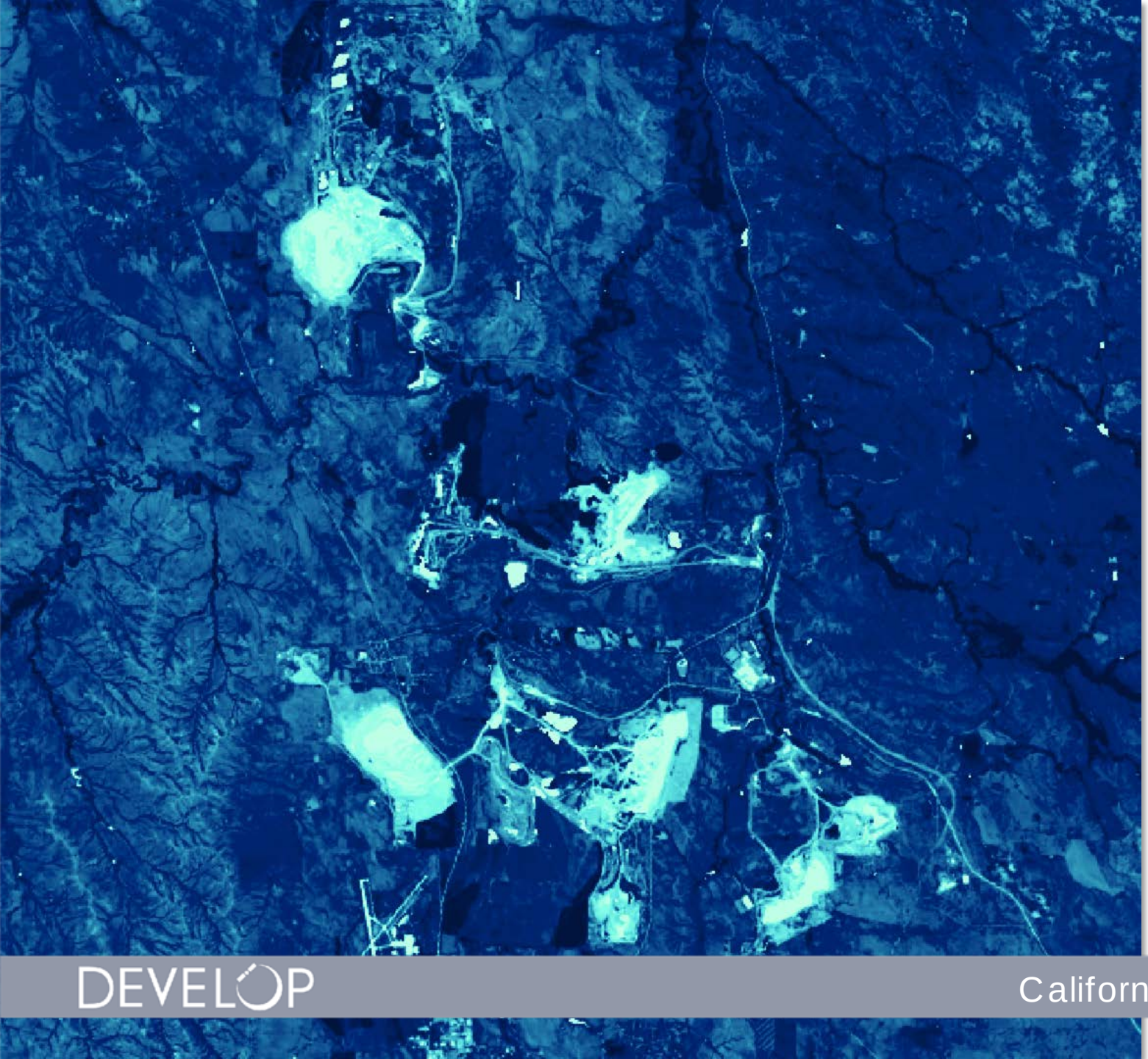


National Aeronautics and Space Administration

POWDER RIVER BASIN TRANSPORTATION & INFRASTRUCTURE

Monitoring Land Disturbances Caused by Coal Mining in the Powder River Basin Using Remote Sensing

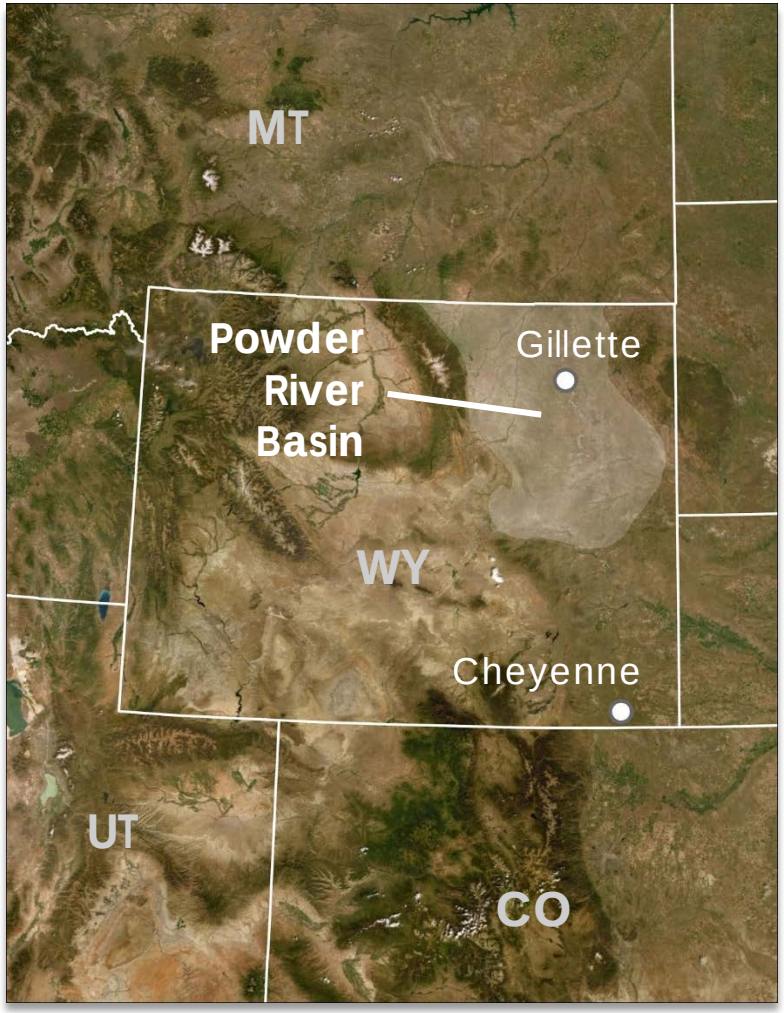
Gina Cova

Andrew Bake

Claudia Herbert

Hayley Pippin

The Powder River Basin



- Predominantly herbaceous grassland
- Home to 41% of the United States' coal production, ⅓ of the nation's coal reserves
- 11.3 billion tons of coal mined since 1865 – the most since the 1990s

