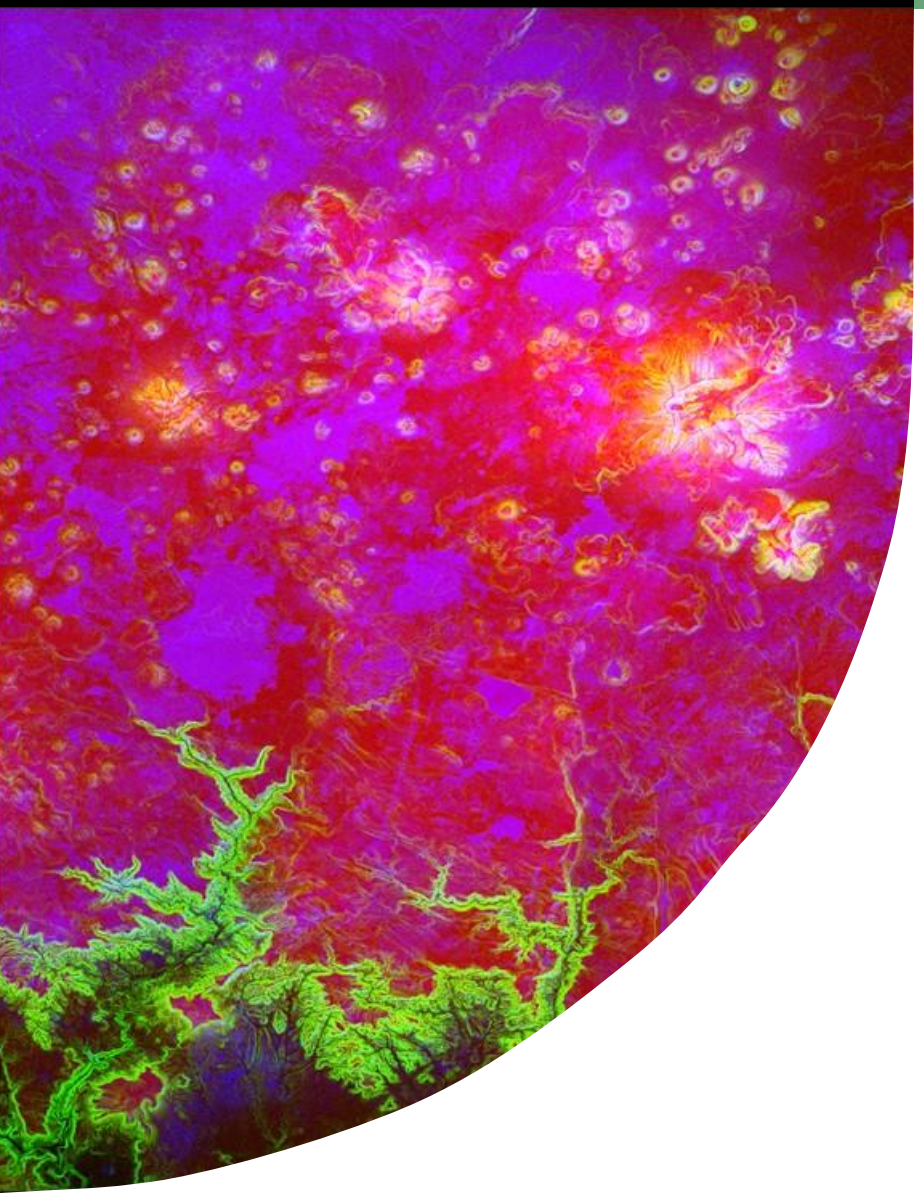
National Aeronautics and Space Administration



Northern Arizona Ecological Conservation

Assessing Quaking Aspen Health in Northern Arizona Using Earth Observations

Luke Collins, Margaret Cox, Ikram Morso, & Melissa Schwan (Analytical Mechanics Associates)

Pop-Up Project – Northern Arizona University | Summer 2025

Quaking Aspen

Image Credit: Sergey Guk

What?

Deciduous species, iconic fall color

Where?

North America northern latitudes & Western U.S. mountainous regions

Why?

Culturally and economically important, ecologically vital

Aspen Ecosystem Benefits

Image Credits: Eleanor Bricetti, Ingrid Arlton

- Provide critical habitat for nesting Williamson's and Red-naped Sapsuckers
- Provide food source for deer and elk
- Act as a natural firebreak
- Protect water resources
- Fix nitrogen and sequester carbon

Threats to Aspen

Wildfires

Climate Factors

Disease & Insects

Ungulate Browsing

Conifer Encroachment

Image Credits: USFS, Jordi, Webb, Thiele, Smith, Biernacki

Partners

Image Credit: USFS

Image Credit: NPS

USFS Northern Research Station

NPS Wupatki, Sunset Crater Volcano, Walnut Canyon

USFS Coconino National Forest, Flagstaff RD

USFS South-western Region, Arizona Zone Forest Health

Northern Arizona University, School of Forestry

USFS Coconino National Forest, Mogollon Rim RD

Arizona Dept. Of Forestry and Fire Managment

Objectives

Describe Vegetation and Seasonality
Assess vegetation seasonality trends and peaks across the study area

Detect Aspen Trees
Train and validate a Random Forest model using Earth Observations and field-based measurements

Determine Change in Aspen Health
Calculate difference in vegetation index to assess aspen health change

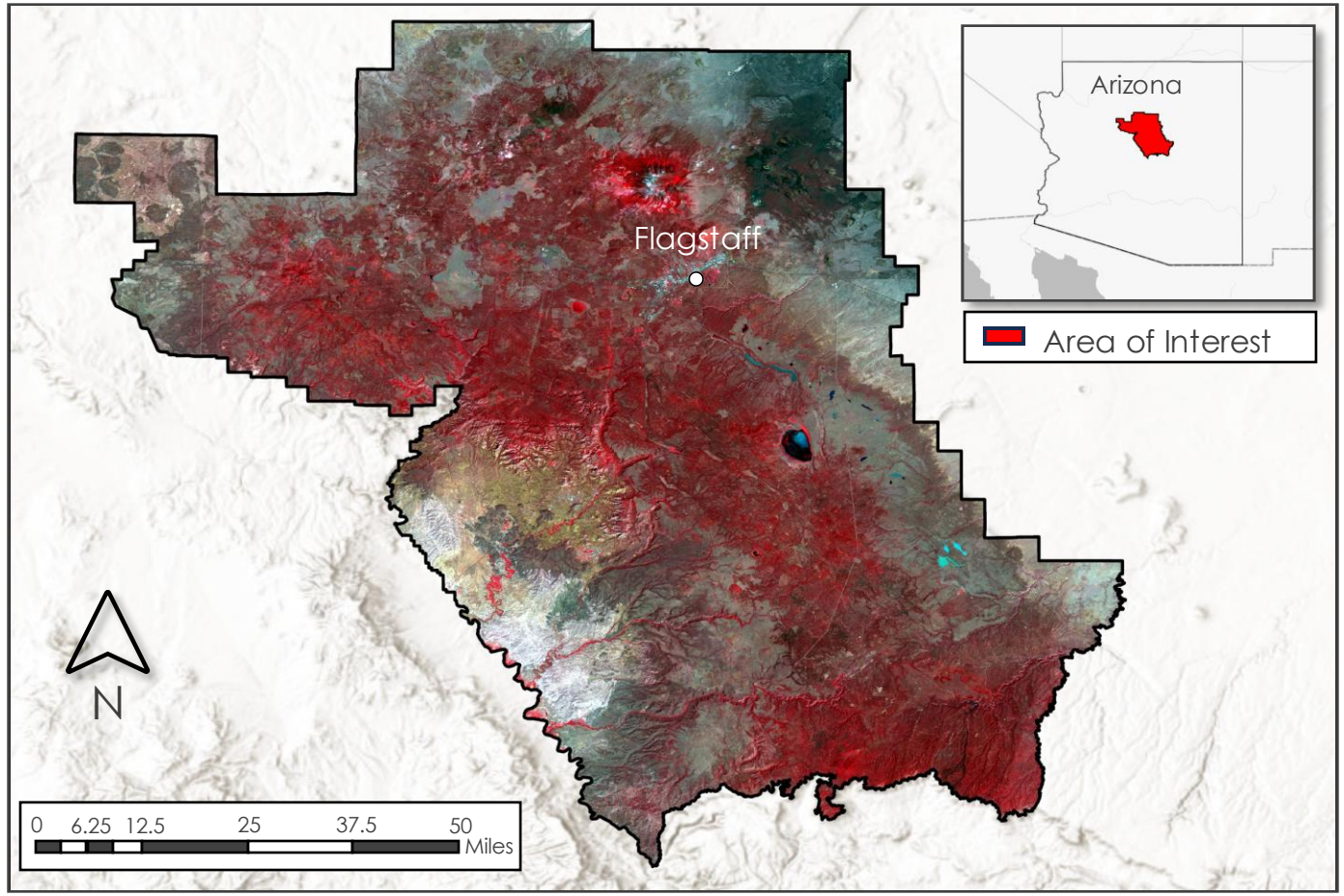
Support Management Using EO
Provide feasibility results that support aspen management using Earth Observations

Area of Interest

Coconino and Southern Kaibab National Forests

Jan. 2014 – Dec. 2024

- Area of interest spans approximately **4111.2 mi²**
- Elevational gradient from **2,600** to **12,633 ft**.



