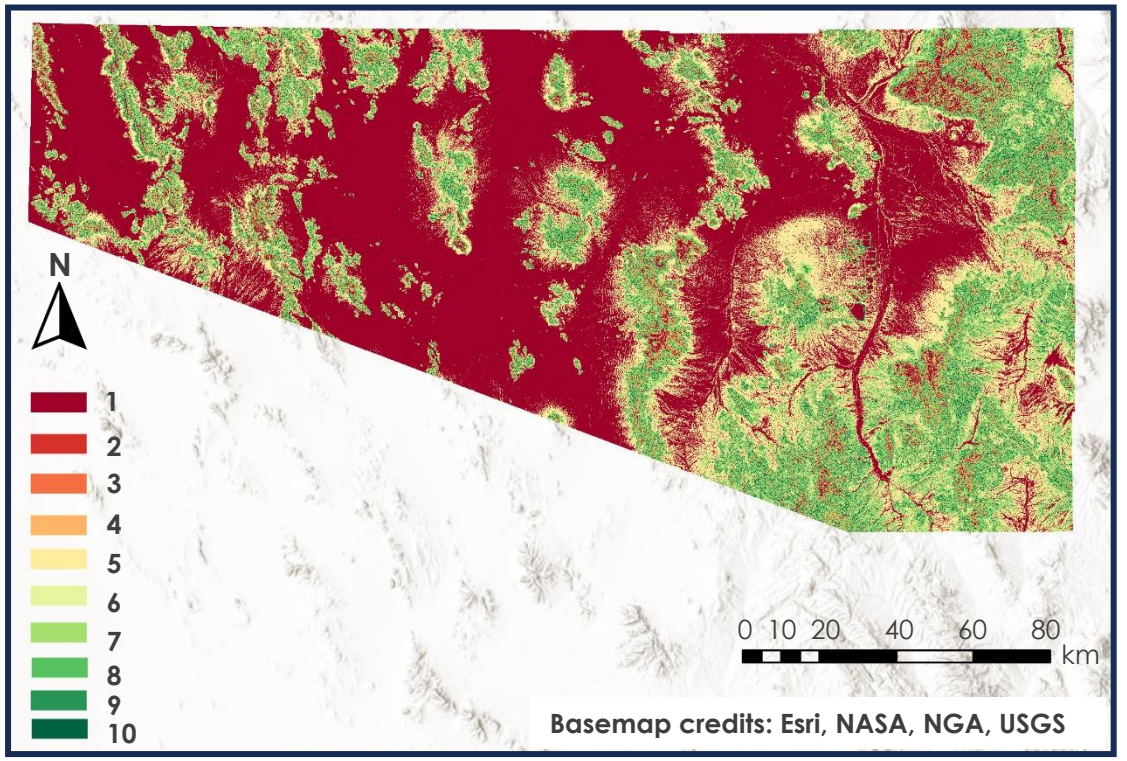
- Elevation values transformed to suitability values
- Ideal elevation values between 839-1,476 m

Slope

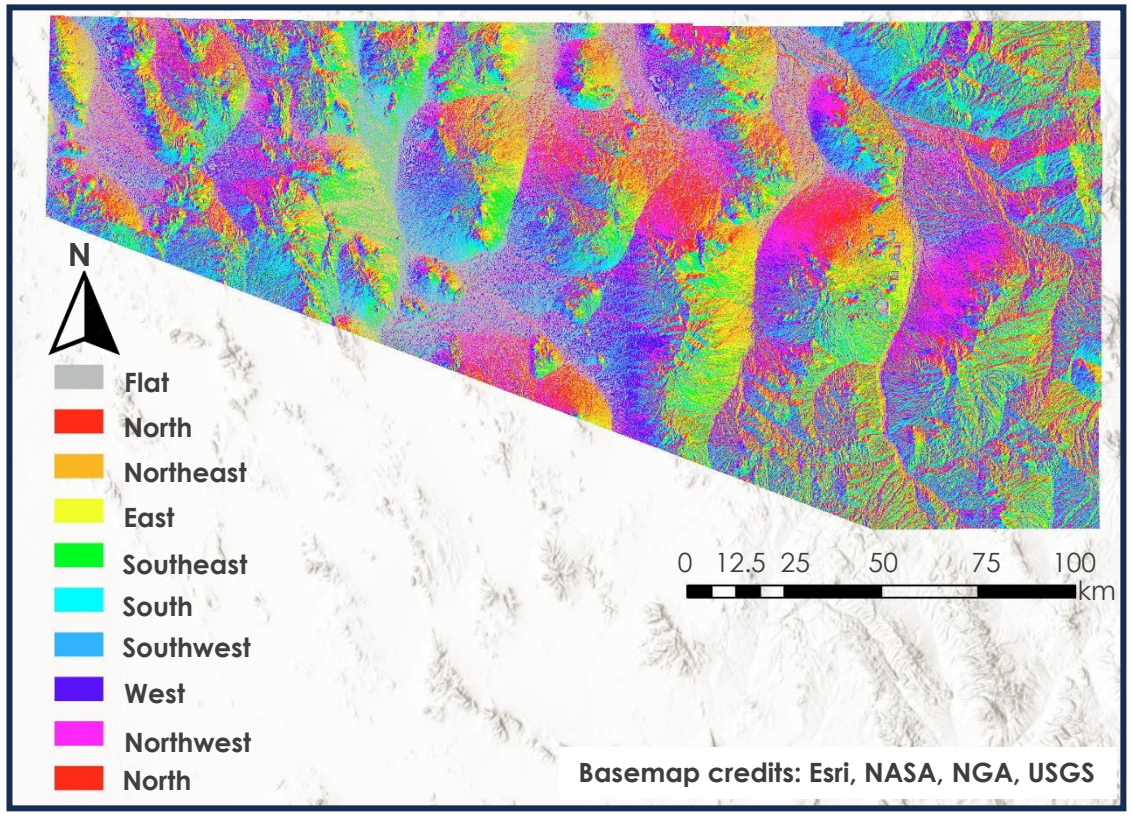


- Derived from USGS DEM
- Suitable slope range 25-34%

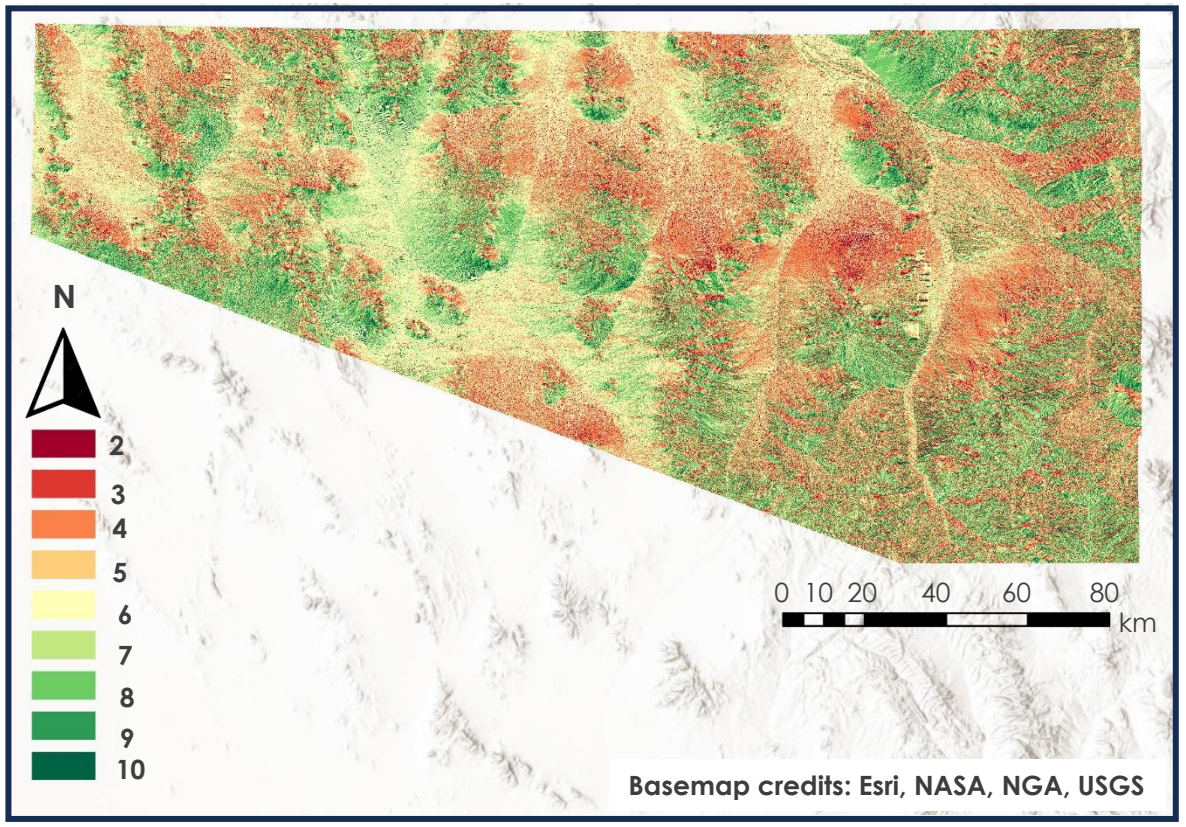
- Slope Values transformed to suitability values