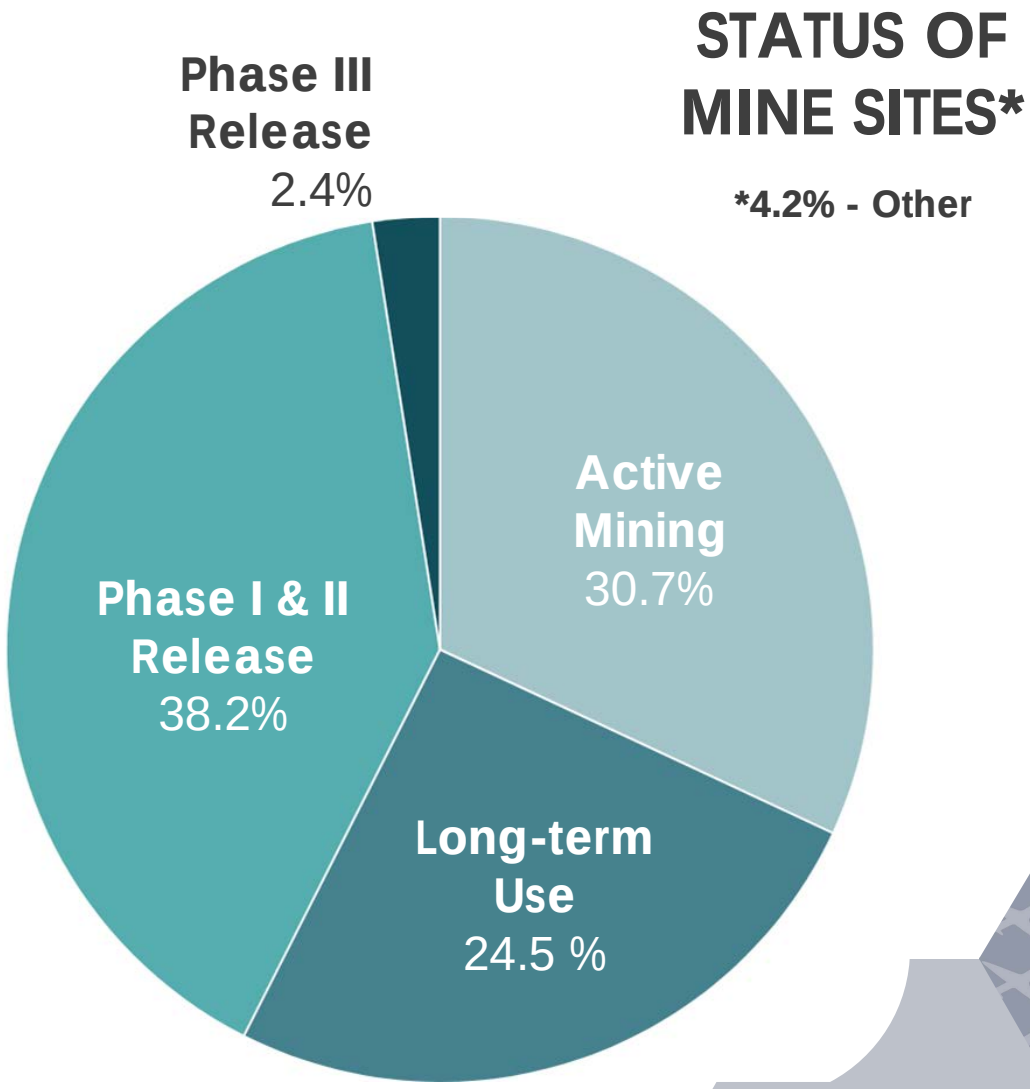
Environmental Impacts of Coal Mining

- Surface mining requires removing large amounts of topsoil
- Land disturbance reduces habitat for key species: Sage-grouse
- Mineral leaching → acid mine drainage
- Excess water extraction → too arid for re-vegetation

Image Source: EcoFlight

Reclamation

- Coal companies required to complete contemporaneous reclamation
- Three phases of reclamation:
  - Phase I: Replace topsoil, regrade
  - Phase II: Re-seed vegetation
  - Phase III: Vegetation succession, minimum of 10 years
- Phases tied to bond release
- Legally required, but lots of loopholes



Community Concerns

- Environmental degradation
- Financial decline of coal industry → less money for thorough reclamation, orphaned mines
- Orphaned mines → unlikely to ever fully recover, environmental and public health impacts

Image Credits: EcoFlight

Project Partners

- Powder River Basin Resource Council (PRBRC)
- Western Organization of Resource Councils (WORC)
  - 7 western states
  - Western Native Voice
- Northern Cheyenne Tribe
- Clemson University Energy-Economy-Environment Systems Analysis Group
- SkyTruth

Image Credit: EcoFlight

Project Objectives

- In the Powder River Basin
  - Recognize disturbance from coal mining
  - Identify re-vegetation from mine reclamation
- Provide the Coal Mining Assessment Tool (CMAT) to end users
- Generate output data from CMAT for project collaborators

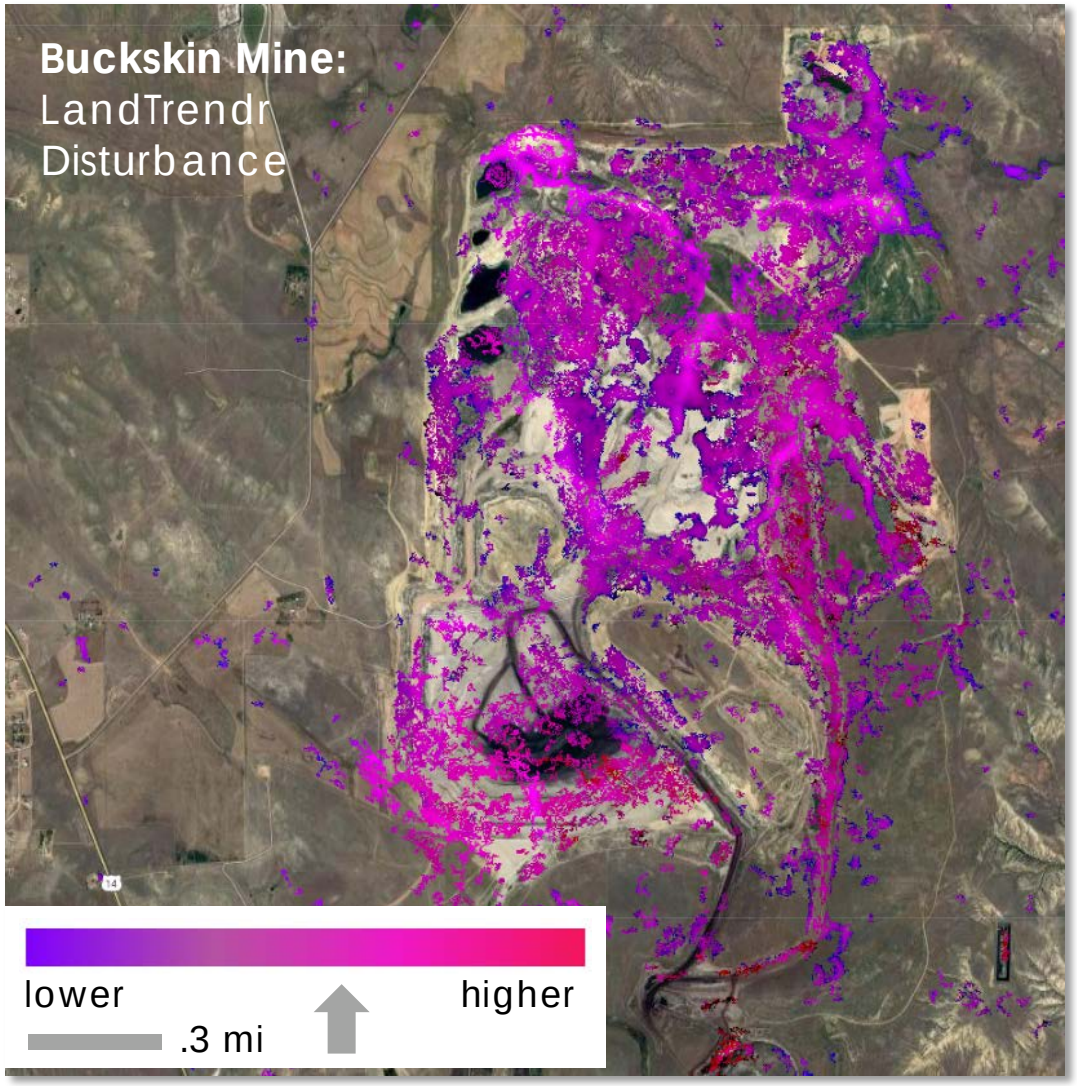


Image Credit: GEE Basemap

Methodology

Study Design

- **Study Location**
  - Campbell County, Powder River Basin, Wyoming
- **Study Period**
  - 1985 to 2018
  - June 1st to August 31st
    - Least snow on the ground