Basemap Credits: Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community
Source: USGS Landsat 8 Collection 2, Level-2 Surface Reflectance. Sensor: OLI. © 2023 U.S. Geological Survey.

Earth Observations

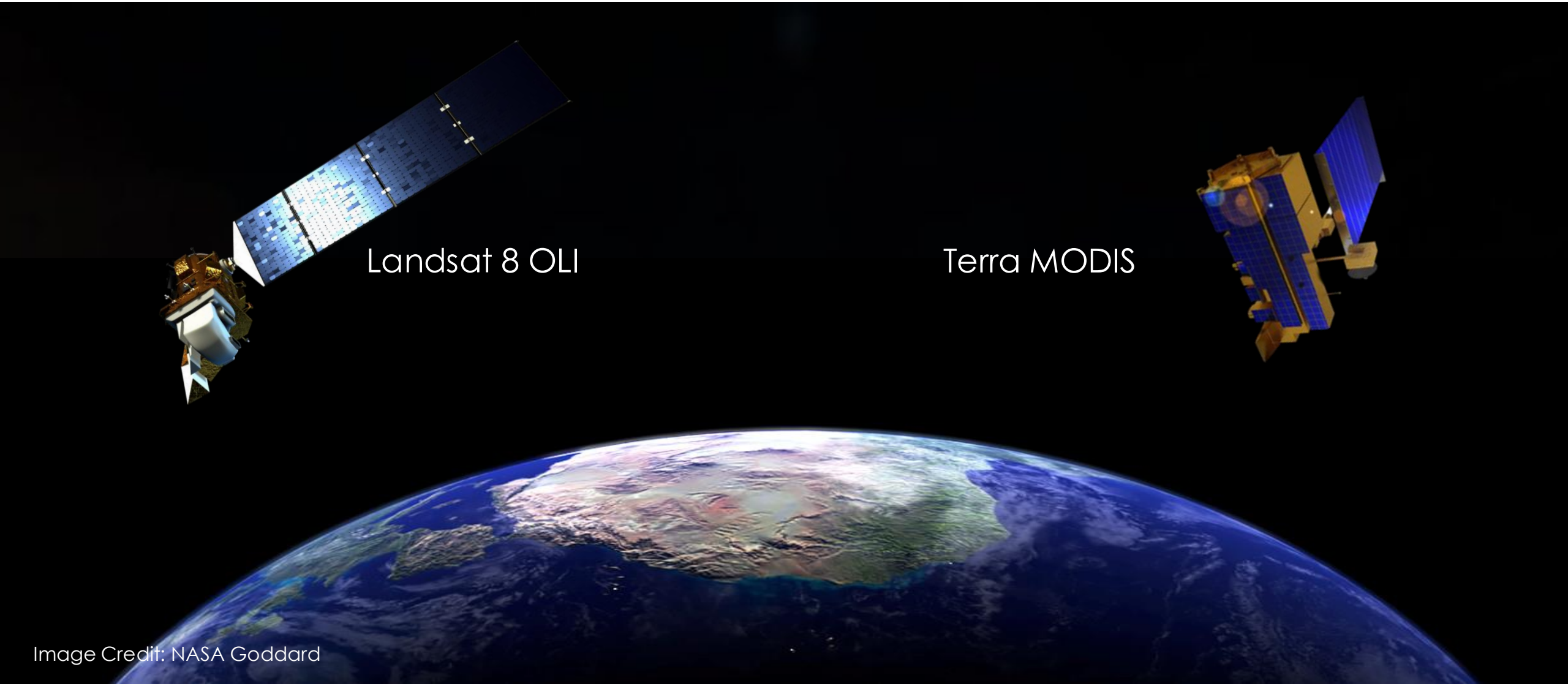
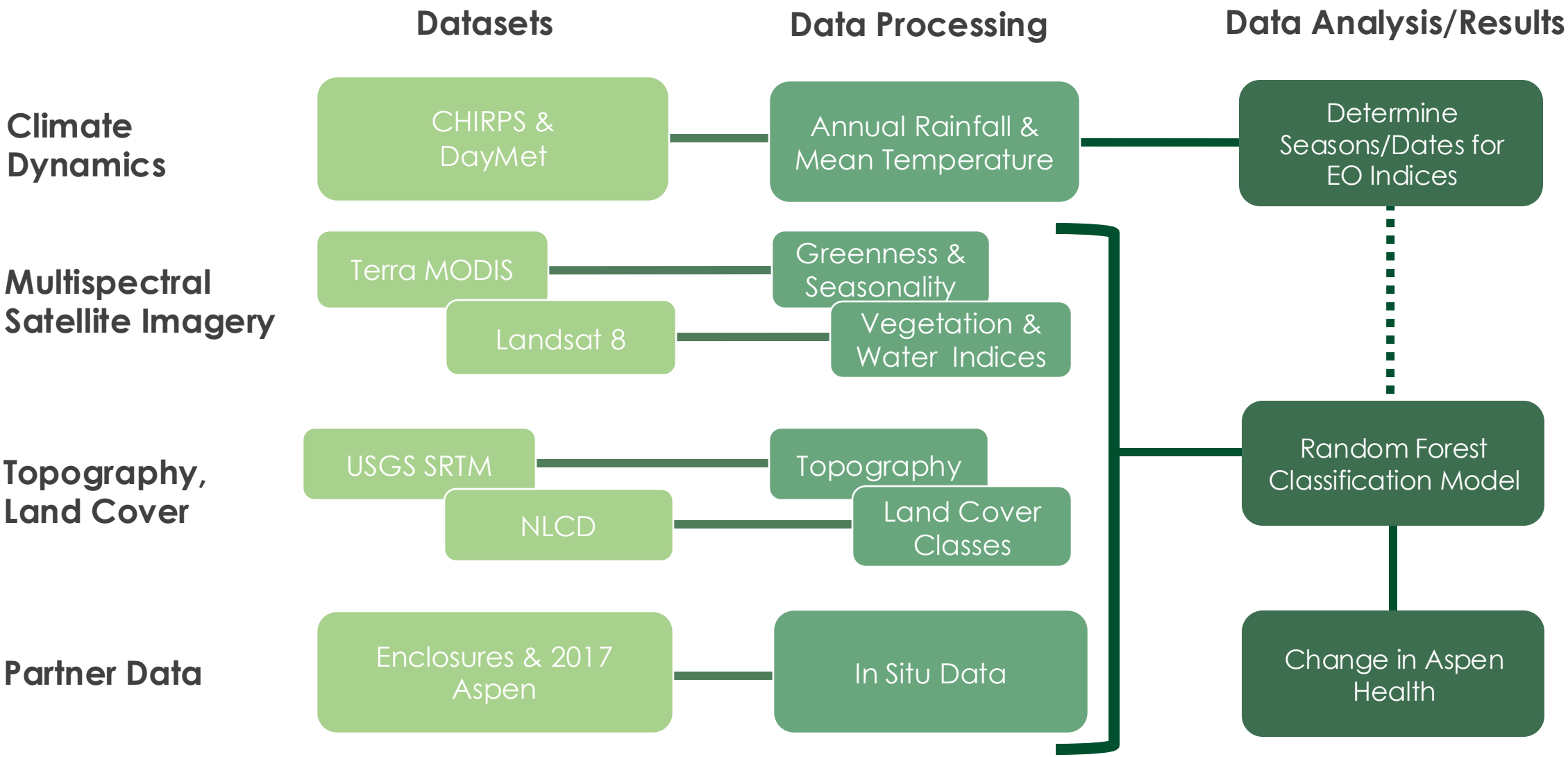
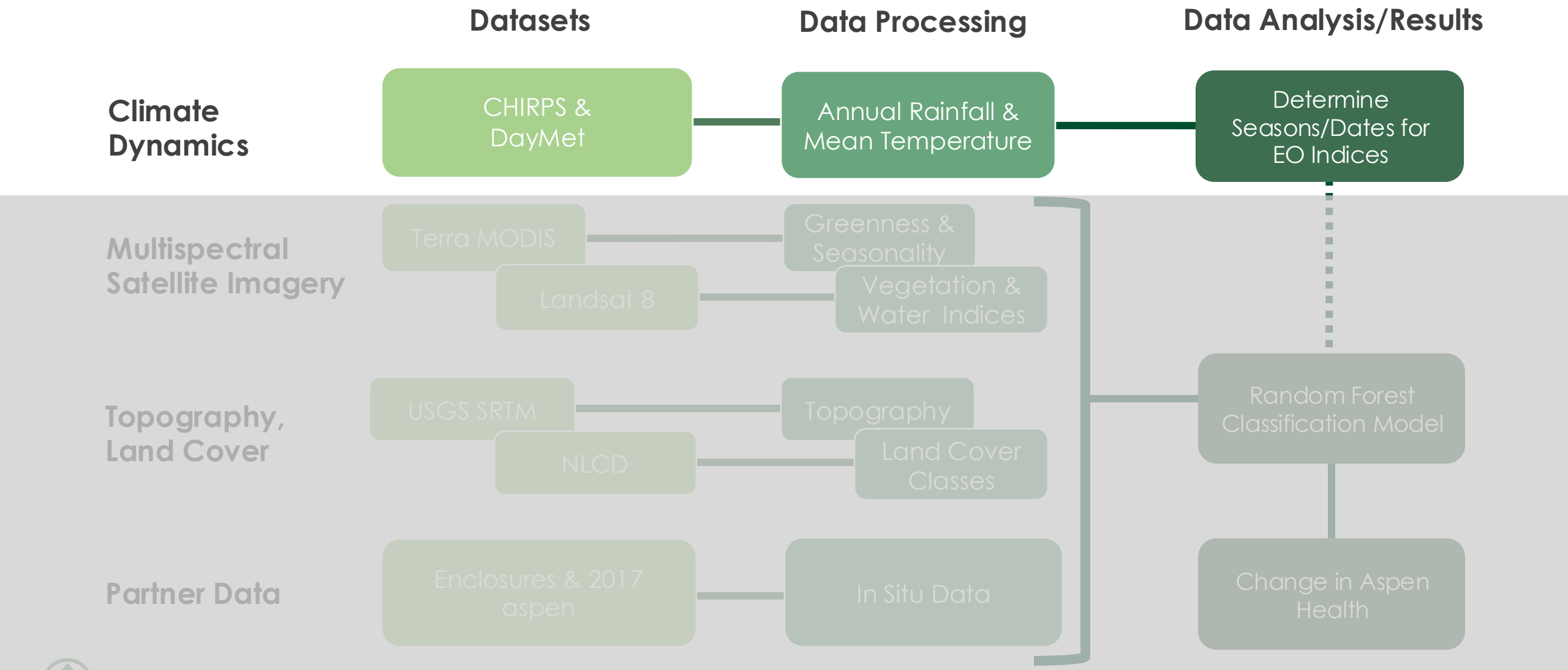