Aspect

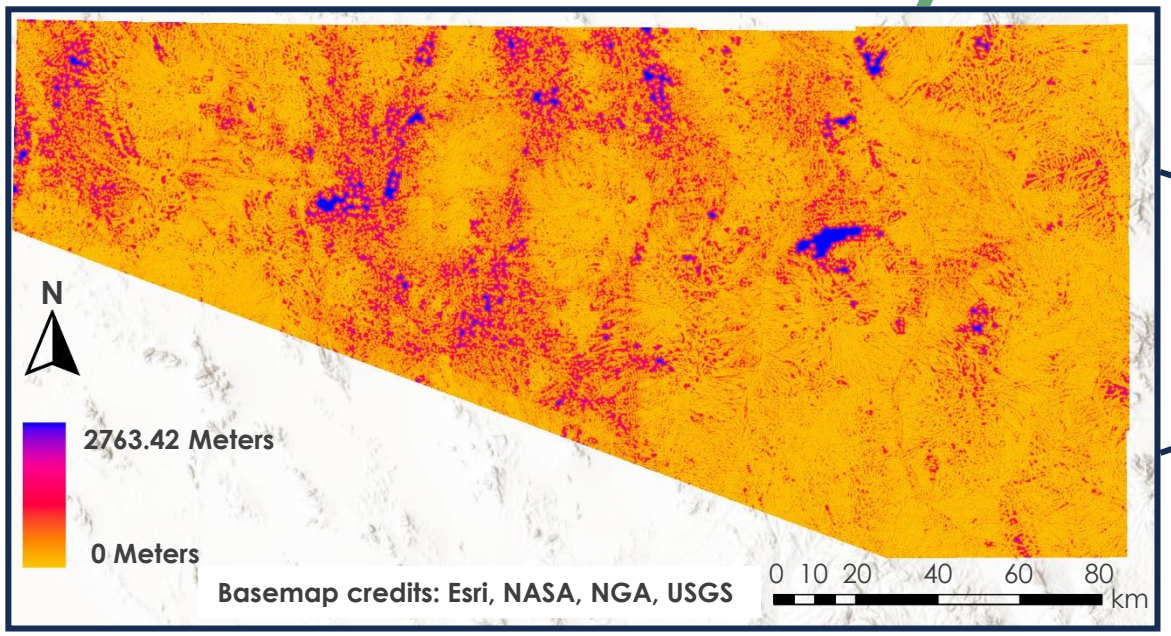


- Made from USGS DEM
- Grows well on south facing slopes



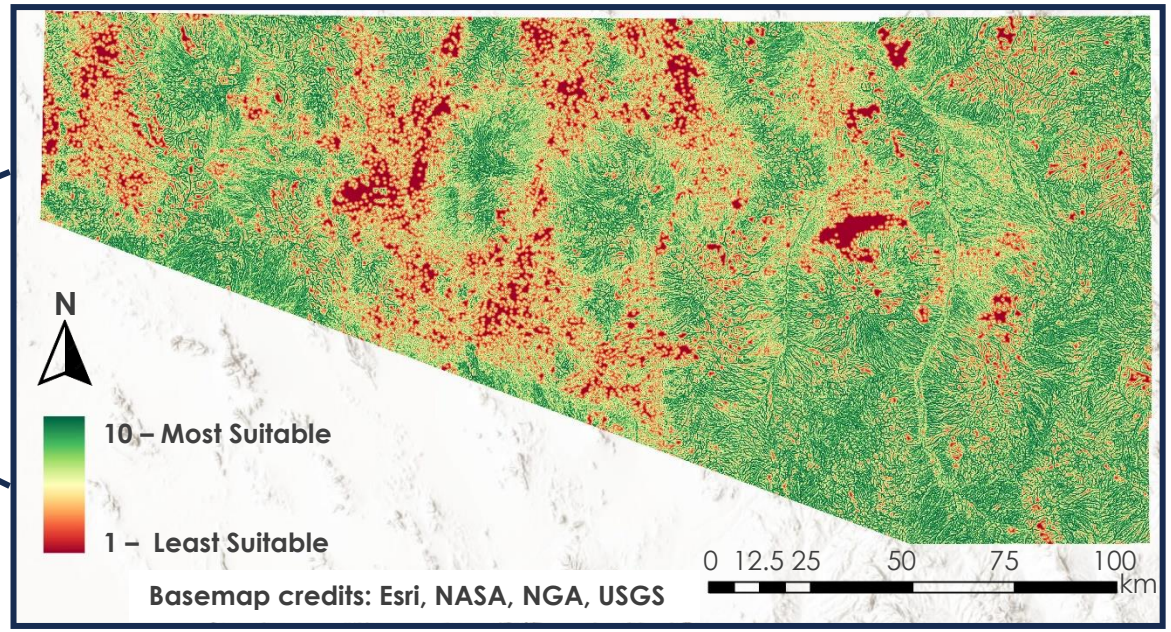
- Aspects transformed into suitability values
- Dark green areas are south facing slopes

Distance From Valleys

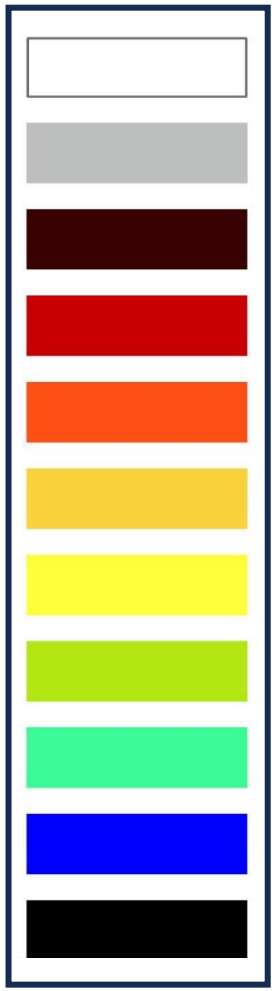


- Distance from valleys
- Created by first identifying where washes are and then setting a distance from them.

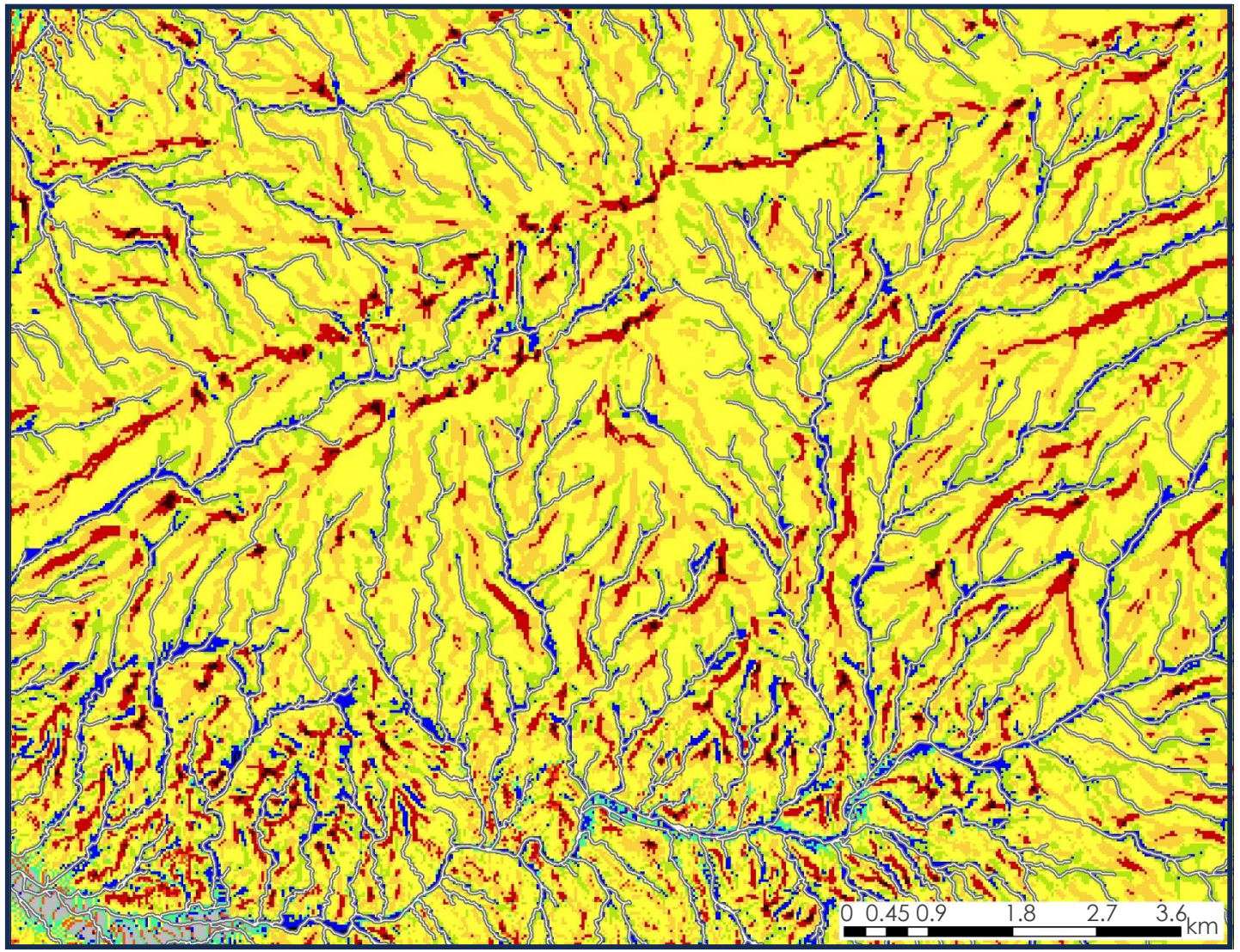
- Integrated into suitability model
- Closer to a valley = high suitability