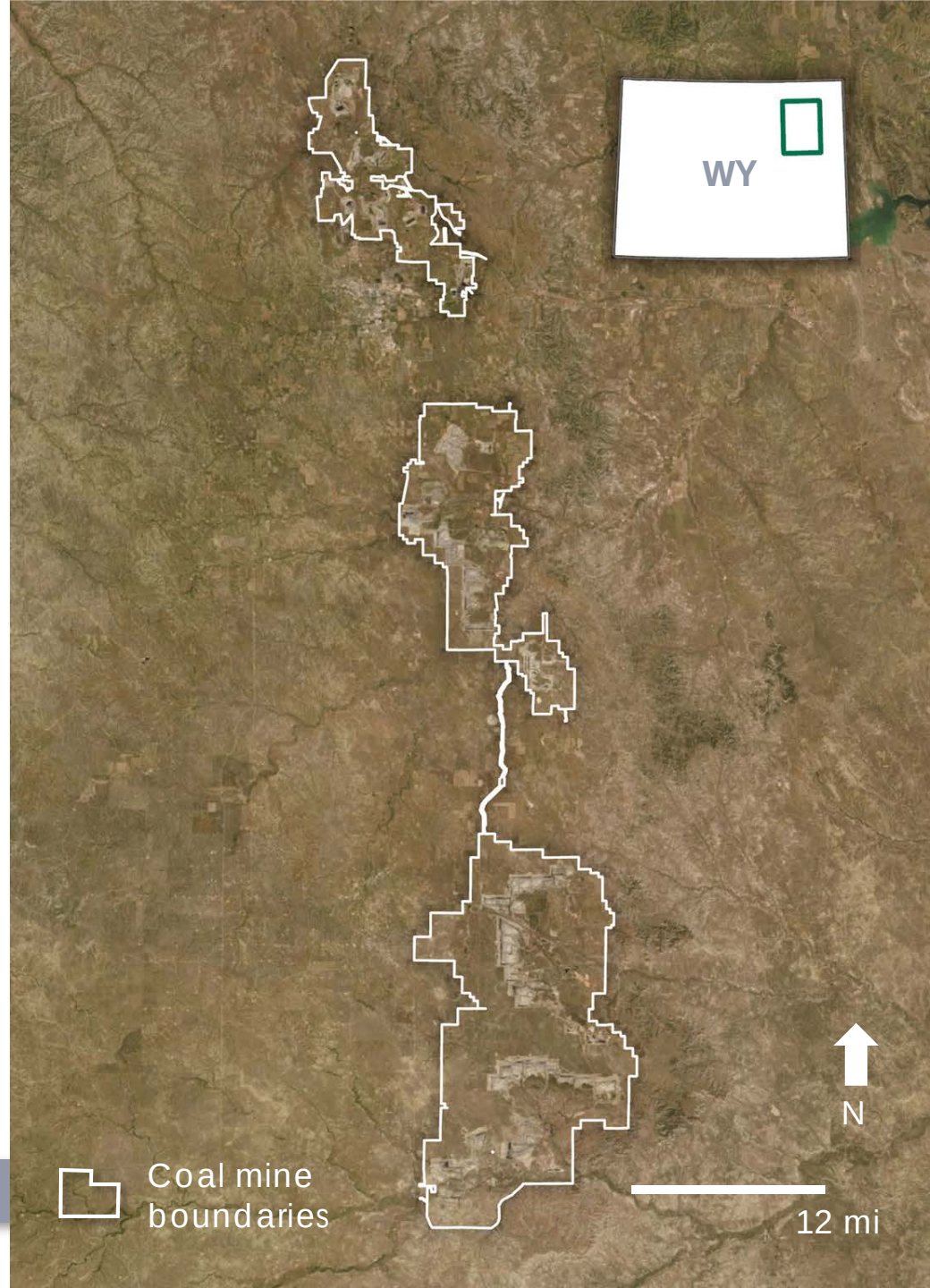


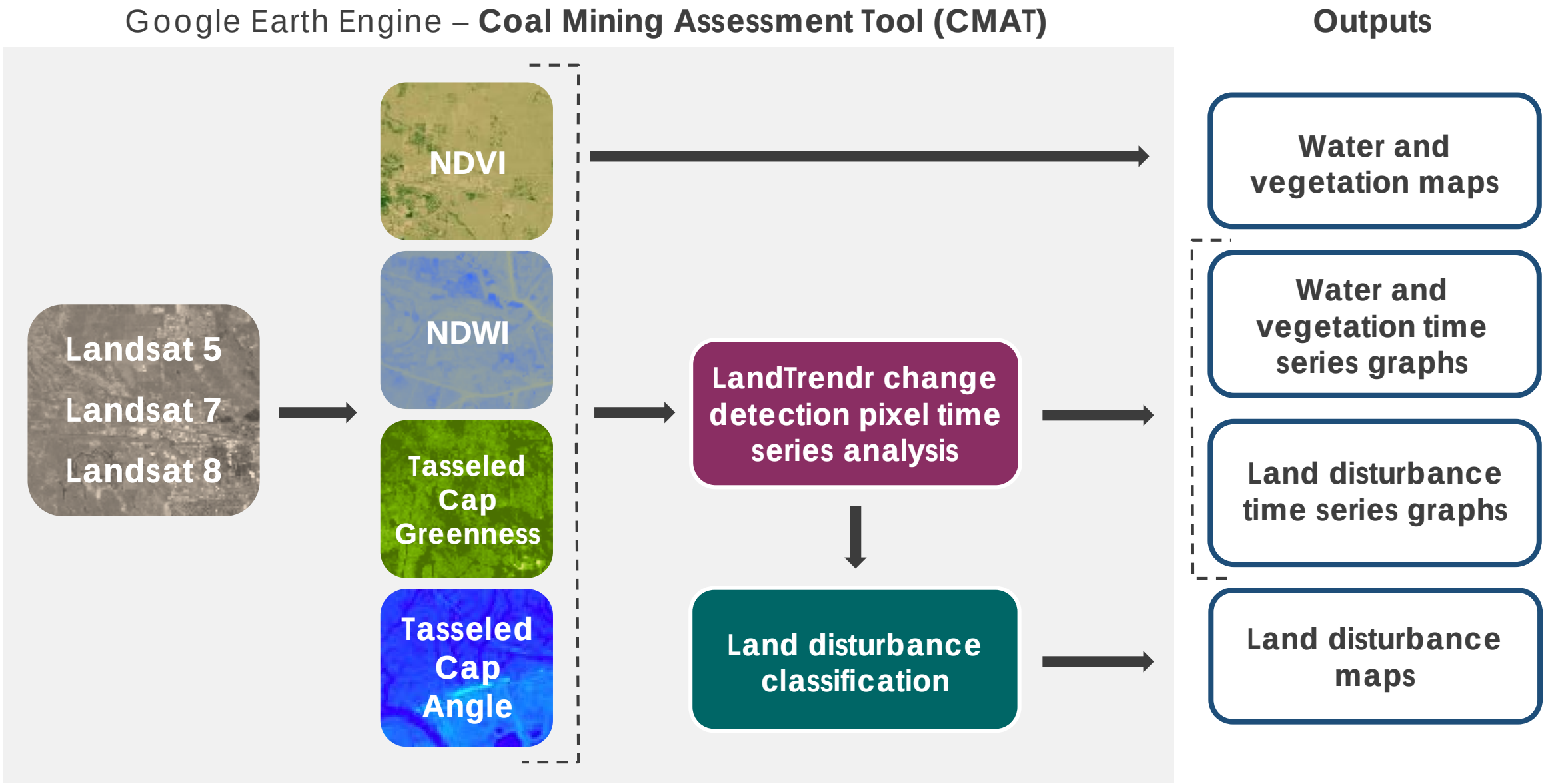
Image Credits: Esri Basemap

NASA Earth Observations

Satellite/Sensor	Dates
Landsat 5 Thematic Mapper (TM)	1985 to 2011
Landsat 7 Enhanced Thematic Mapper Plus (ETM+)	2012
Landsat 8 Operational Land Imager (OLI)	2013 to 2018