Image Credit: NASA Goddard

Methodology

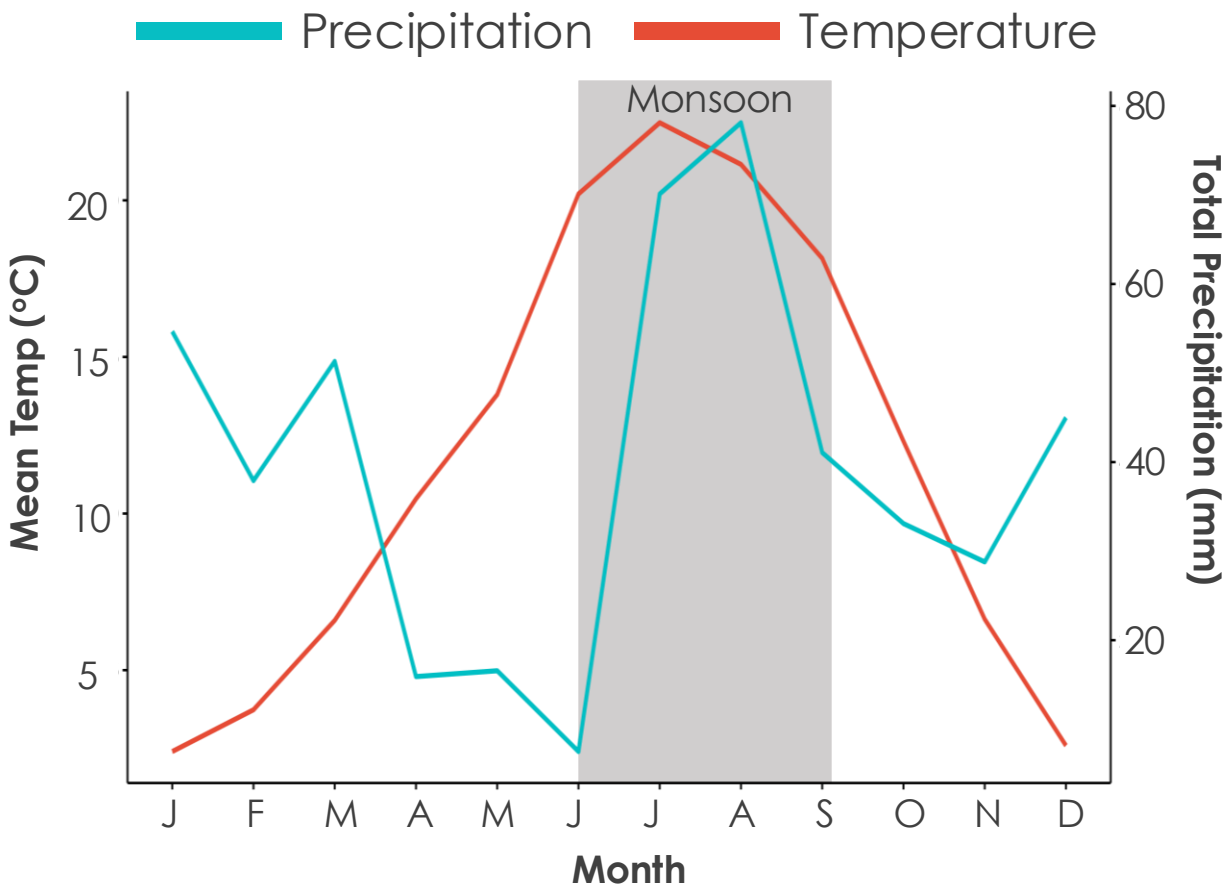


Methodology

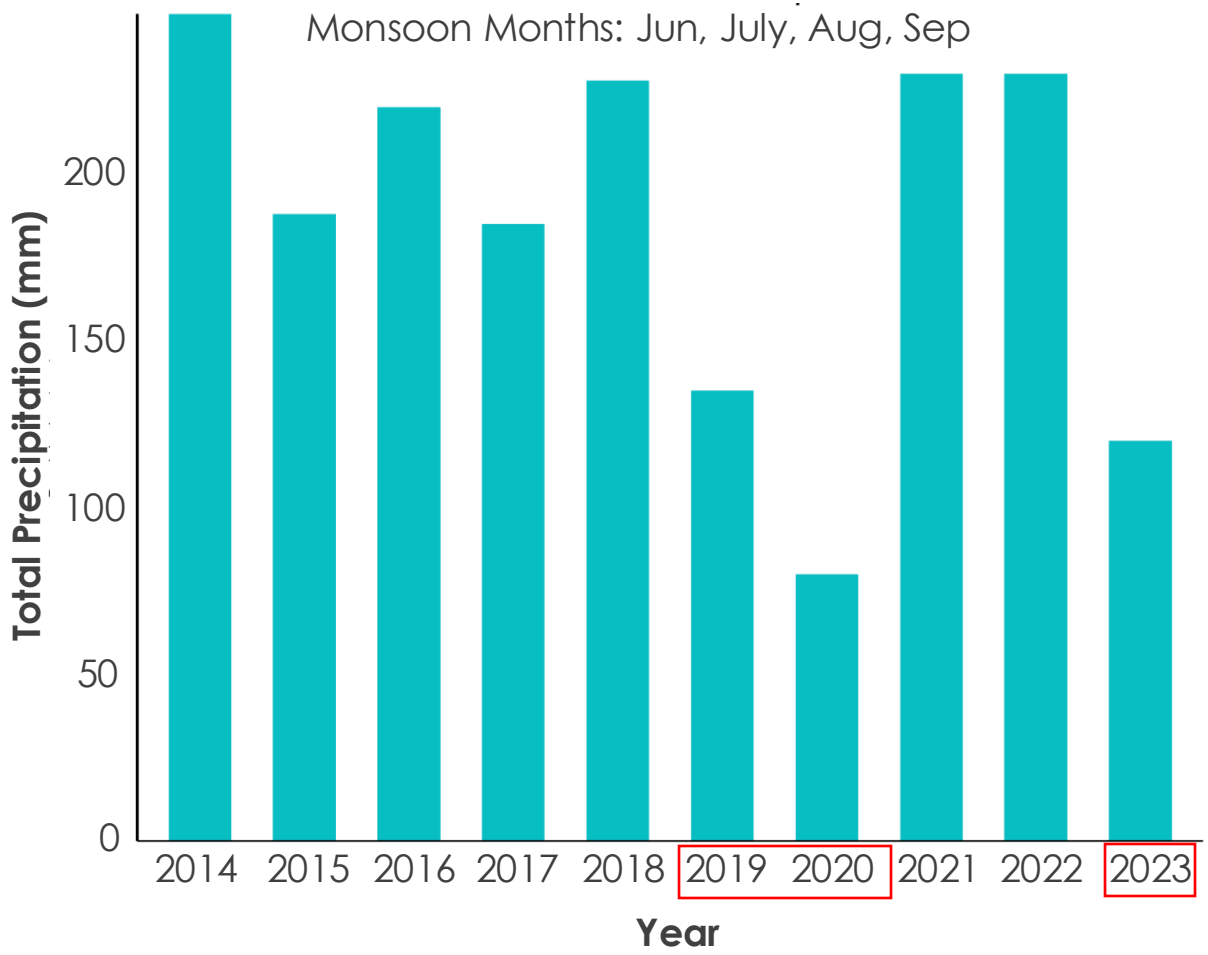


Climate Dynamics: Summer Monsoon

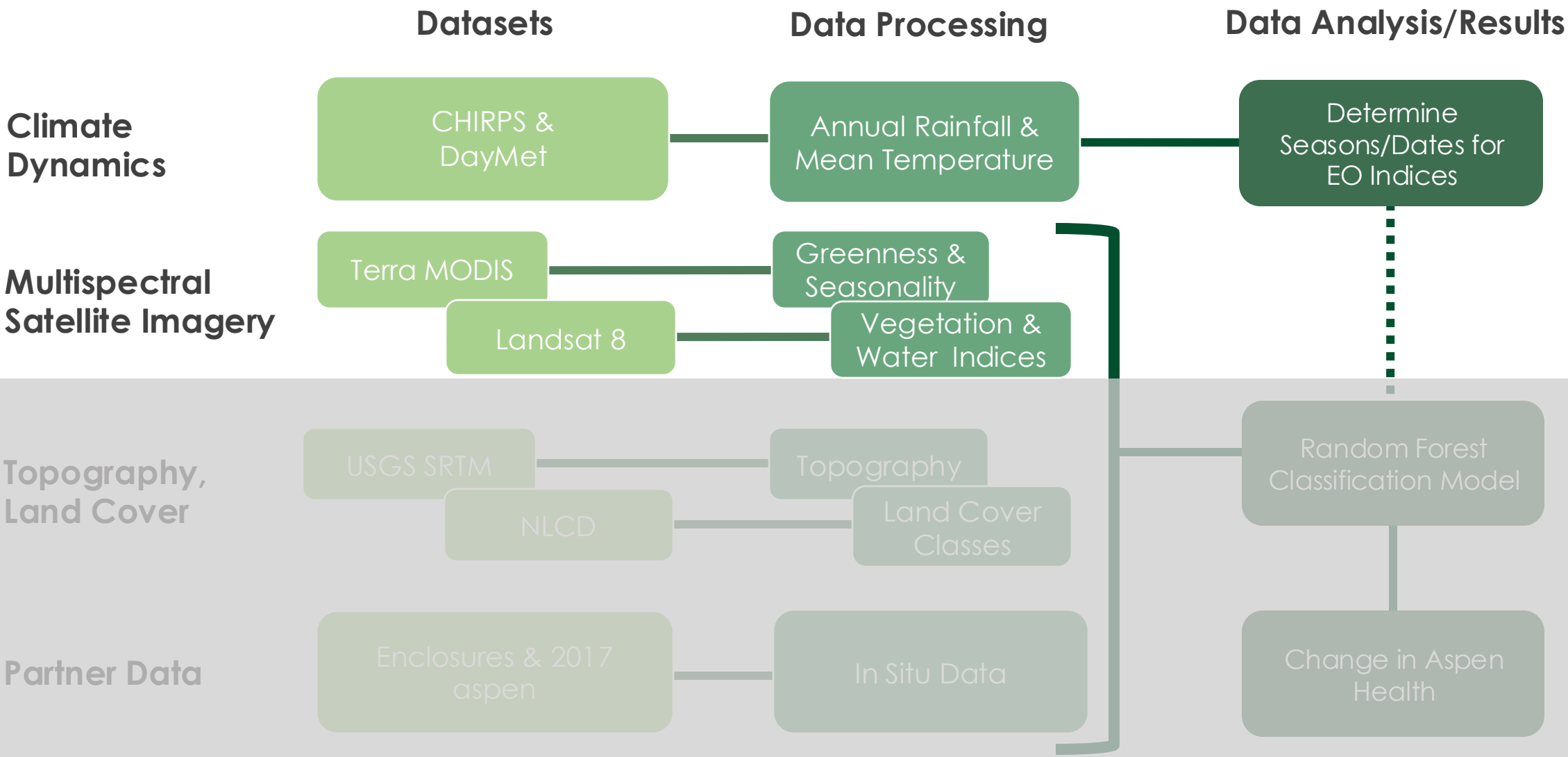
Monthly Precipitation and Temperature