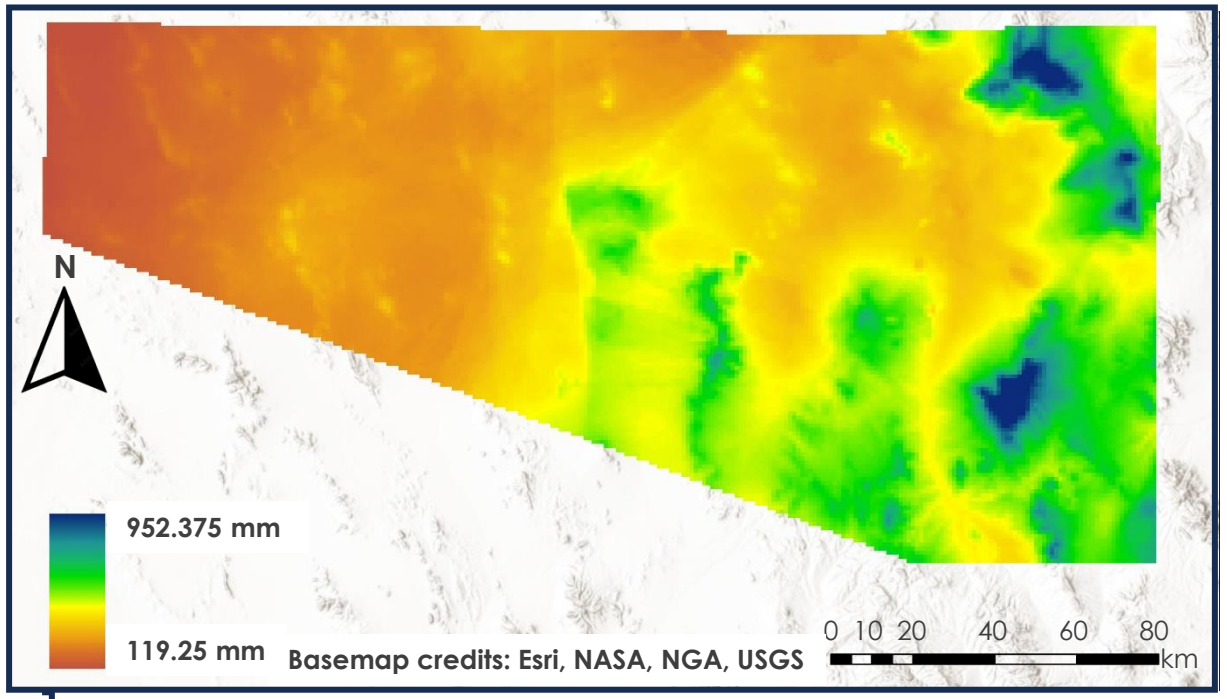
Landforms and Washes

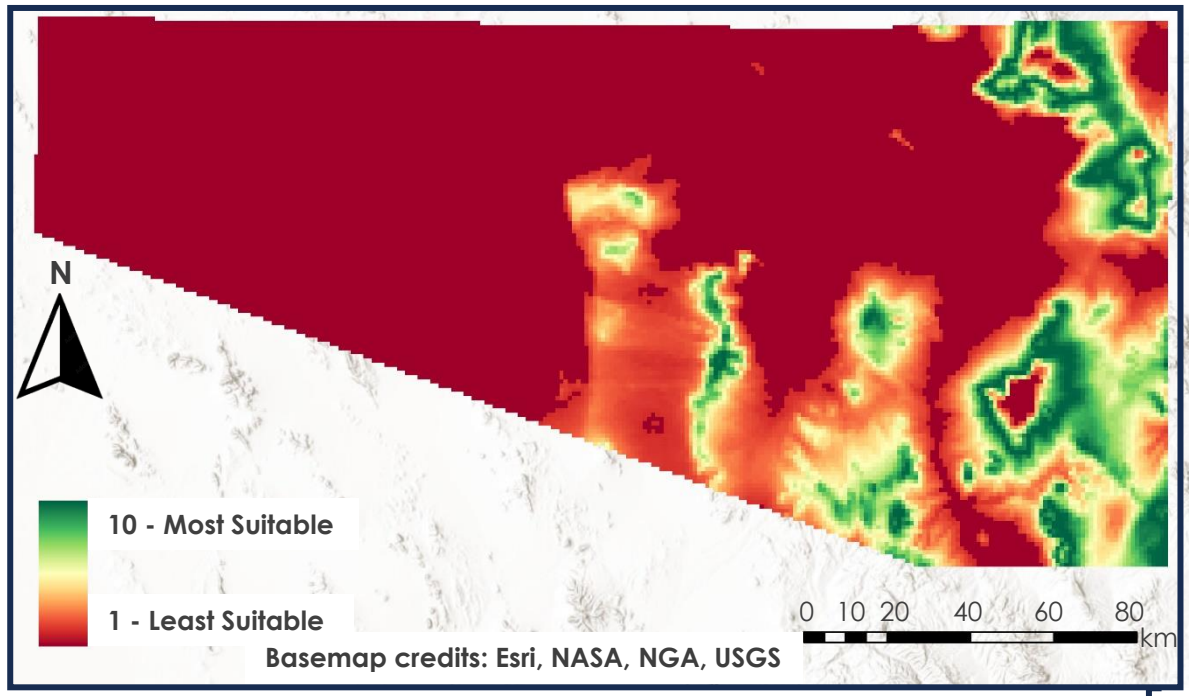


Saguaro Washes
Flat
Peak
Ridge
Shoulder
Spur
Slope
Hollow
Foot slope
Valley
Pit



Average Annual Precipitation

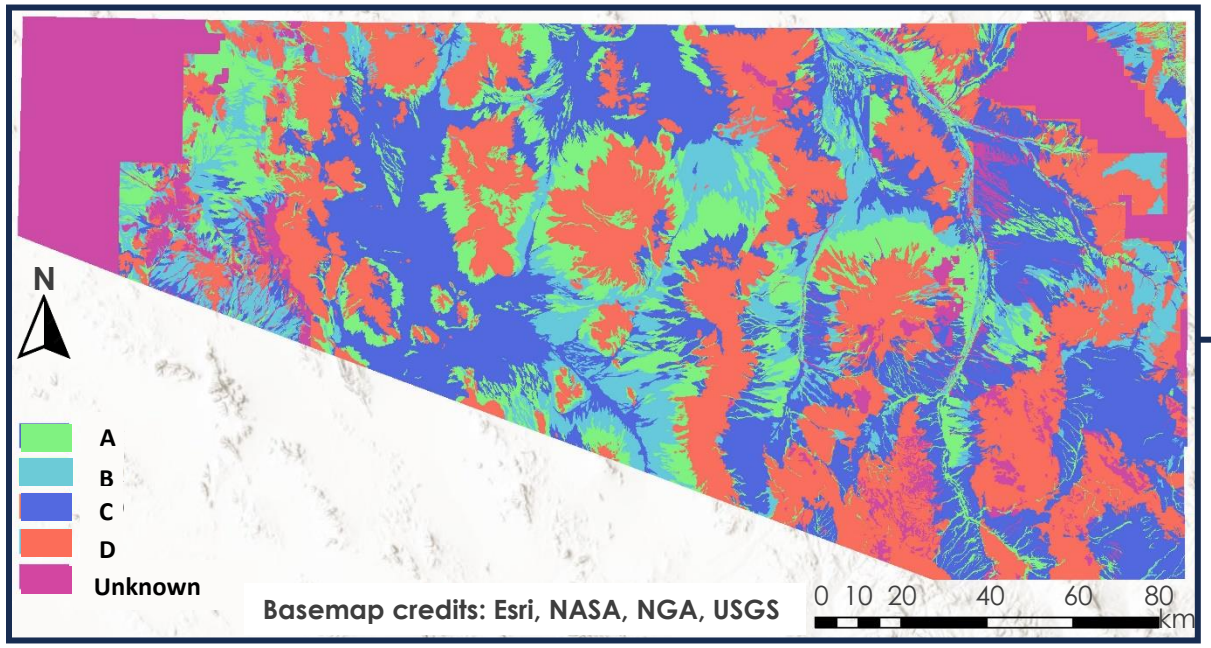




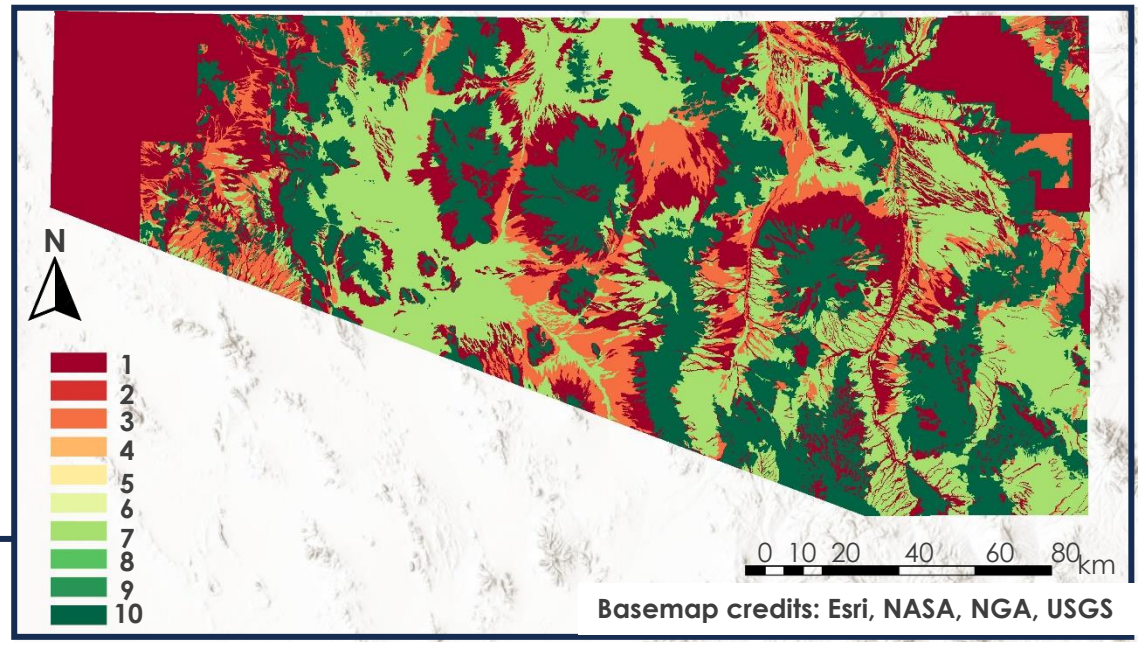
- Averaged Annual Precipitation from 2016-2023

- Precipitation values between 375 mm to 750 mm are suitable

Hydrologic Soil



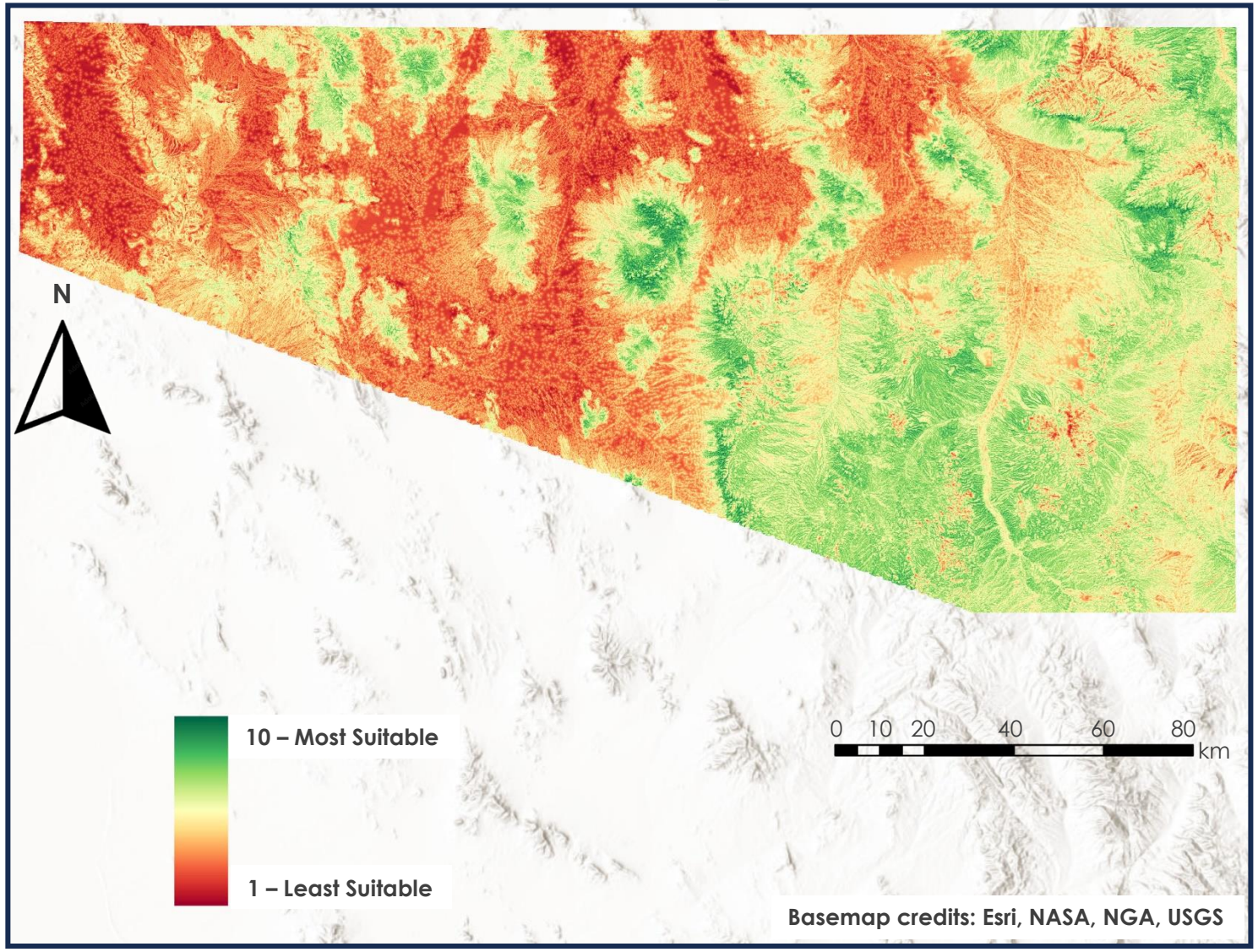
- Hydrologic Soil Groups ranked from highest runoff potential to lowest runoff potential
  - D,C,B,A



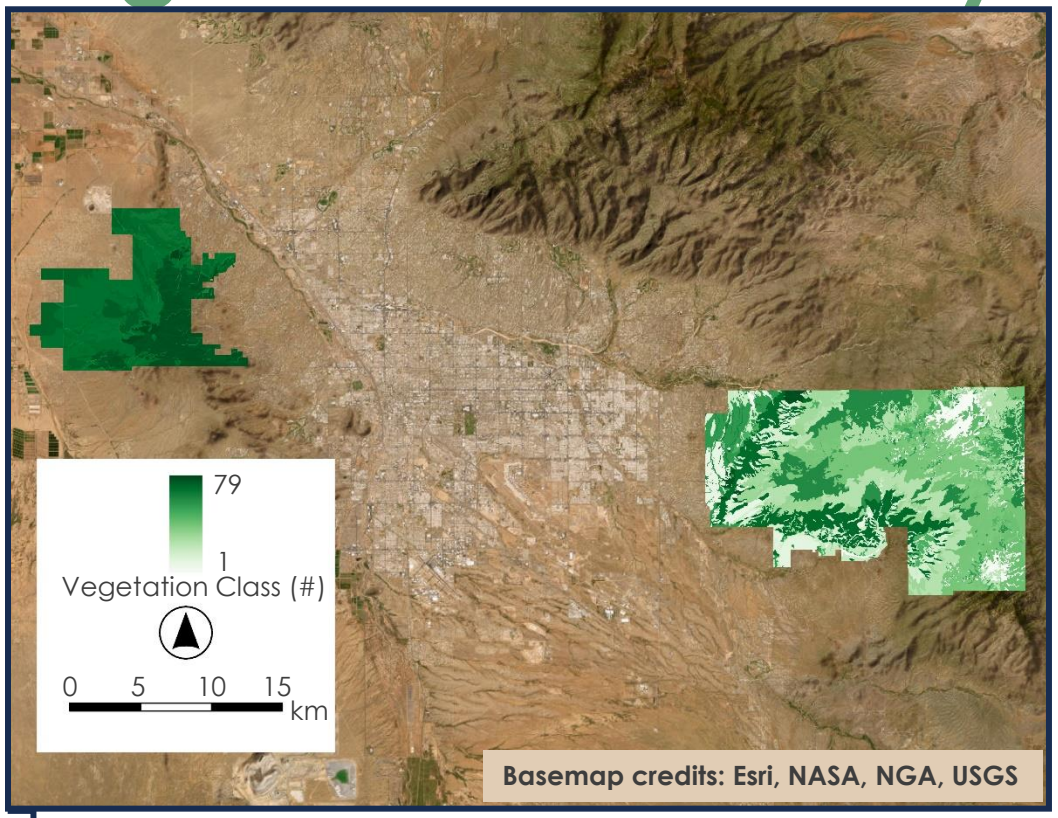
- Transformed hydrologic soil group
- Group D has highest value