Image Credits: NASA

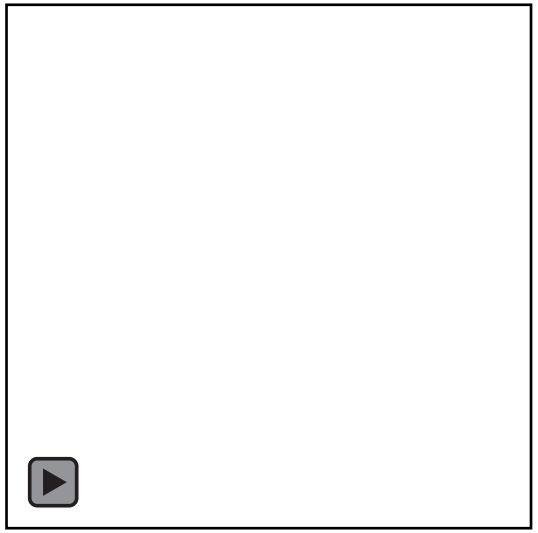
Methods Overview



Black Thunder Mine 1985 to 2018

True Color

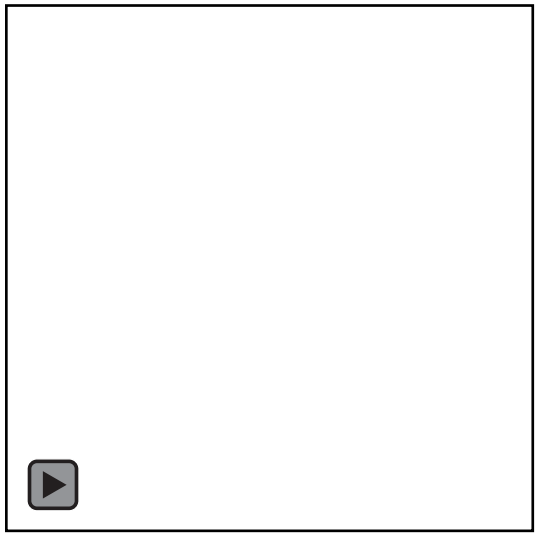
2.5 mi



Tasseled Cap Greenness

-75 805