(averaged across 2014-2023)



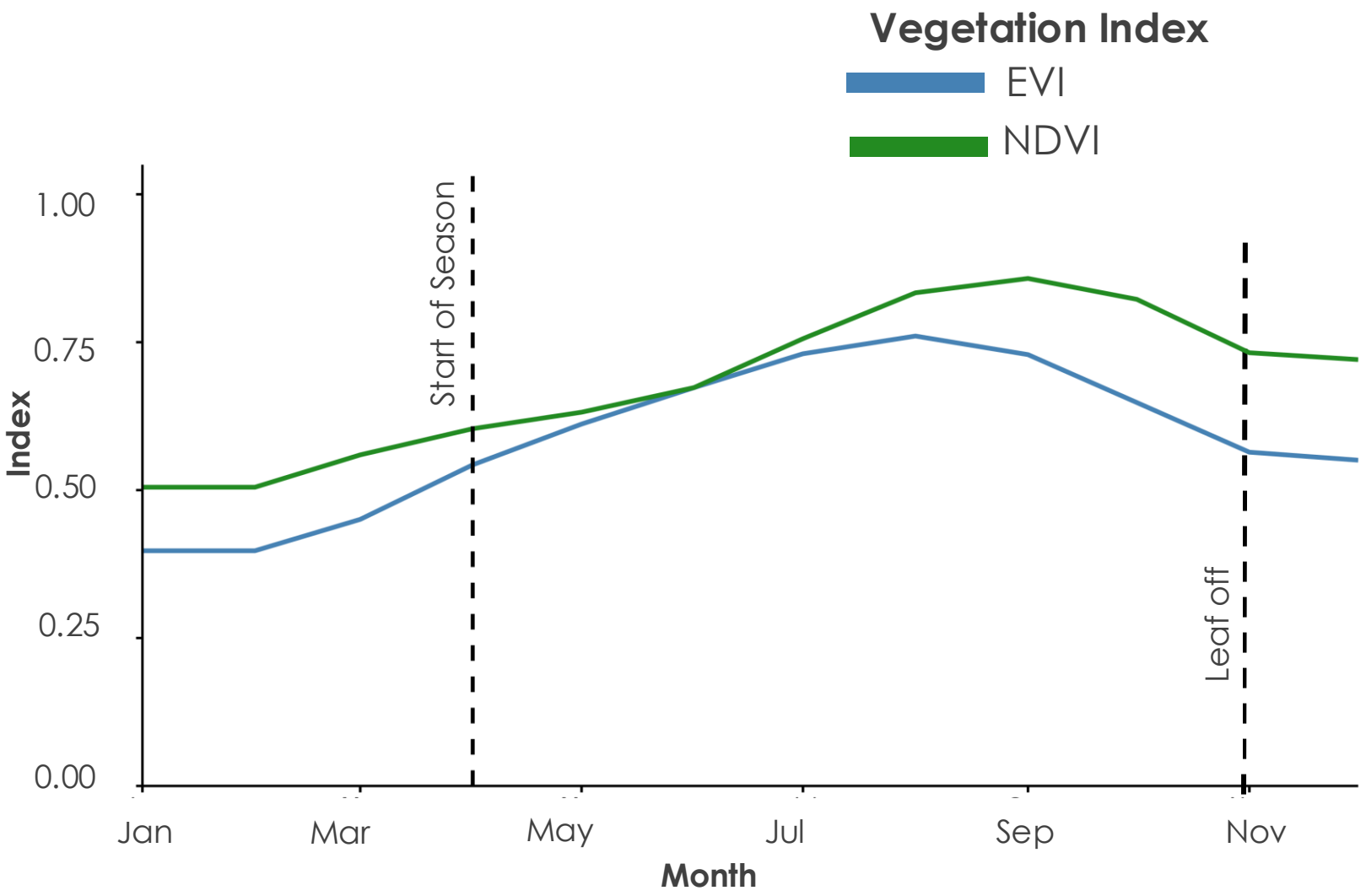
Total Monsoon Precipitation 2014-2023



Methodology



Vegetation Seasonality



2014-2023

Start of season: March – April (20% increase in NDVI from winter)