Habitat Suitability Model - Entire Study Area

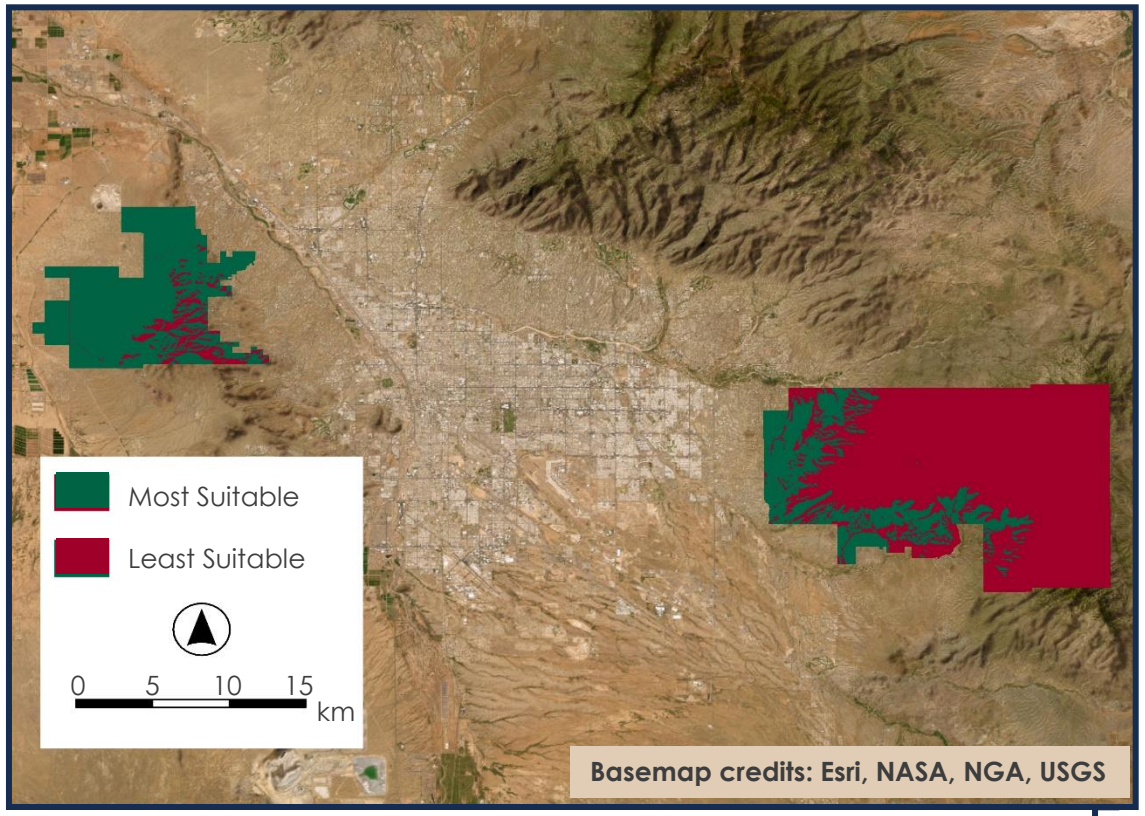
Suitability Model (Study Area)	
Variables	**Weight (%)**
Elevation	20.0
Slope	20.0
Aspect	20.0
Soil Hydrologic Group	10.0
Average Annual Precipitation	10.0
Distance from valleys	20.0



Vegetation Class Layers



- Data provided by partners & USDA
- Desert scrub: Yellow paloverde, saguaro, brittle bush, acacia, spiny hackberry, etc.

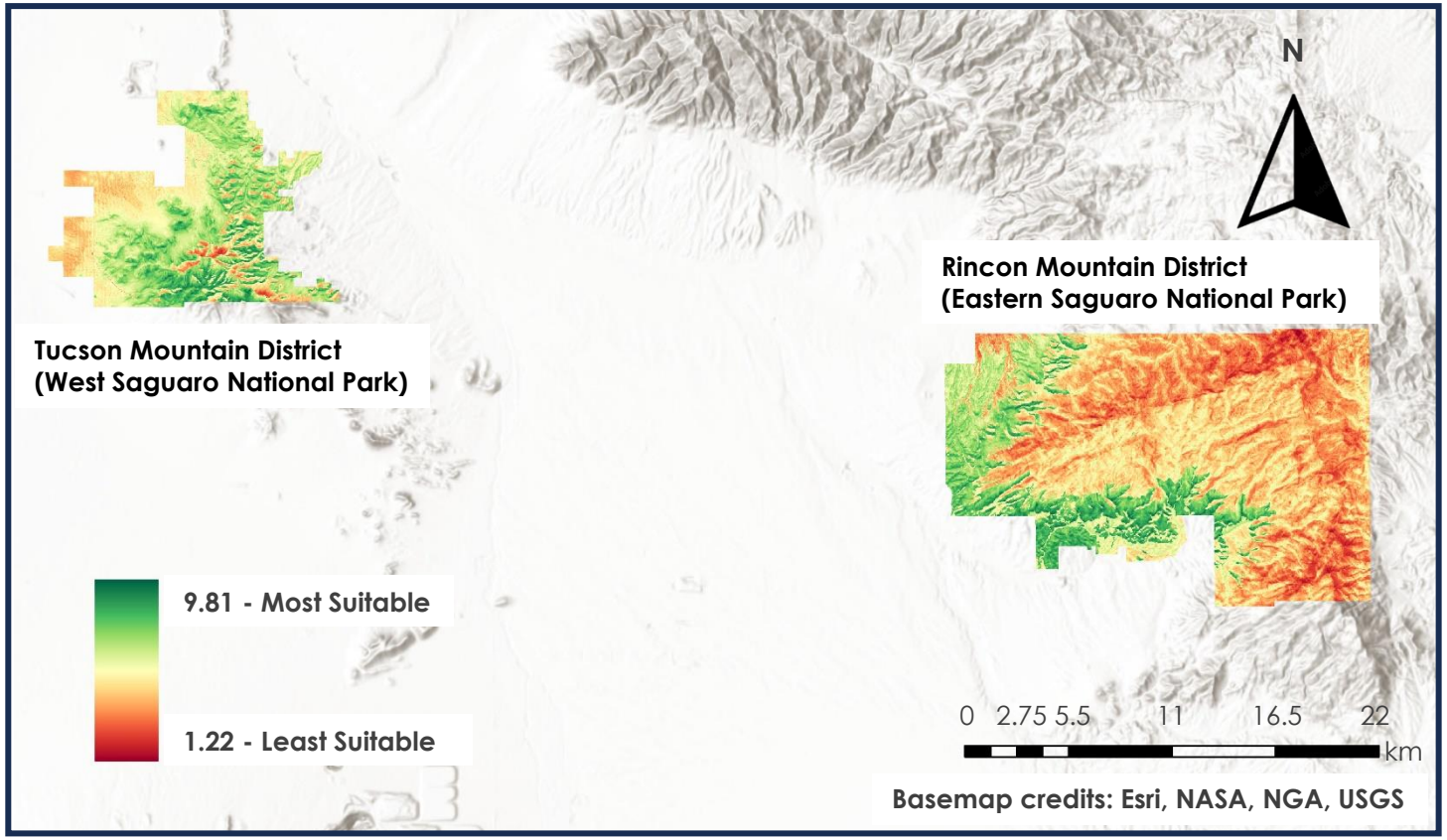


- Integrated into suitability model
- Vegetation buffelgrass commonly invades are in green

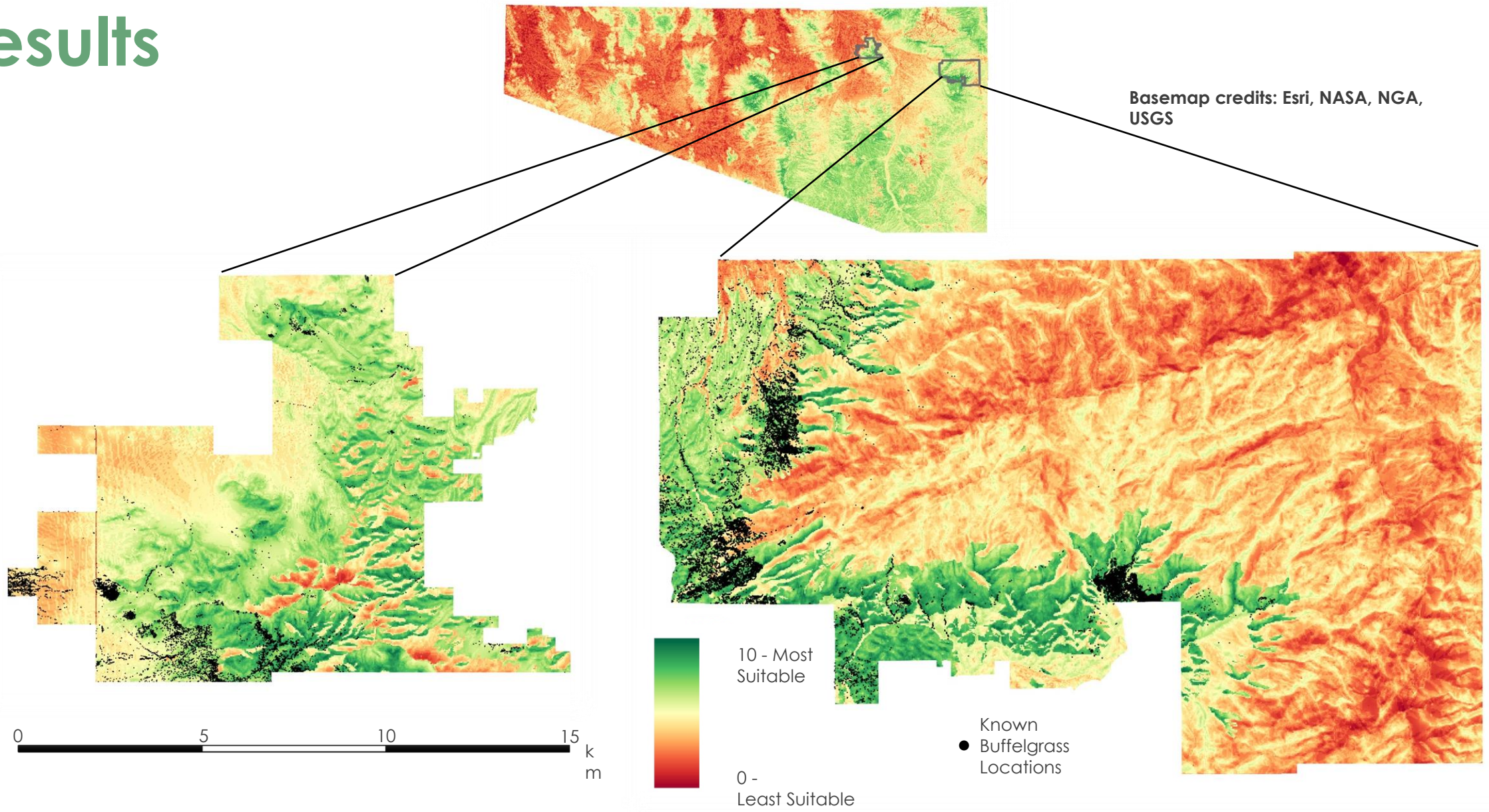
Habitat Suitability Model - Saguaro National Park

The Suitability Model that contains Vegetation Classes for Saguaro National Park.