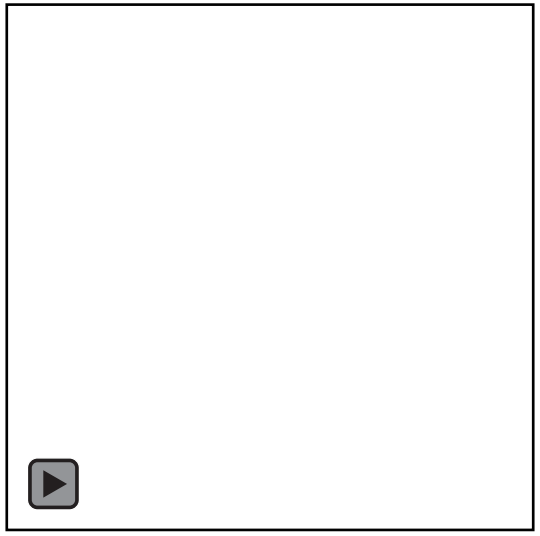
2.5 mi



NDVI

0 1

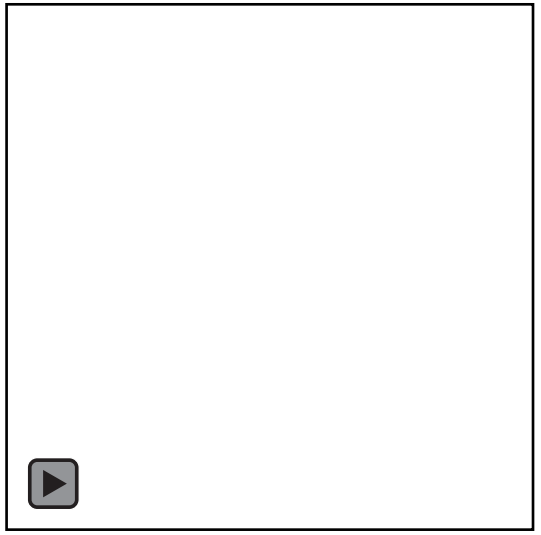
2.5 mi



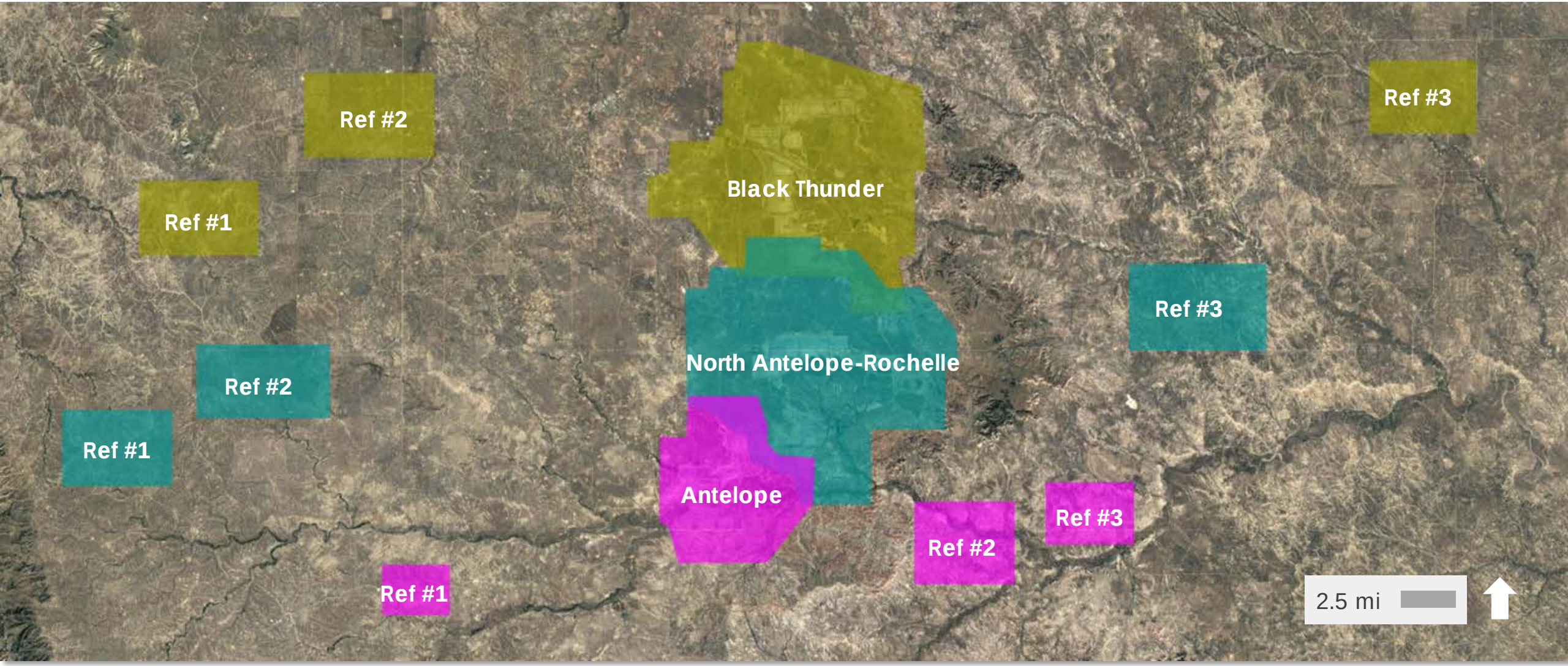
Tasseled Cap Angle

-91 907

2.5 mi

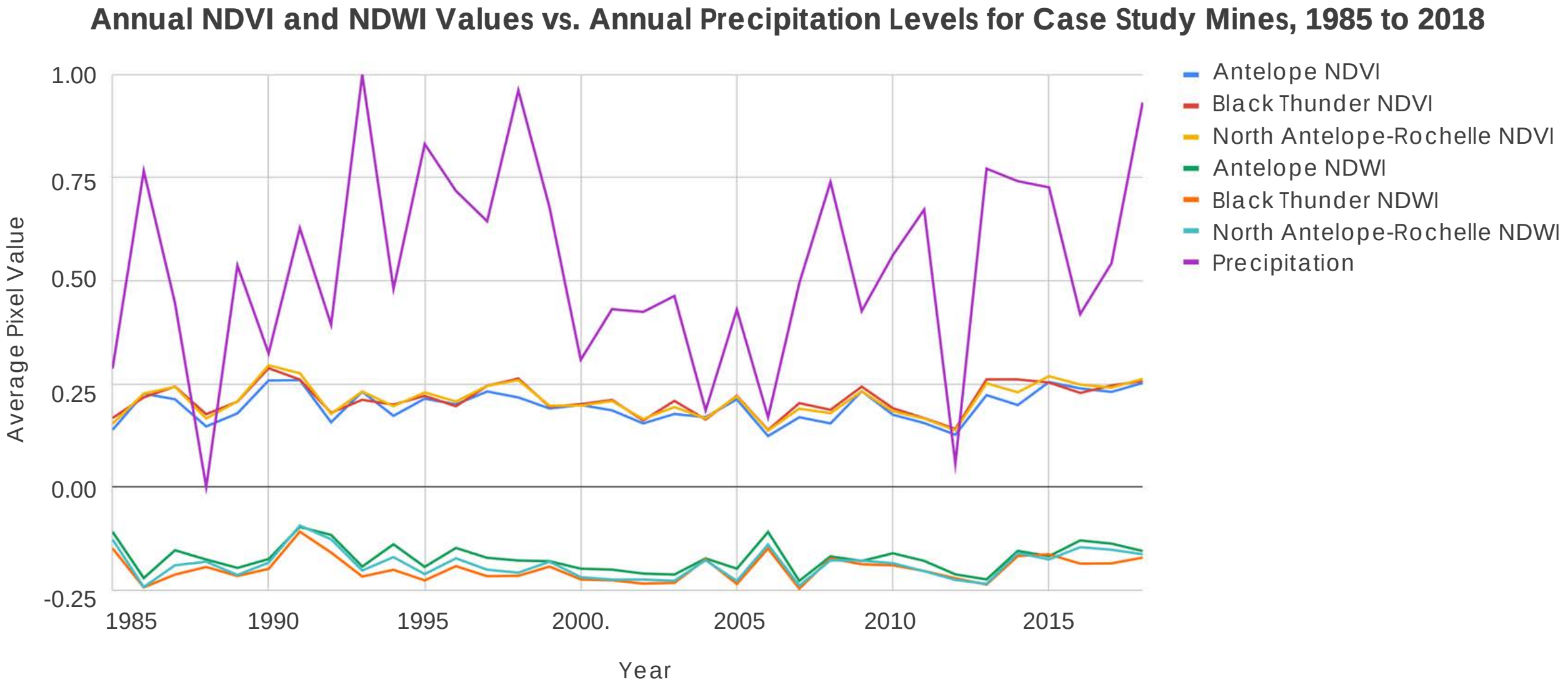