Peak growing season: August – September

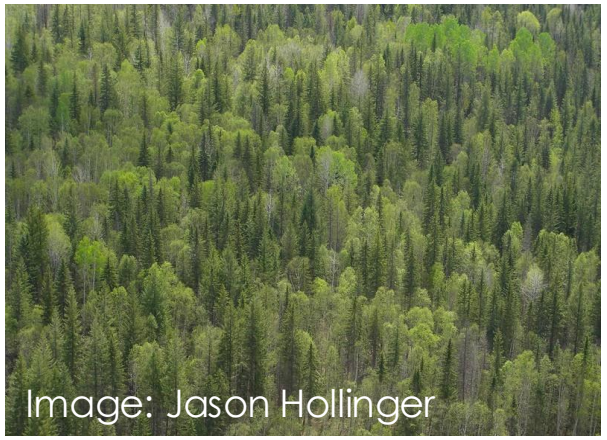
End of season: End of October – early November

Dates support future analysis

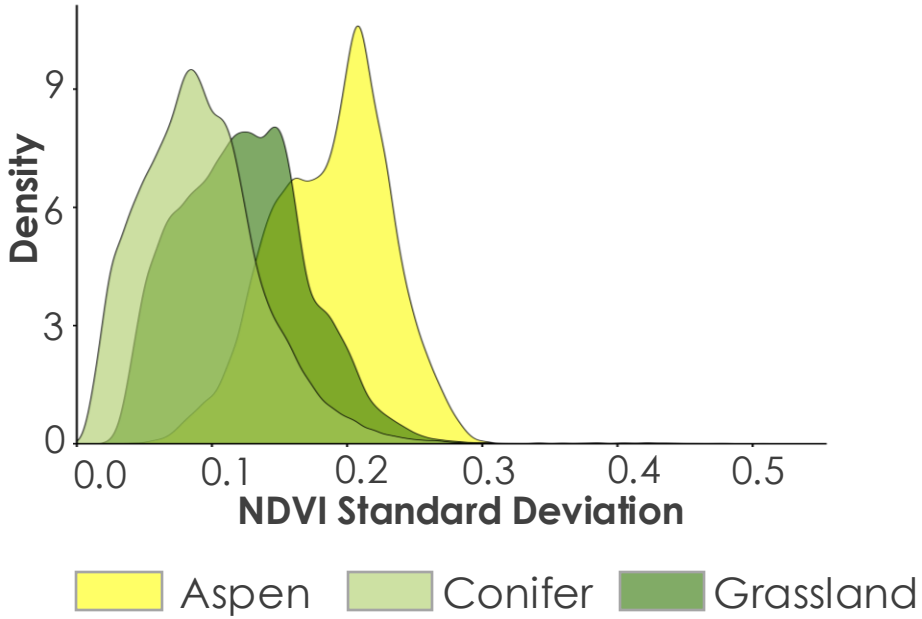
Critical dates for calculating vegetation indices for the aspen classification model