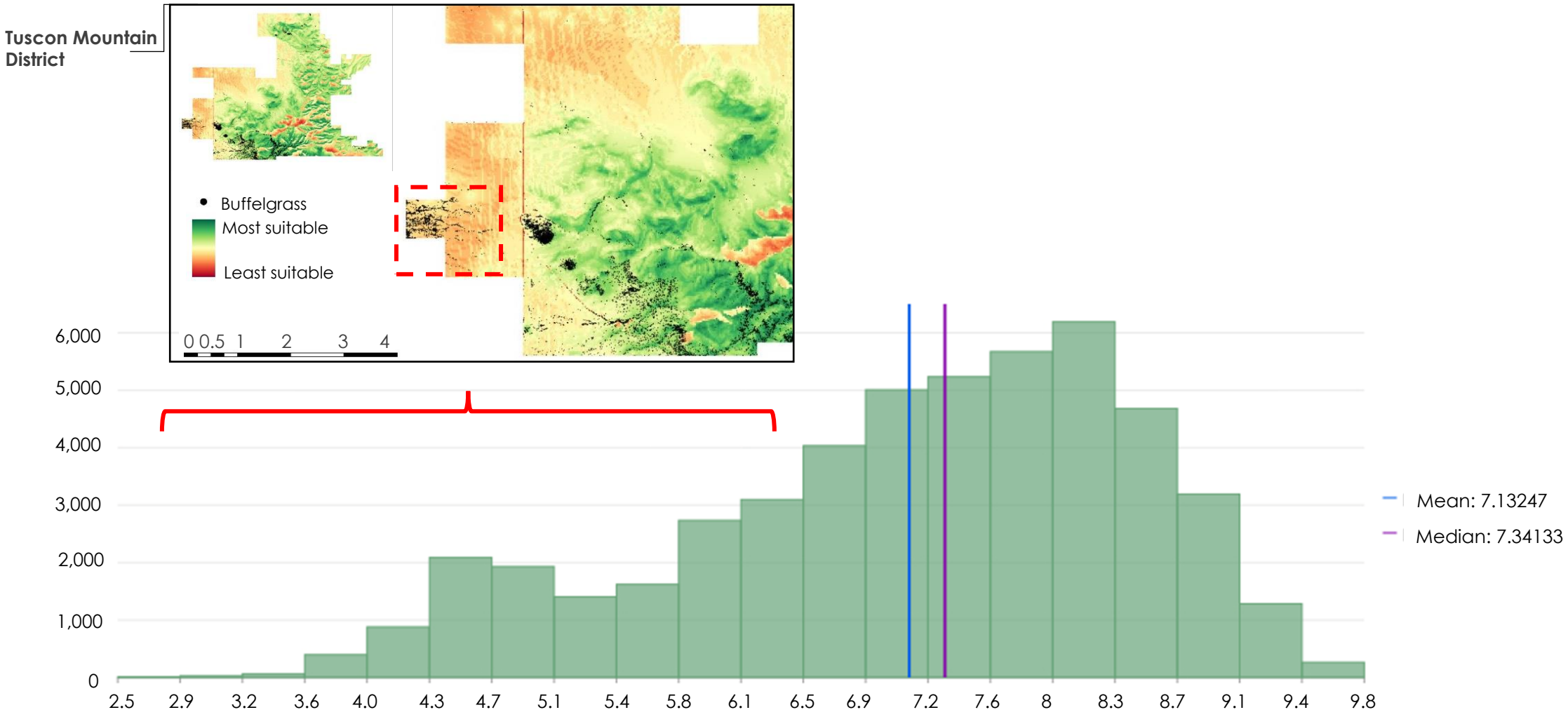
Suitability Model (Saguaro National Park)	
Variables	**Weight (%)**
Aspect	20.0
Elevation	15.0
Slope	15.0
Soil Hydrologic Group	5.0
Average Annual Precipitation	5.0
Distance from valleys	15.0
Vegetation Classes	25.0



Results

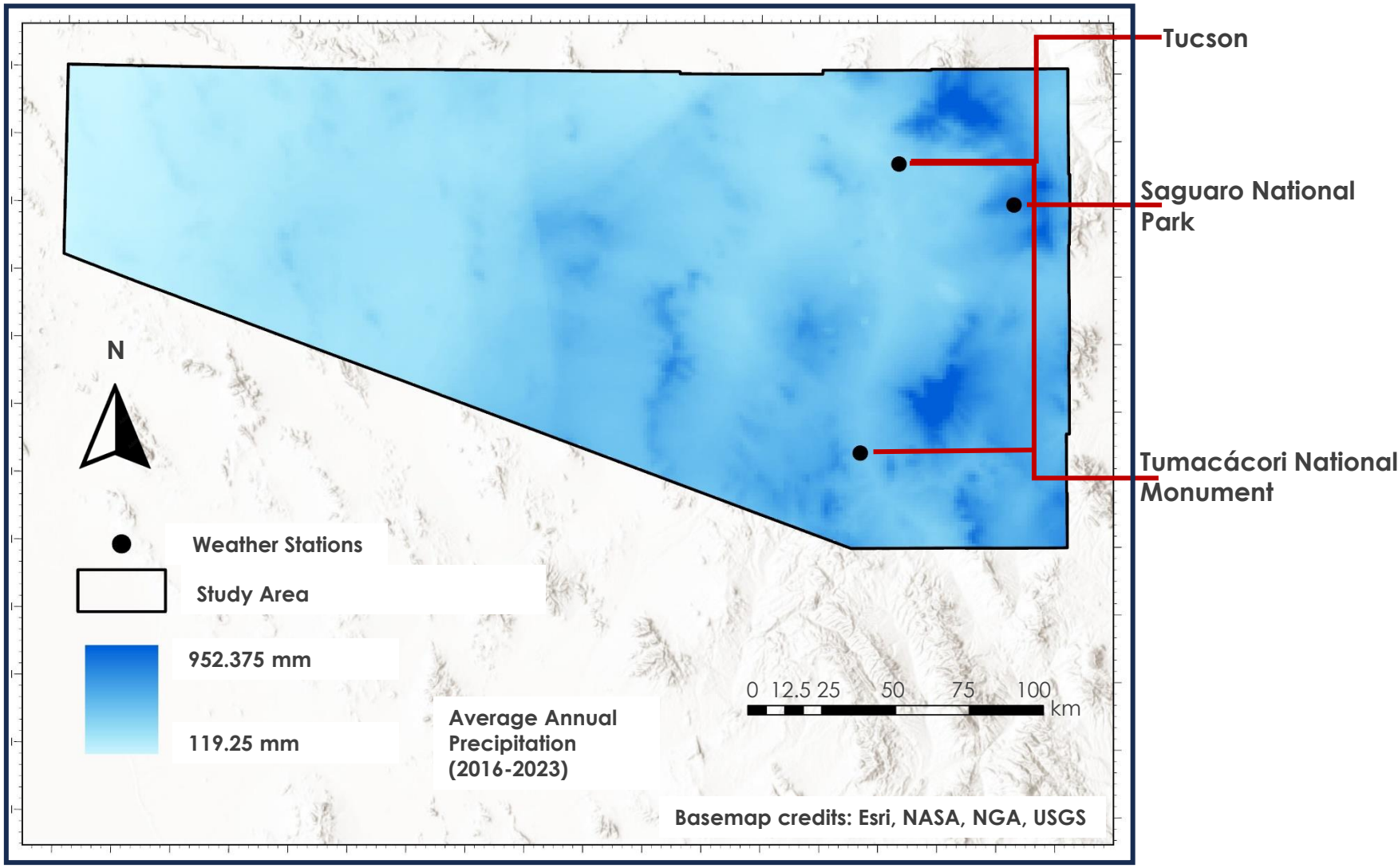

Basemap credits: Esri, NASA, NGA, USGS
0
5
10
15
km
10 - Most Suitable
0 - Least Suitable
Known Buffelgrass Locations

Results- Suitability Values of Known Buffelgrass

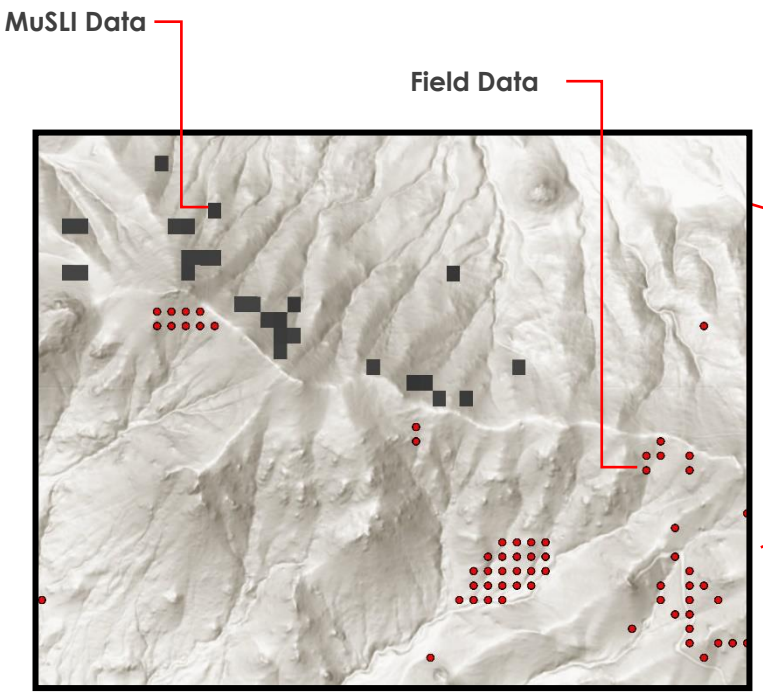


Vegetation Distribution Time Series- Methods

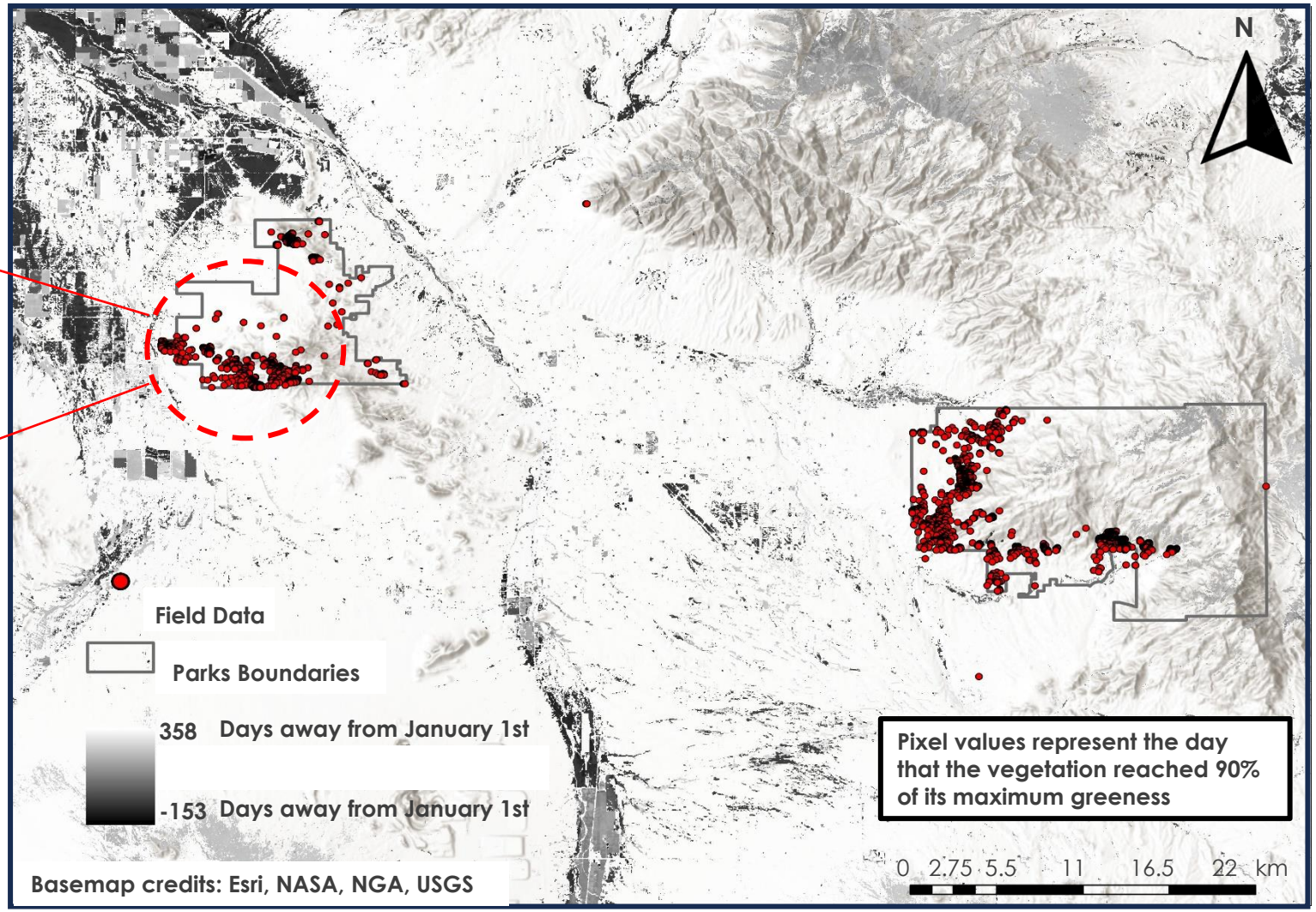
- Identified significant rainfall events
- Buffelgrass greens up 3-7 weeks after rainfall events over 1 inch over several days
- Weather Station Data from NOAA was used to validate Daymet data