Reference Sites

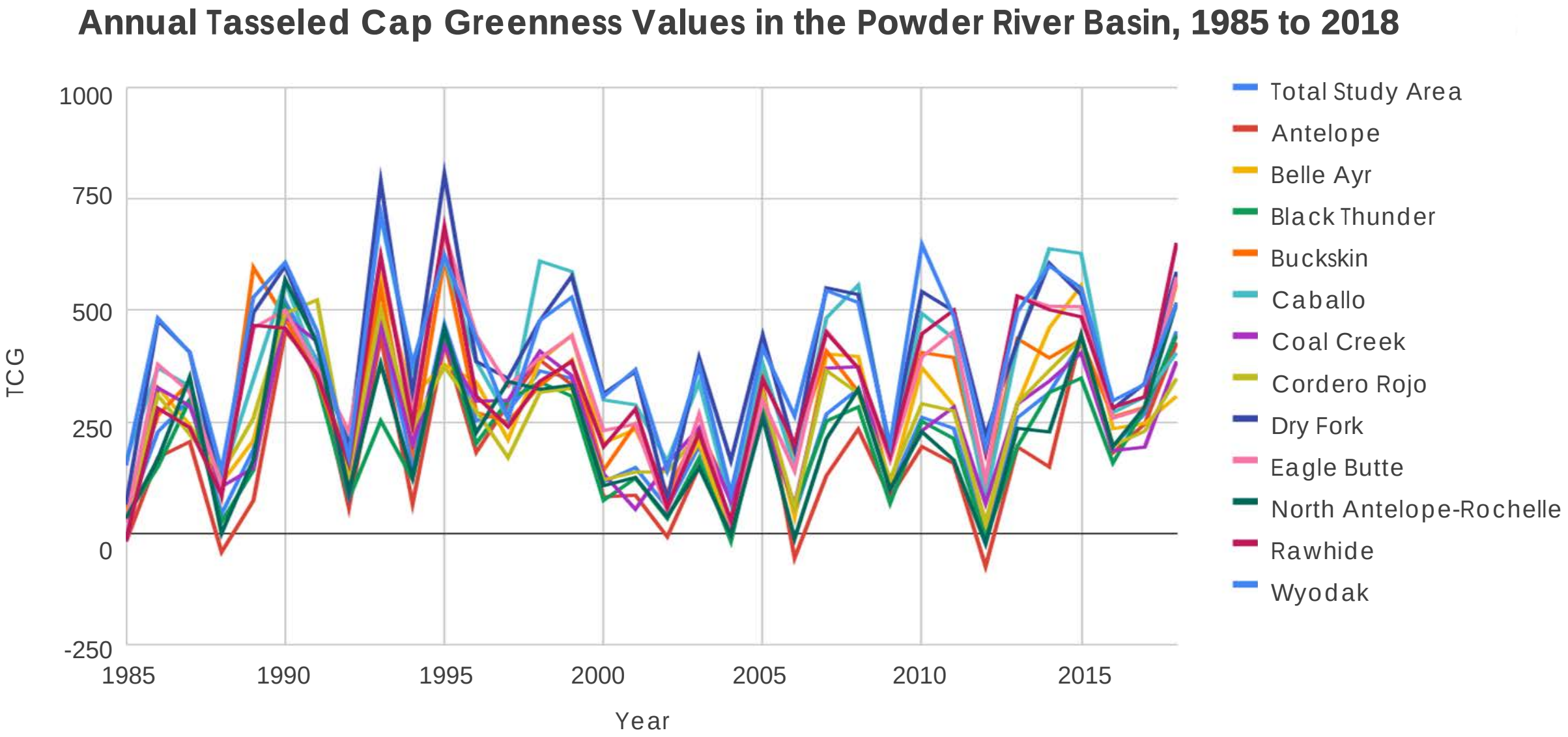


Results

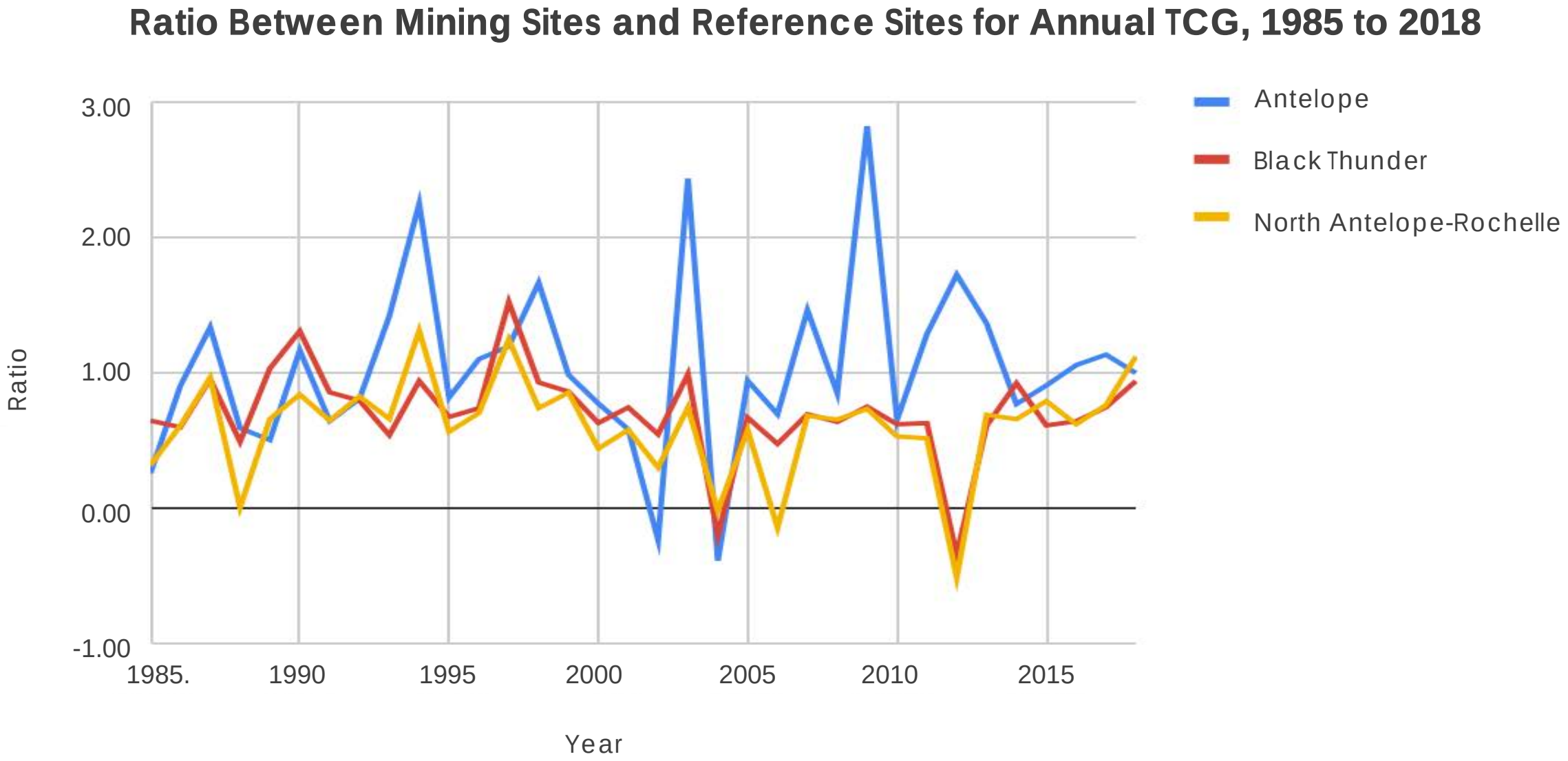
Changes in Water and Vegetation



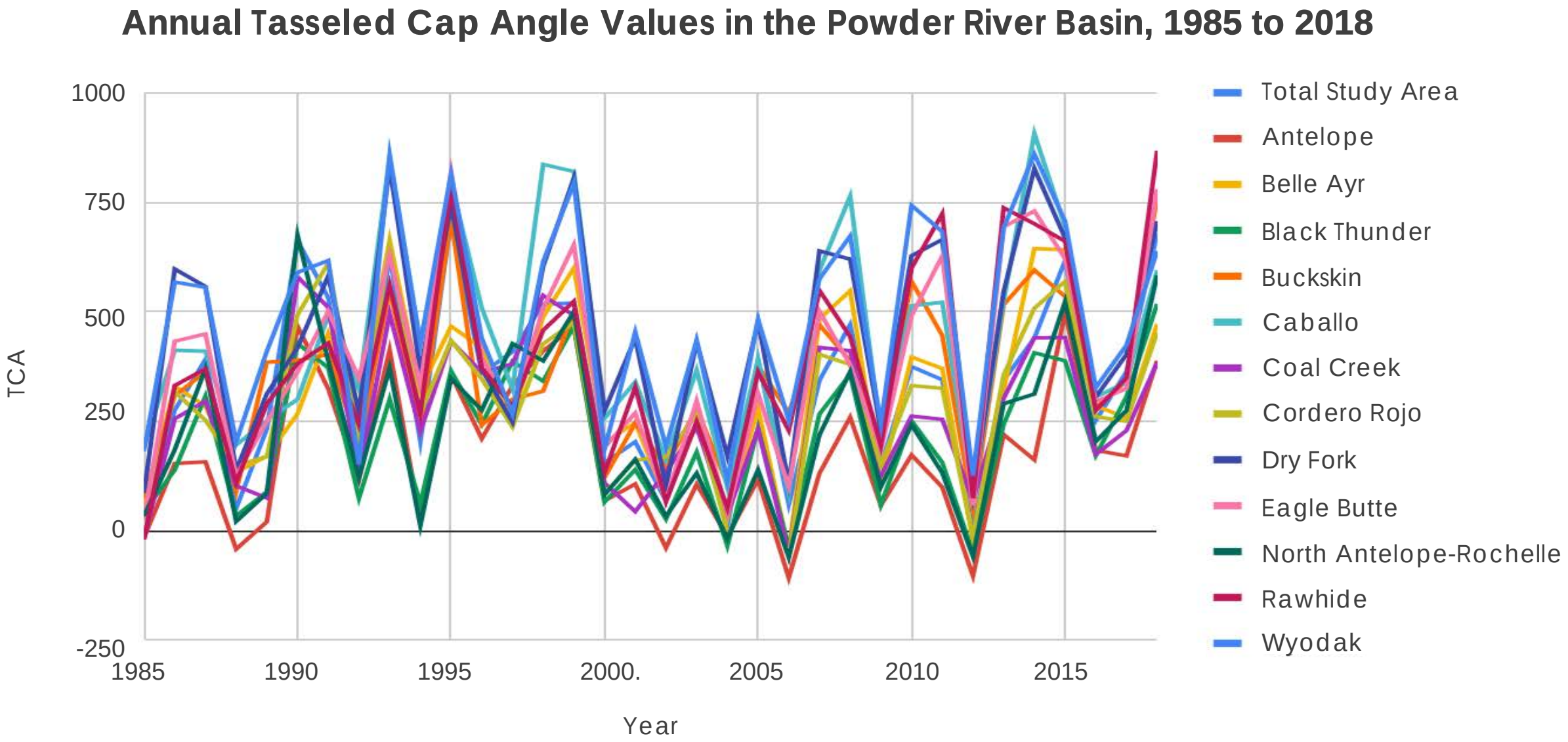
Tasseled Cap Greenness (TCG)