Phenological Differences in Vegetation

Normalized Difference Vegetation Index

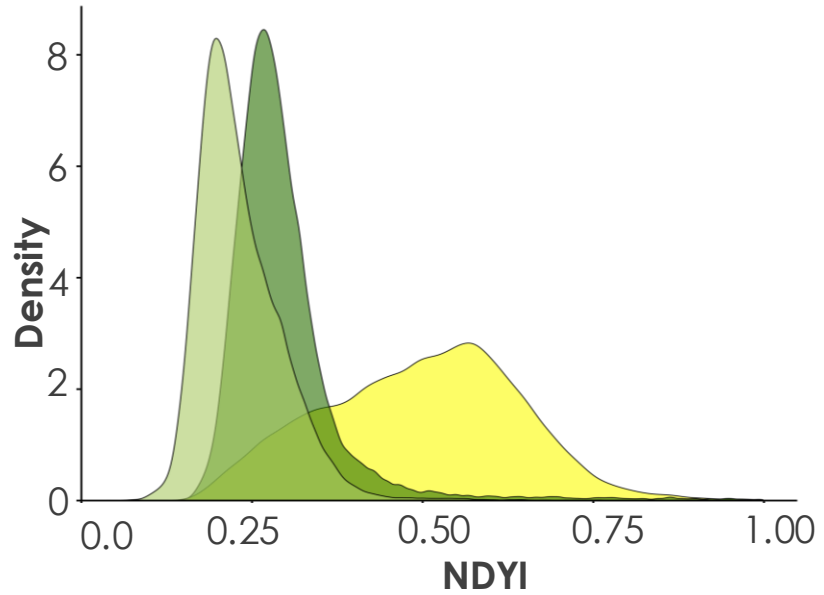


$$NDVI = \frac{NIR - Red}{NIR + Red}$$

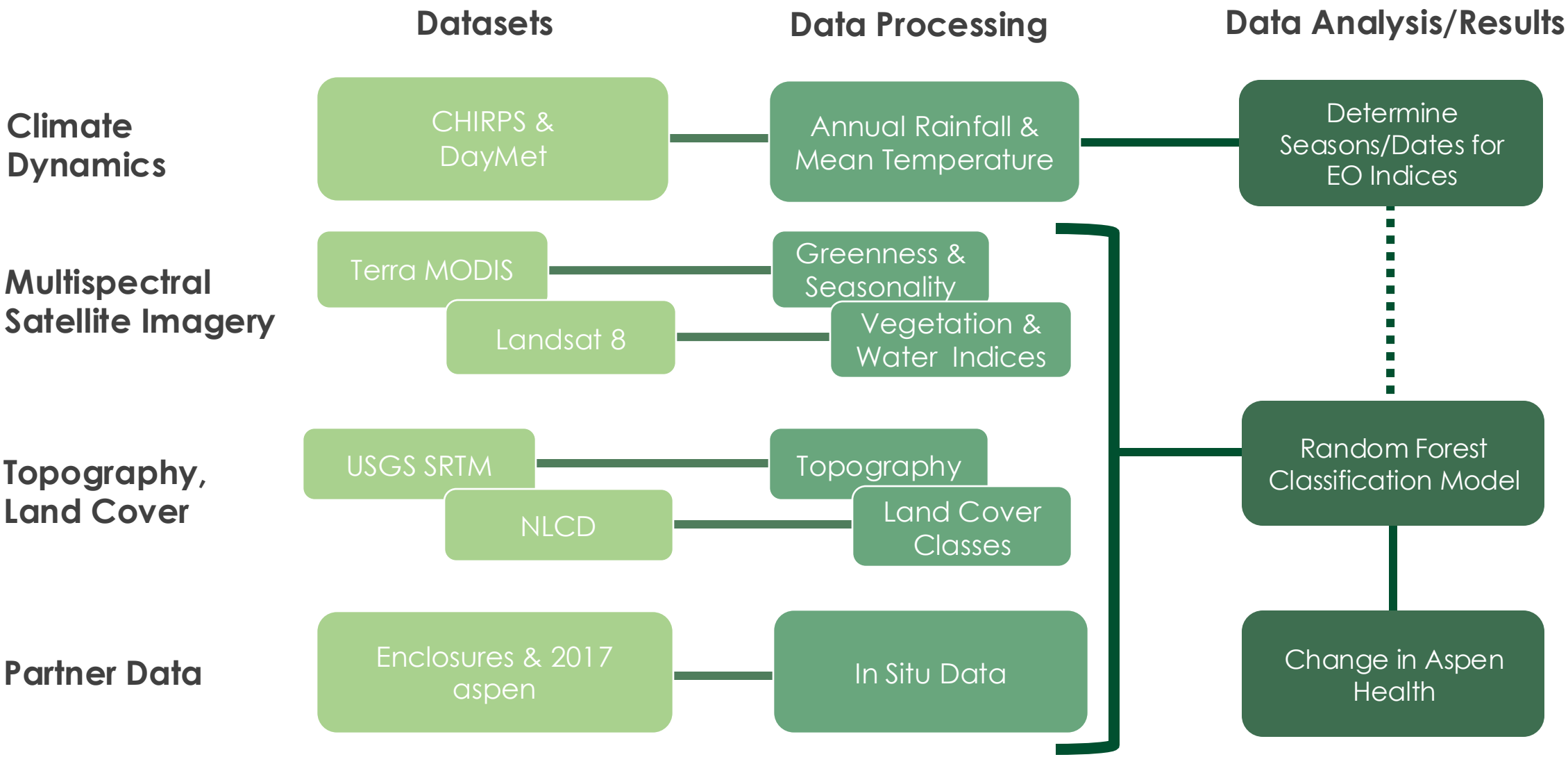


Normalized Difference Yellowness Index

$$NDYI = \frac{Blue - Green}{Blue + Green}$$

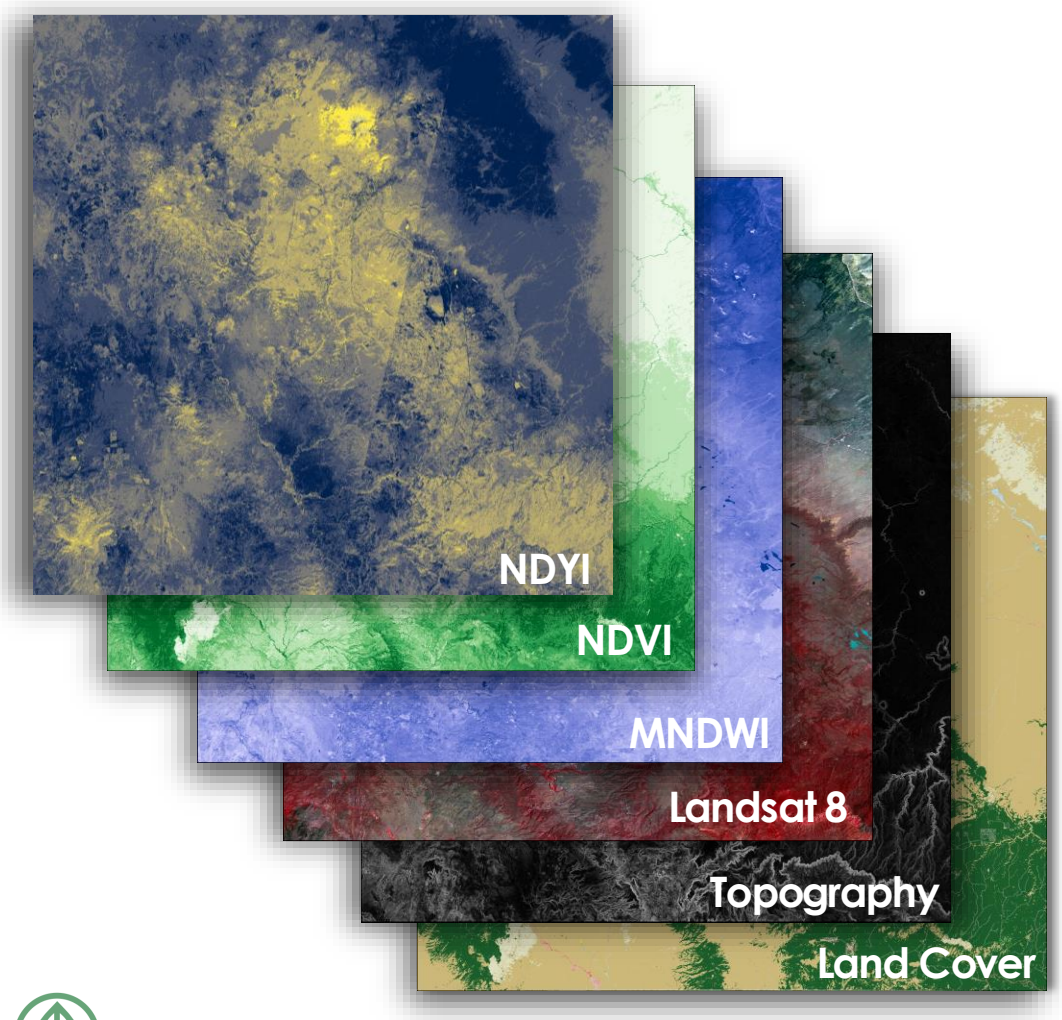


Methodology



Building the Random Forest Model

Remote Sensing data: Predictors → **In situ data** → **Random Forest (RF) Model**



- Aspen Polygons
- Mixed aspen polygons
- Conifer polygons
- Grassland/ shrub points

Polygons Sampling: Polygon Leave-One-Out (POLO) cross-validation

Points Sampling: Random stratified

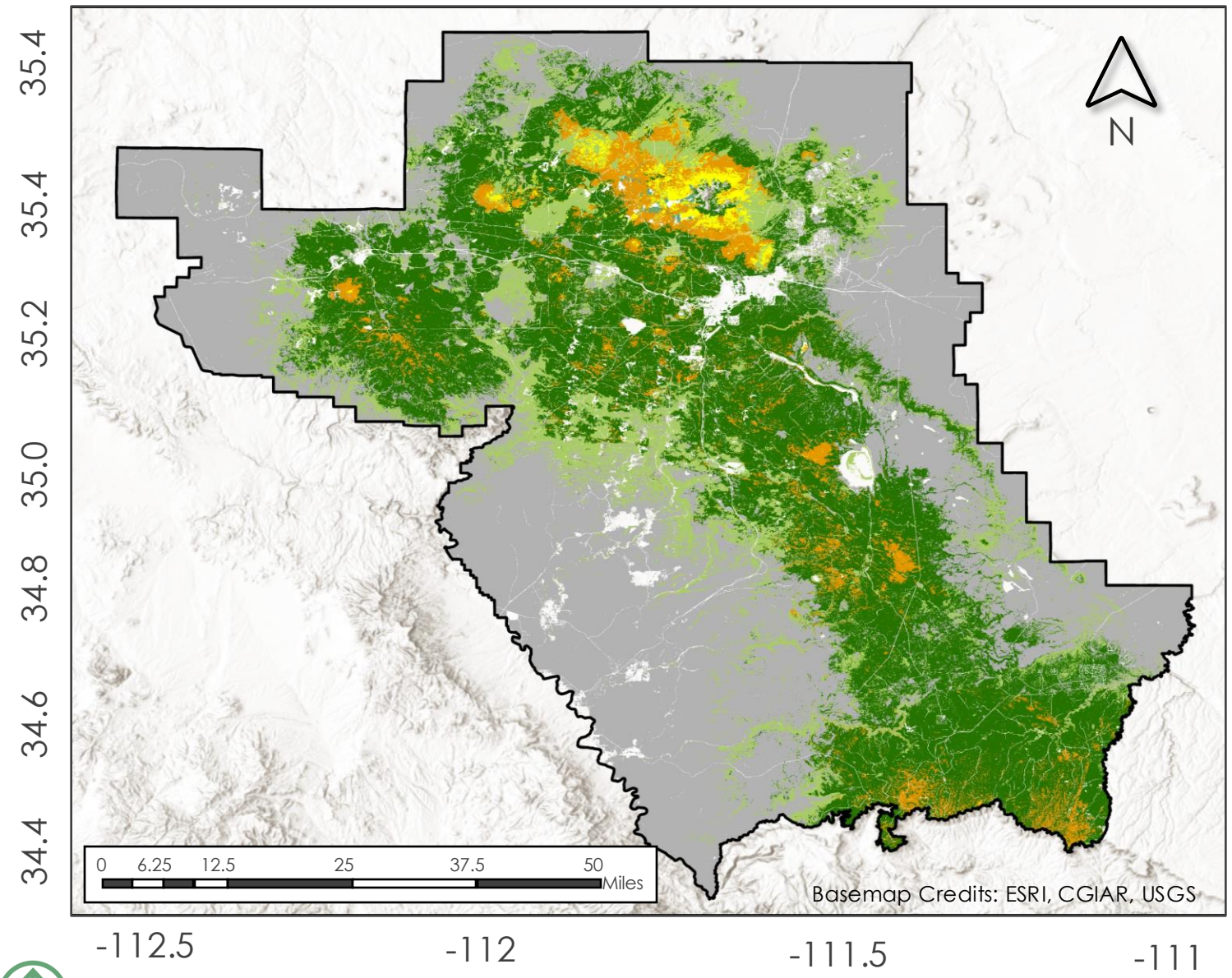
Balanced classes: Same number of points per class

Training dataset: 75%

Testing dataset: 25%

nTrees in RF: 500

Results | Random Forest



Detected Aspen in 2017

- Model accuracy: **79.15%**
  - **41.41 sq. miles** of aspen
  - **195.45 sq. miles** of mixed aspen
- **15.5%** of forested area is aspen/mixed aspen

Legend

- Aspen
- 'Mixed' Aspen
- Conifer
- Grassland
- Shrub
- Non-Vegetative

Results | Random Forest

Classification Statistics

Class	Producer's Accuracy (Recall)	User's Accuracy (Precision)	F1-score
Aspen	0.754	0.736	**0.745**
Mixed-Aspen	0.678	0.727	**0.702**
Overall Accuracy (All classes)			**0.7915**