Methods- 90% Green-up



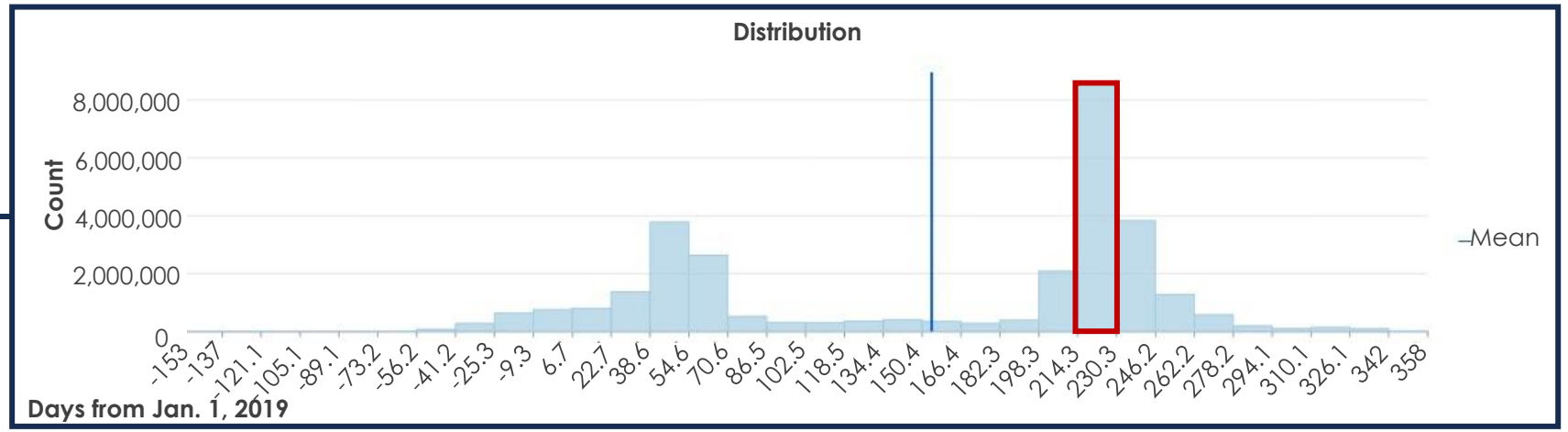
- We looked for 90% green-up in the winter months
- Overall, field data and 90% green-up data did not overlap



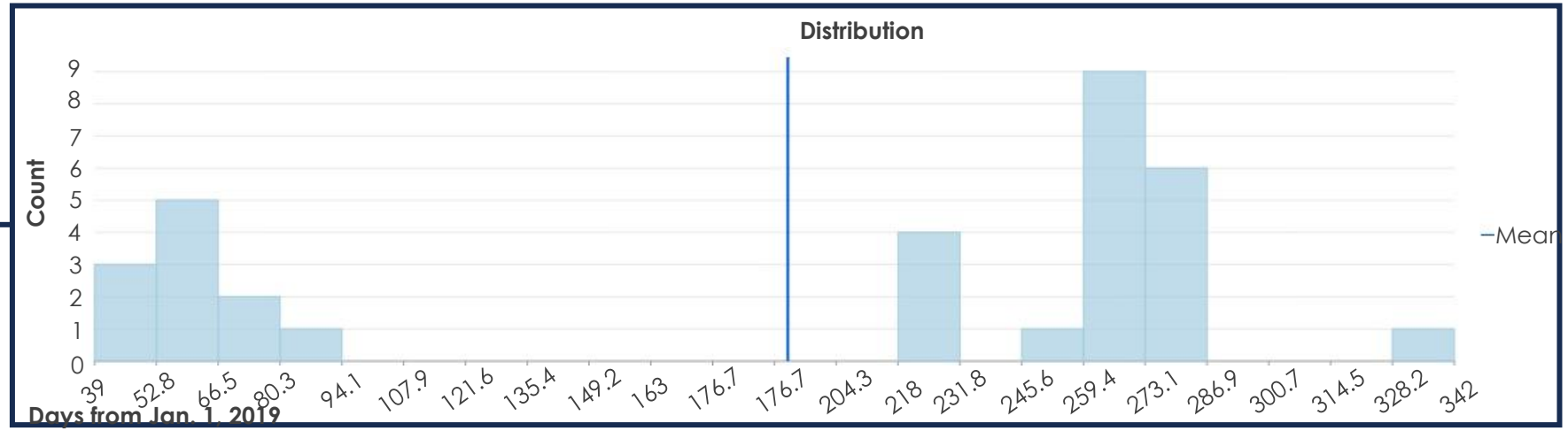
Example from 2019 showing buffelgrass field data and MuSLI 90% green-up data

Methods – 90% Green-up

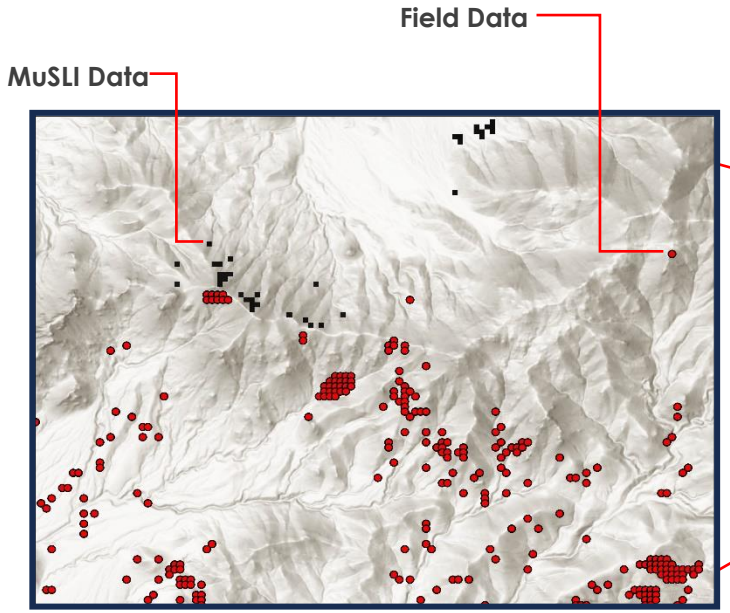
90% green-up histogram for entire study area



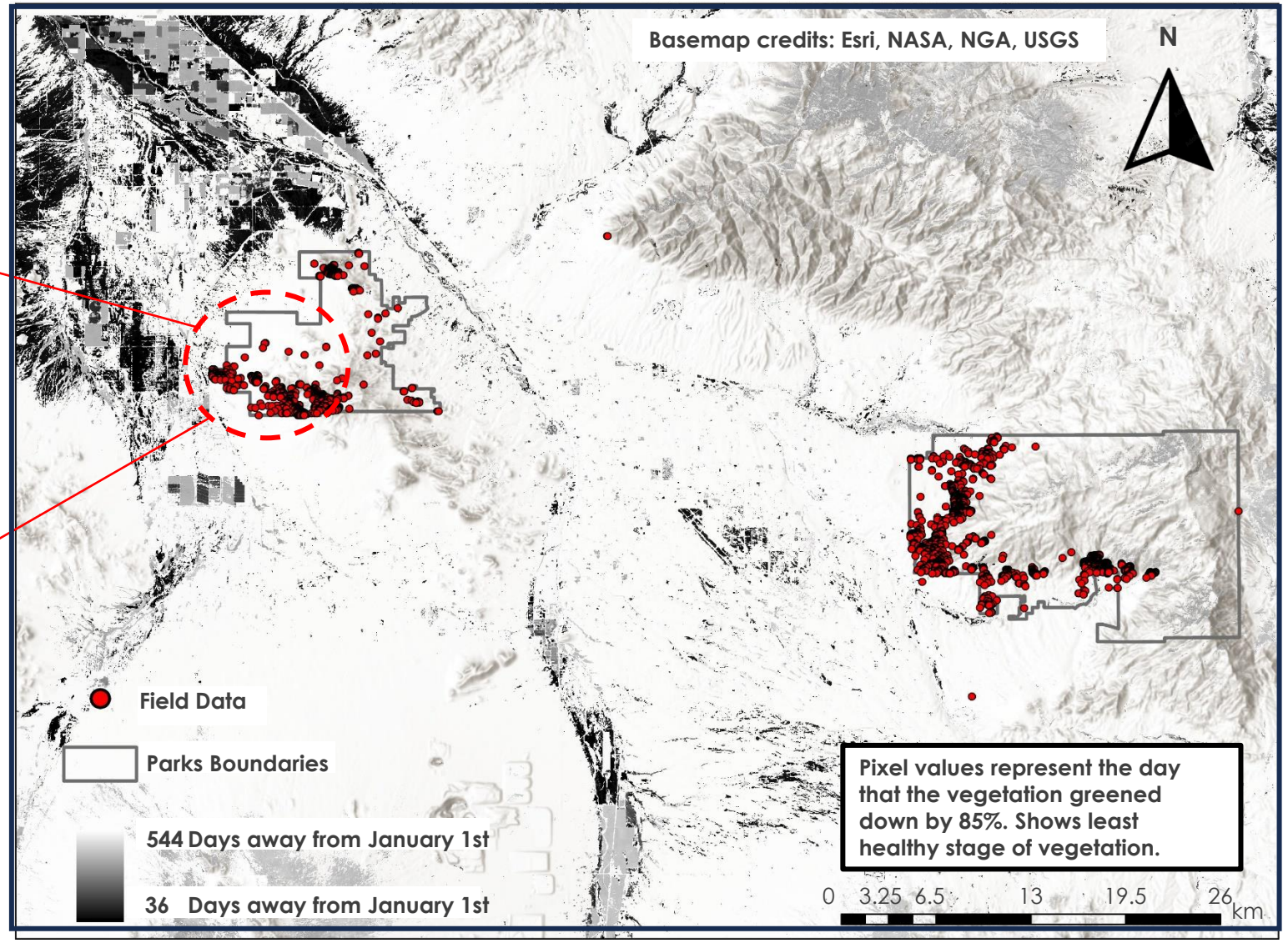
Corresponding 90% green-up values for known buffelgrass locations



85% Green-down



- We looked at 85% green-down data during the winter months
- The 85% green-down data did not match field data