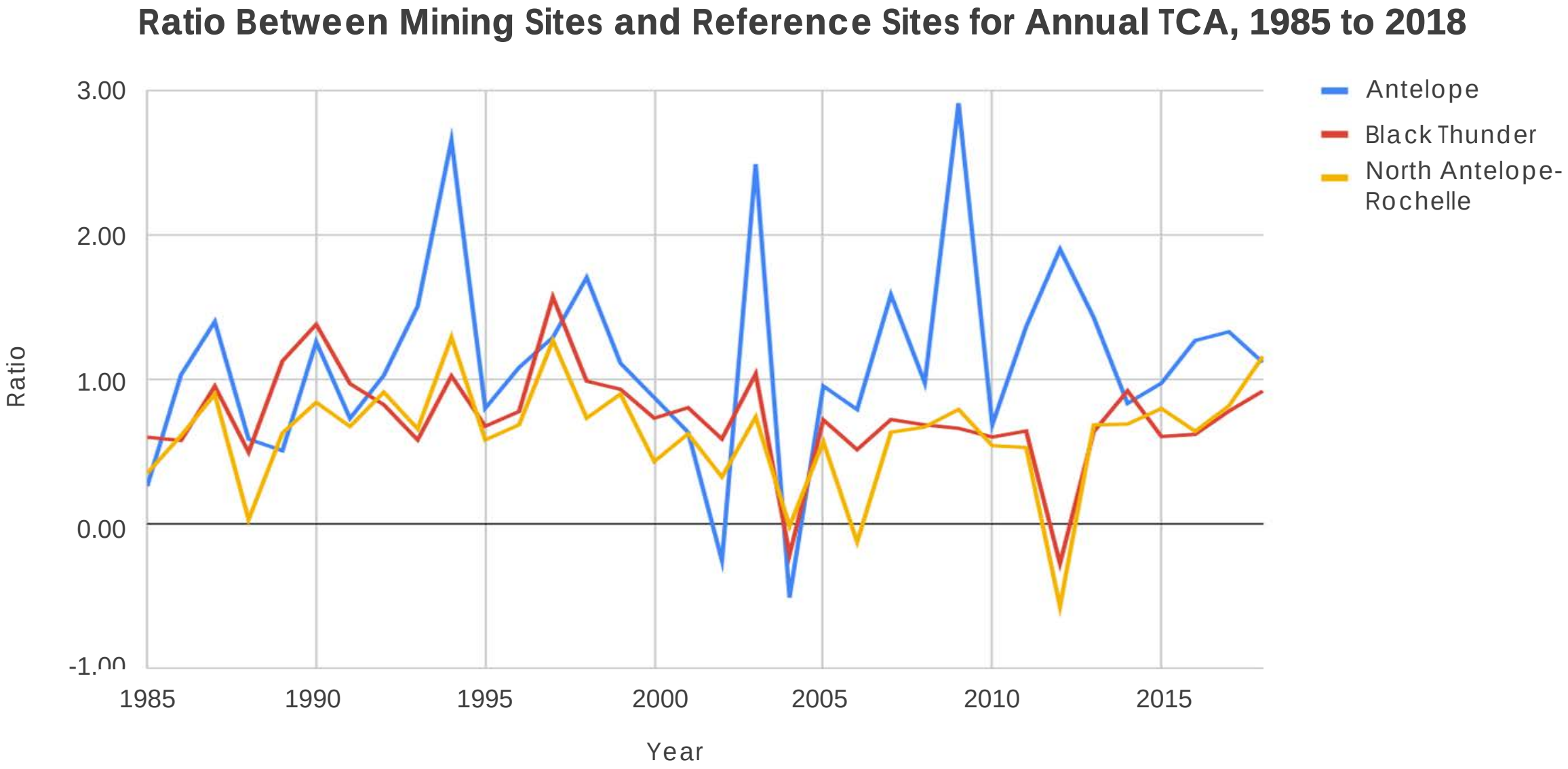
Case Study: TCG Ratio Comparison



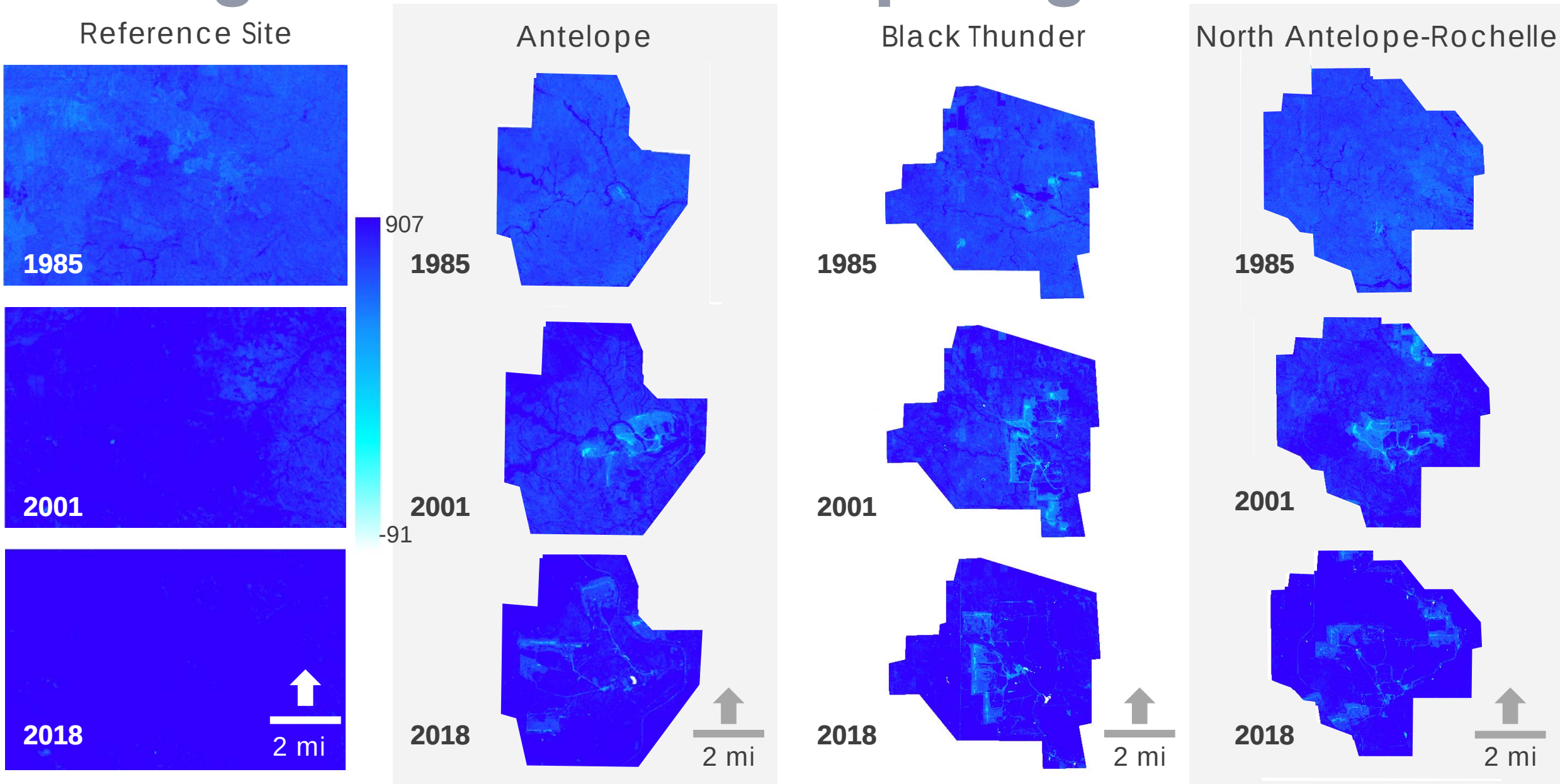
Tasseled Cap Angle (TCA)