Predictor Variable Importance

High Importance

1. Elevation
2. Oct. NDVI
3. Oct. NDYI
4. Nov. NDVI
5. NDVI StdDev

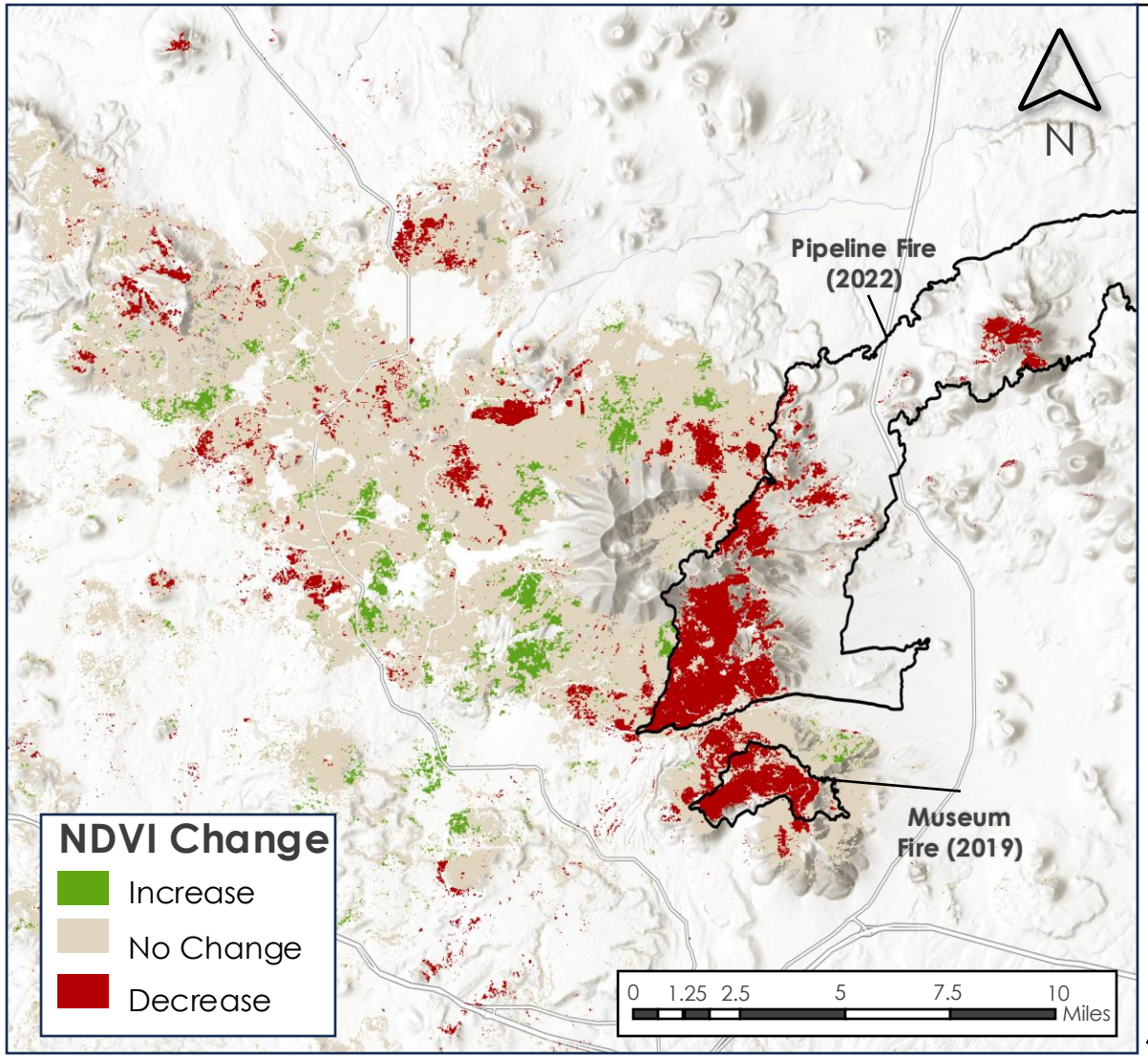
Mid Importance

1. NDVI Mean
2. MNDWI StdDev
3. Sep. Red
4. Aug. NDVI
5. Aug. NIR

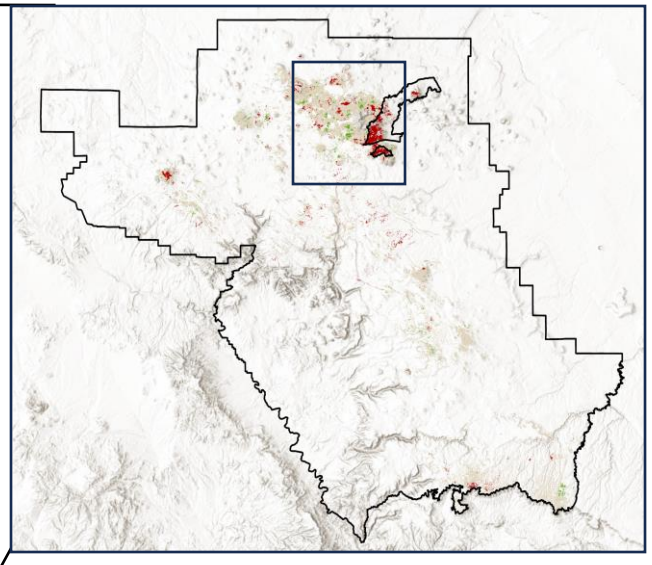
Least Importance

Slope
Aspect
Green band StdDev
Sep. NDYI

Results | Change in Aspen Health (2017-2024)



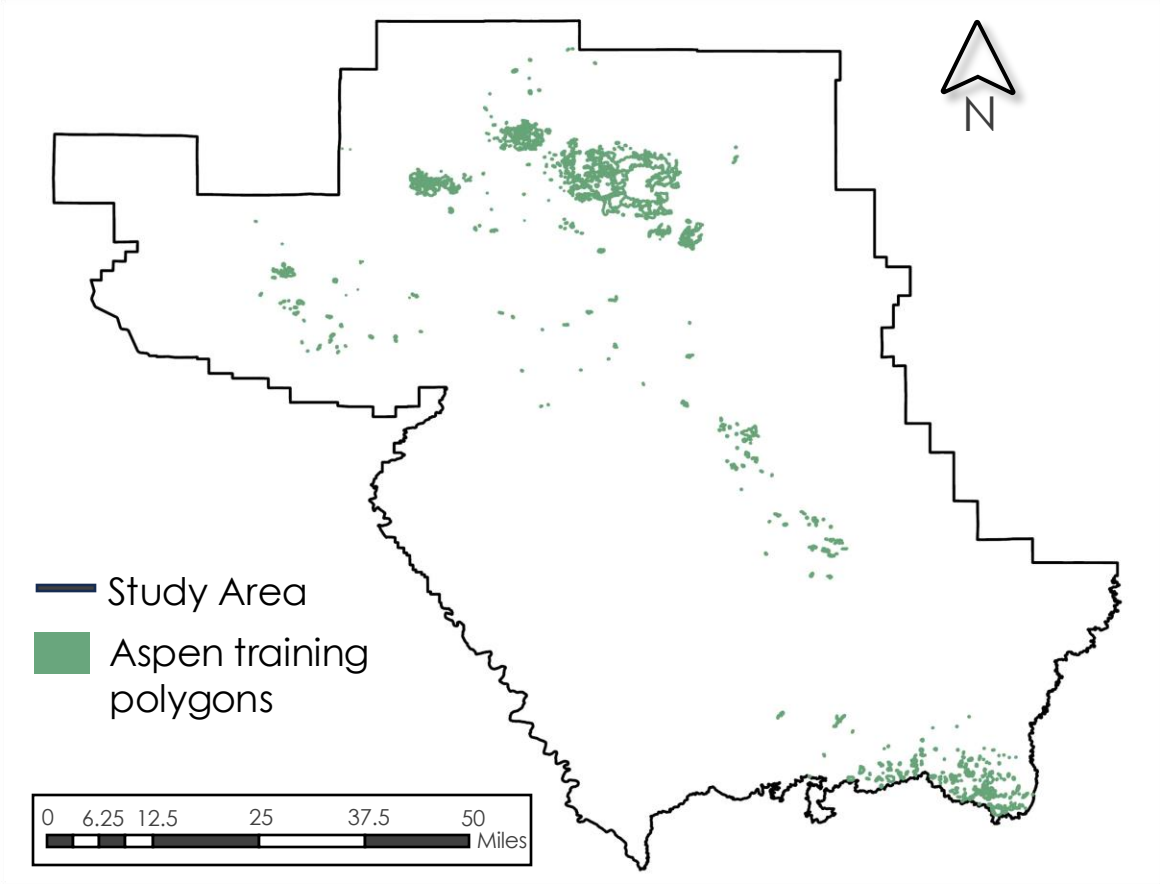
Basemap Credits: ESRI, CGIAR, USGS



Basemap Credits: ESRI, CGIAR, USGS

- **NDVI Increase:** 6.4 mi²
- **No Change:** 324.7 mi²
- **NDVI Decrease:** 30.6 mi²
- **Net Decrease:** 24.8mi²
- **Potential Causes:** Fires, Drought, Diseases

Limitations & Uncertainties



Resolution Limitation

- Coarse (30 m) spatial resolution in detecting aspen patches
- Hyperspectral imagery could improve aspen identification

Training and Testing Data

- Limited coverage of in situ dataset

Imagery Complications

- Cloud cover in fall imagery limited the ability to use NDYI to capture leaf change
- Temporal alignment & mosaics

Feasibility & Partner Implementation

01 It is feasible to use NASA Earth observations to identify aspen with **74.5%** accuracy

02 The assessment of vegetation health in areas of predicted aspen provides insight into priority areas for **management** of aspen & mixed-aspen areas

03 The **replicable** aspen detection **workflow** offers partners a tutorial that can be applied to recent years imagery

Conclusions

- Understanding **vegetation seasonality** prior to applying machine learning models enables the selection of relevant datasets, helping to **reduce overfitting** and improve **classification accuracy.**
- Elevation, October **NDVI** & **NDYI**, and November **NDVI** were the most **important predictors** of aspen in the RF classification.
- **Negative NDVI** change could indicate **vegetation loss or health decline** in aspen stands impacted by wildfire, for example.