Example from 2019 showing buffelgrass field data and MuSLI 85% green-down data

Spectral Imagery

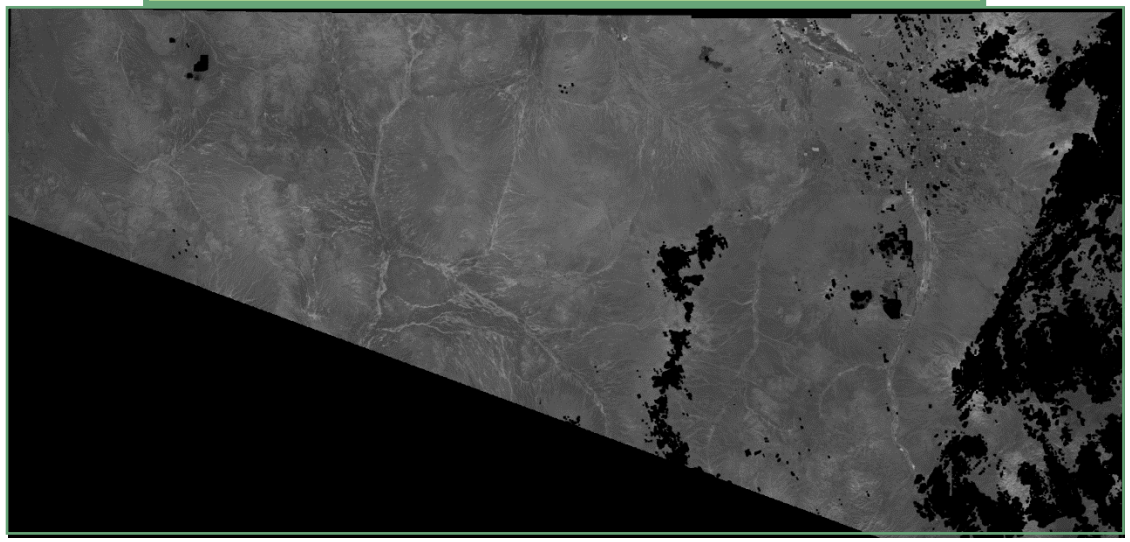
Raw HLS Images

Python

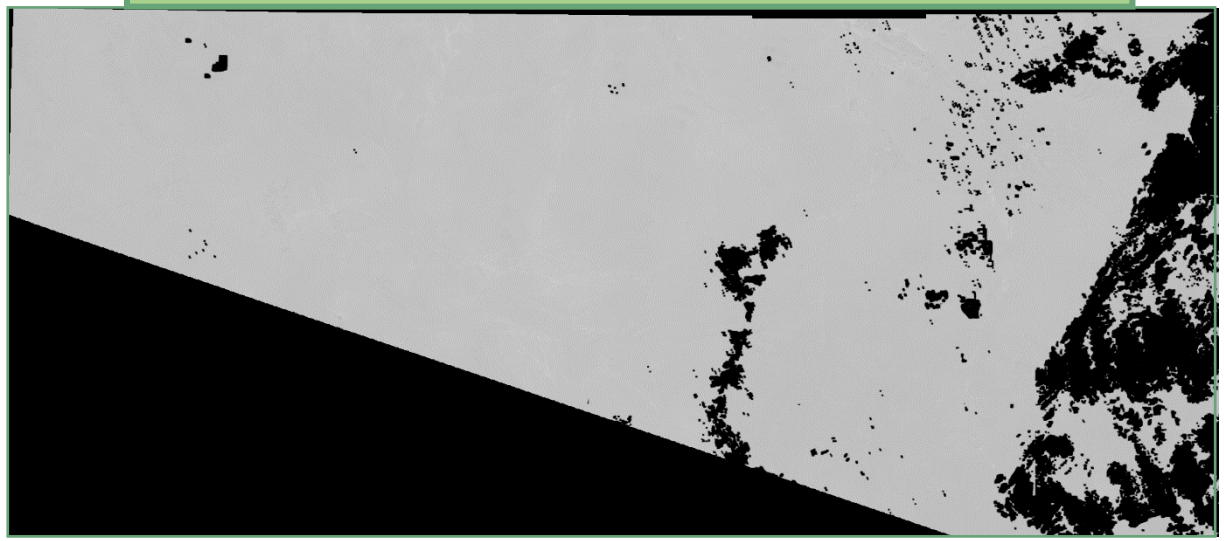
NDVI

MSAVI2

Normalized Difference Vegetation Index

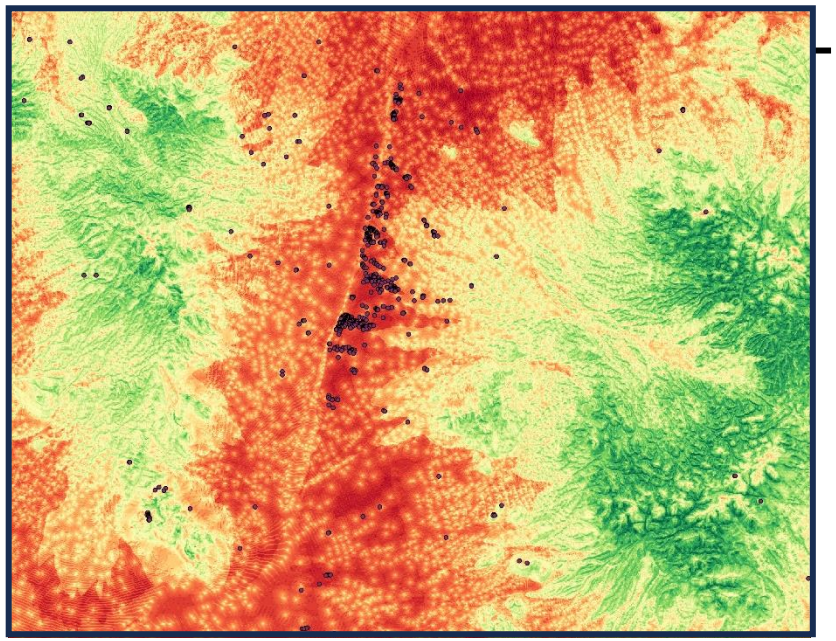


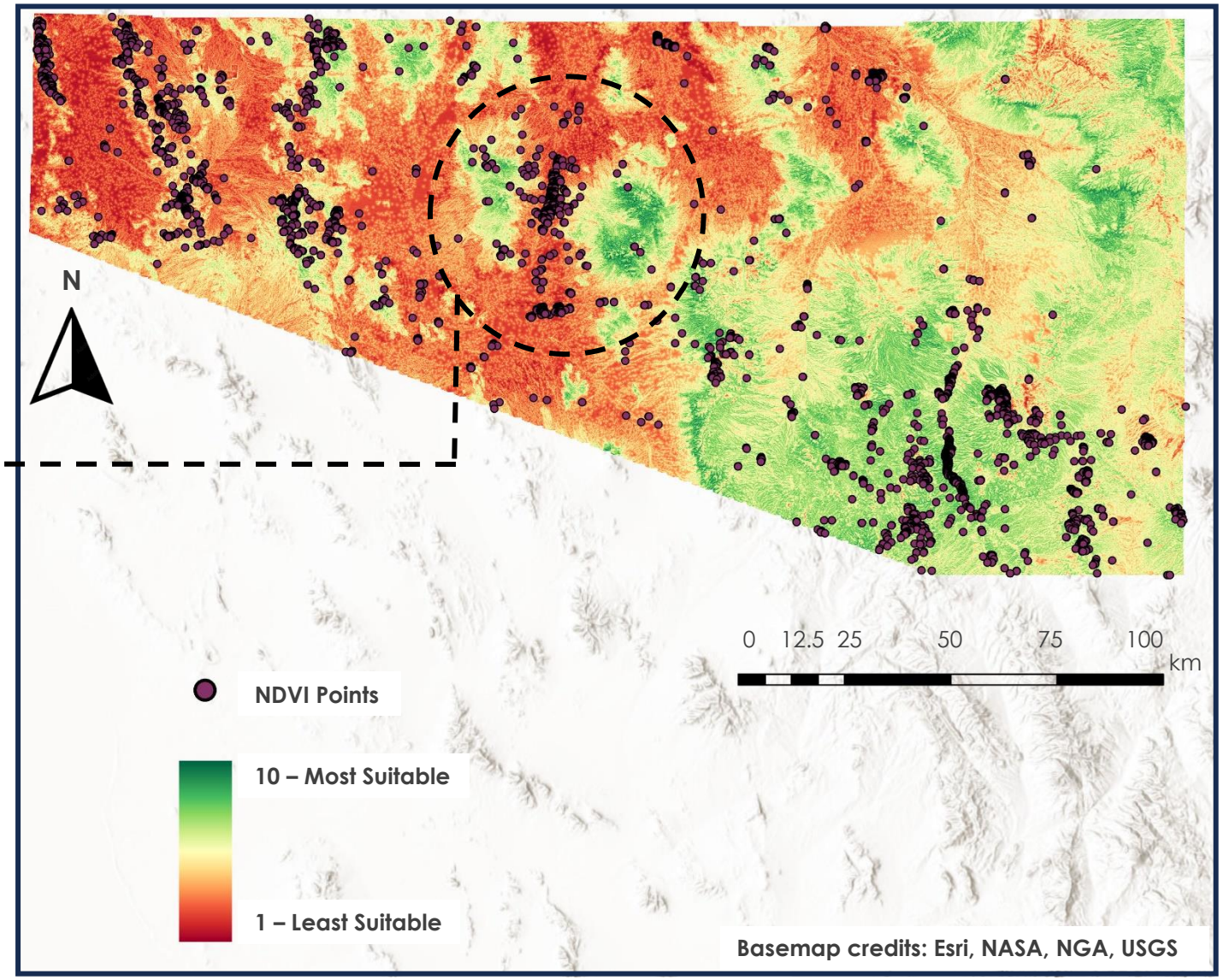
Second Modified Soil Adjusted Vegetation Index



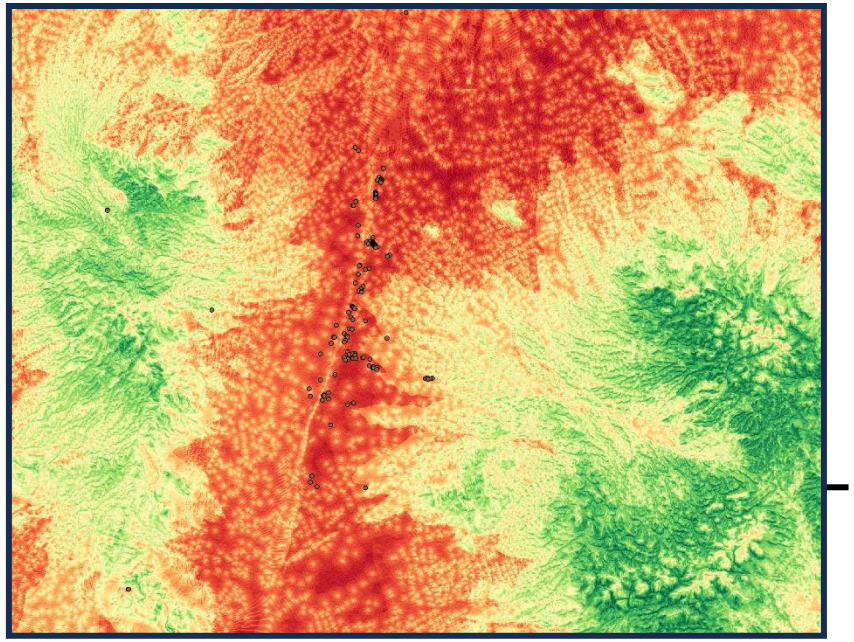
NDVI

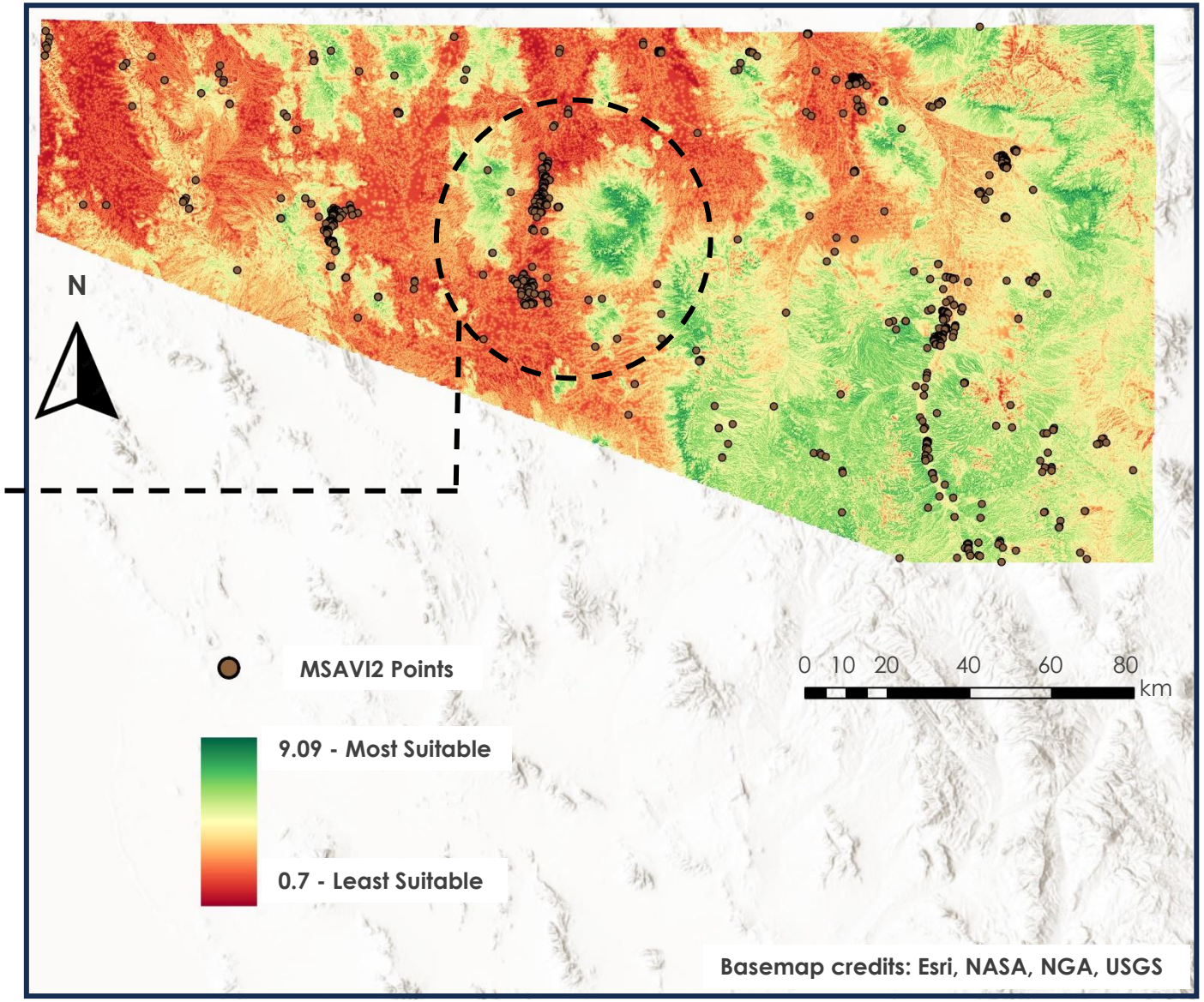
- Points represent significant NDVI increases (0.1-0.7) from a rainfall in 2020





MSAVI2

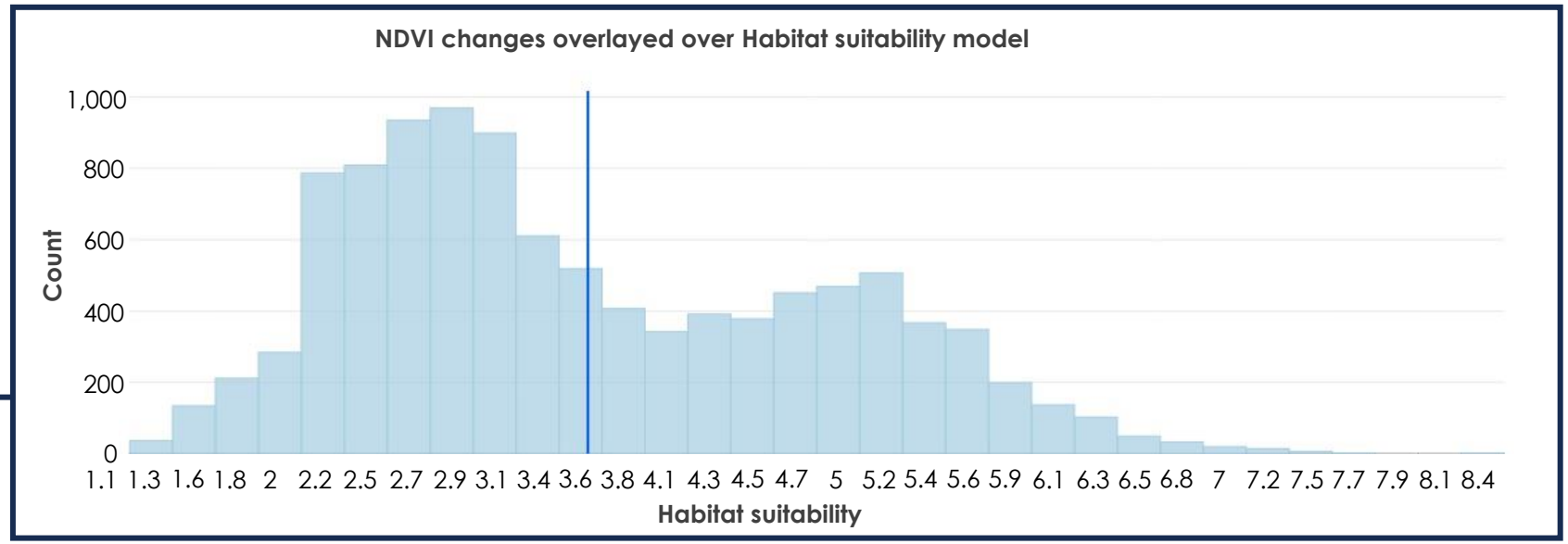




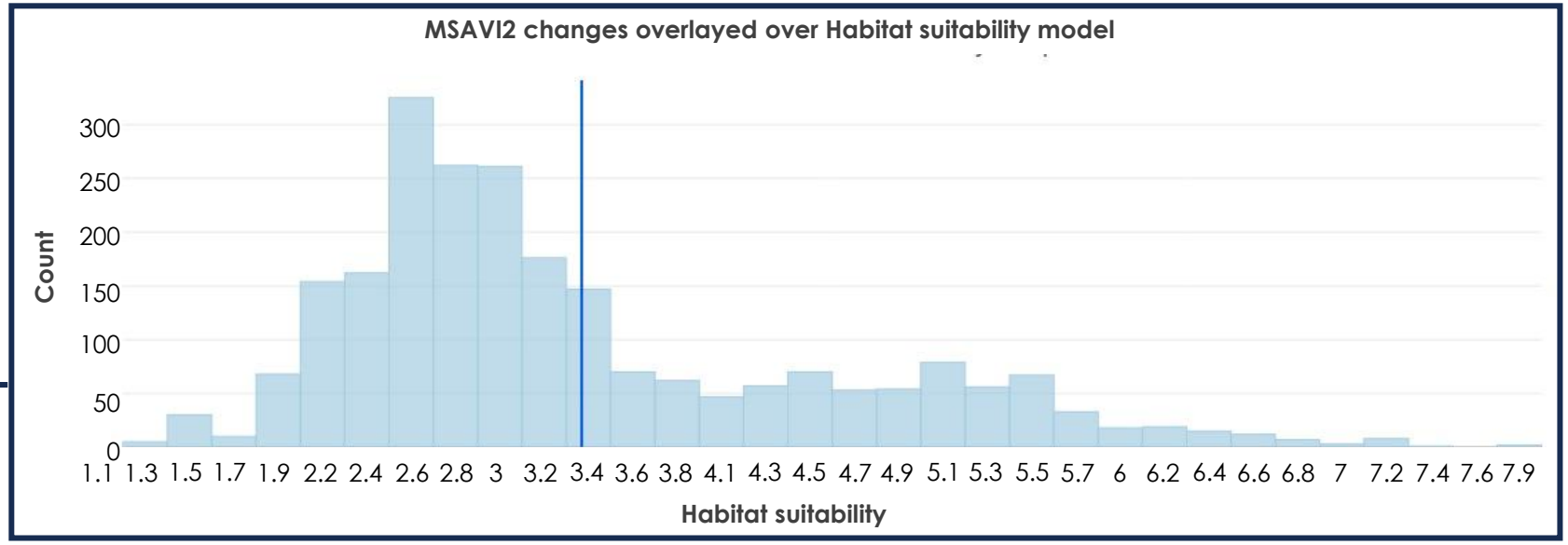
- Points represent significant MSAVI2 increases (0.7-0.1) from a rainfall in 2020

NDVI and MSAVI2 Histogram

NDVI histogram that doesn't show any significant suitability value



MSAVI2 histogram that doesn't show any significant suitability value



Errors, Uncertainties, & Limitations

Data Limitations

- MuSLI
- NDVI & MSAVI2
- Field data

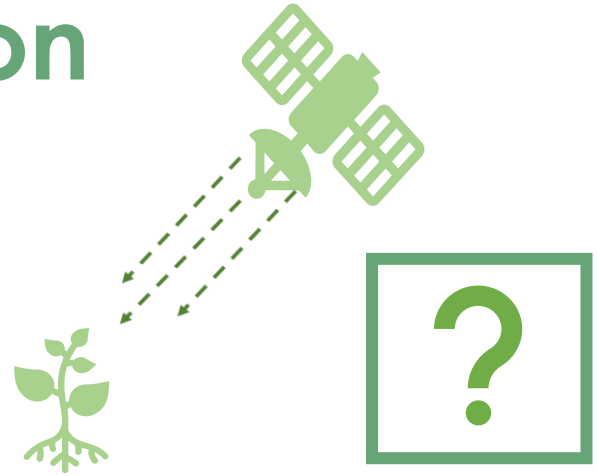
Limited Timeframe

- Unique environmental variables

Image credit: Aaryn Olsson

Feasibility & Partner Implementation

Vegetation Distribution Time Series



- Infeasible at this time
- Two different methods were tried
  - MuSLI
  - NDVI & MSAVI2

Habitat Suitability Model

- Model will allow partners to identify areas most susceptible to buffelgrass infestations
- Adding new layers may increase model's prediction accuracy

Image Credit: NPS Photo

Conclusion

Spectral imagery methods to identify **buffelgrass is inconclusive**. **Hyperspectral imagery and alternative approaches** should be considered in **future work.**

Overall, our **habitat suitability model** was successful at **predicting buffelgrass habitat**. Partners can use and expand upon this model to support **eradication efforts of buffelgrass**.

This work will be used to aid part 2 of this project, focusing on stinknet

Acknowledgements

Lead

- Isaac Goldings | **NASA DEVELOP**, Idaho Center Lead

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- Bethany DeRango | **US Fish and Wildlife Service**, Arizona National Wildlife Refuges
- Britt Smith | **US Geological Survey,** Western Geographical Science Center
- Sarah Studd | **National Park Service**, Sonoran Desert
- Sharlot Hart | **National Park Service**, Tumacácori National Historical Park
- Aaryn Olsson | **Planet**

Special Thanks

- Kait Lemon | **NASA DEVELOP,** Collaboration Coordinator & Previous Center Lead

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