Image credit: Ikram Morso

Acknowledgements

- DEVELOP Lead: Jane Zugarek
- Science Advisors: Dr. Paul Arellano, Dr. Alexander Shenkin, Dr. Xia Cai
- DEVELOP Support: Kait Lemon (Collaboration Coordinator), Maya Hall (Impact Analysis Fellow)
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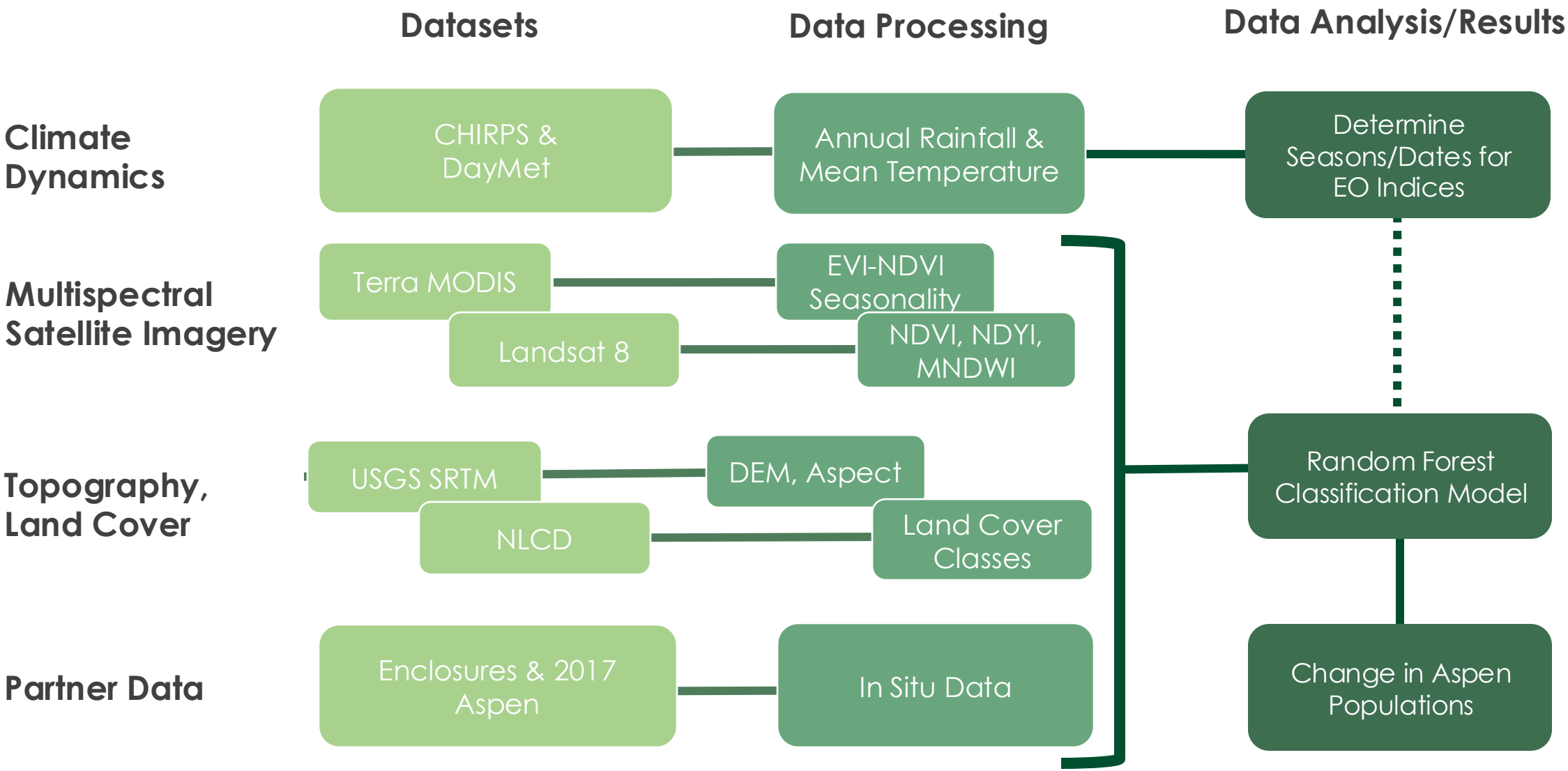
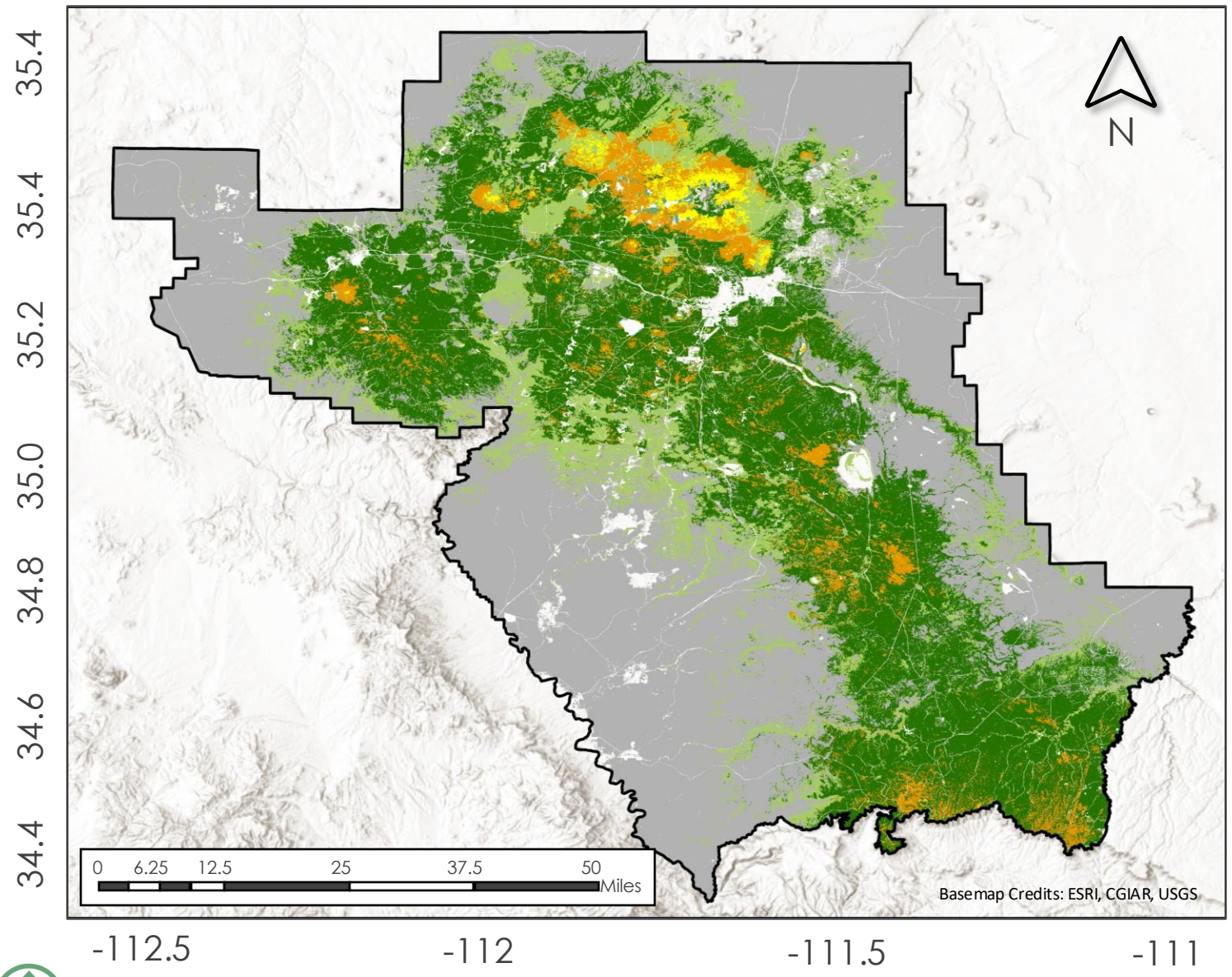
- *This work utilized data made available through the NASA Commercial Smallsat Data Acquisition (CSDA) Program.*

Methodology



Results | Random Forest



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