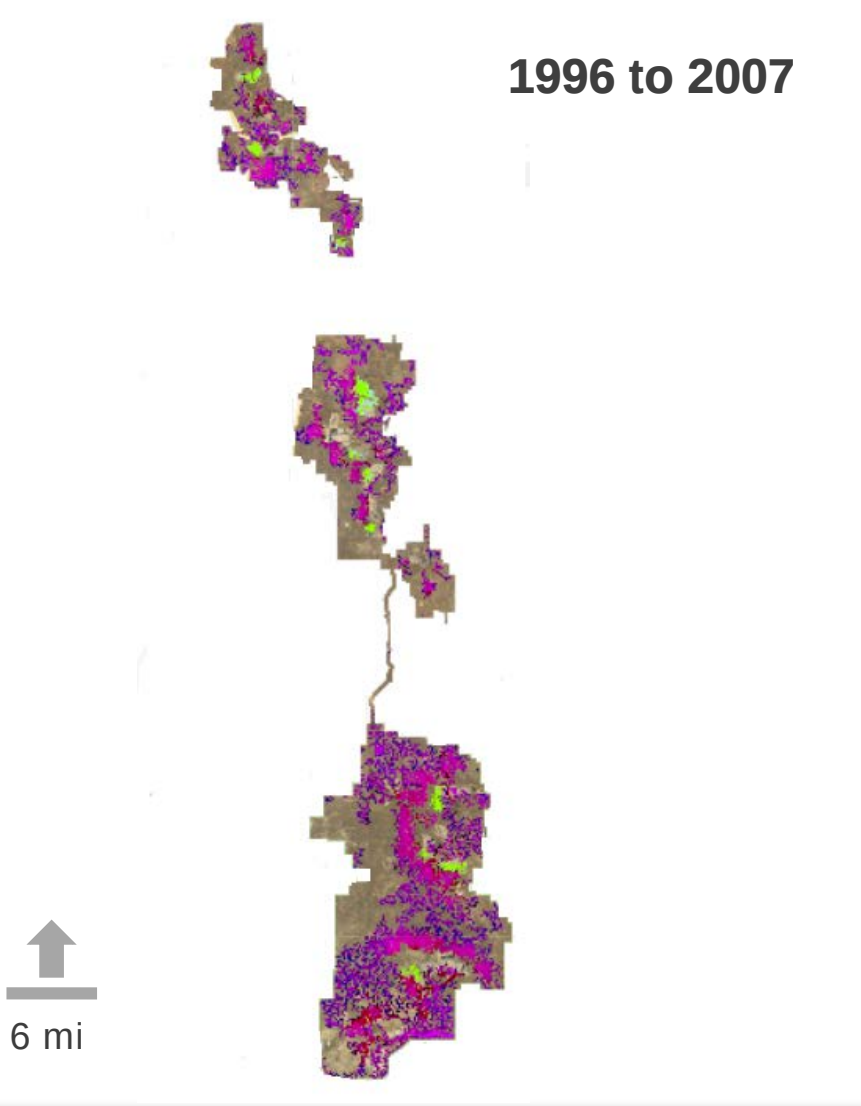
Case Study: TCA Ratio Comparison



Changes in Tasseled Cap Angle



Changes in Land Cover – All Sites



Disturbance

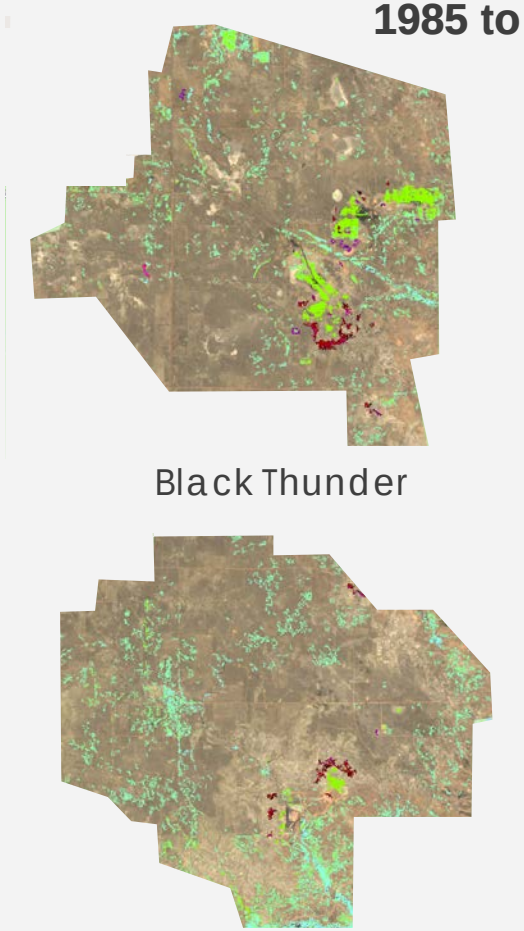
lower higher

Reclamation

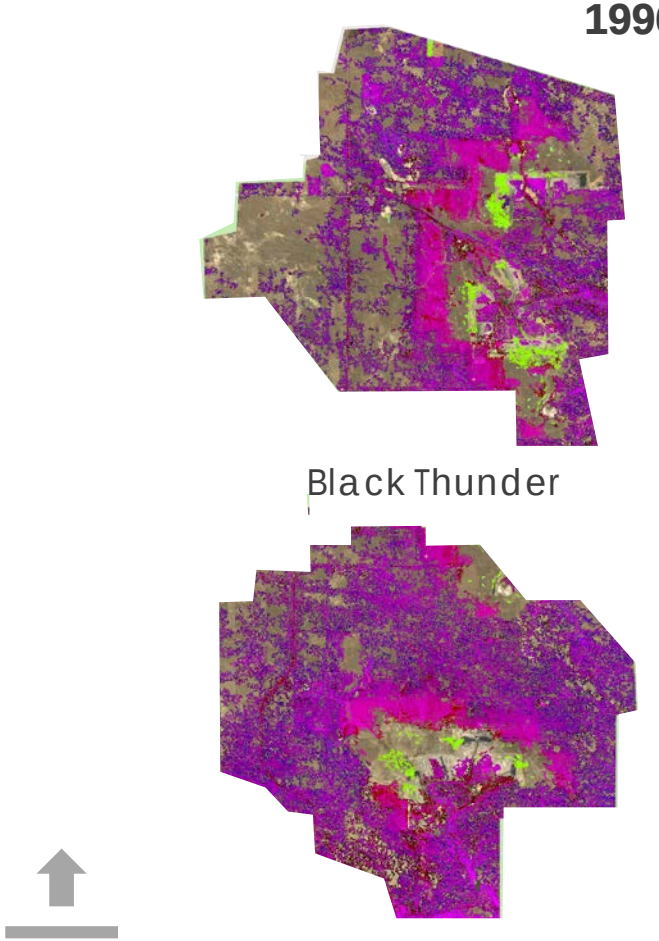
lower higher

Changes in Land Cover – Black Thunder/North Antelope-Rochelle

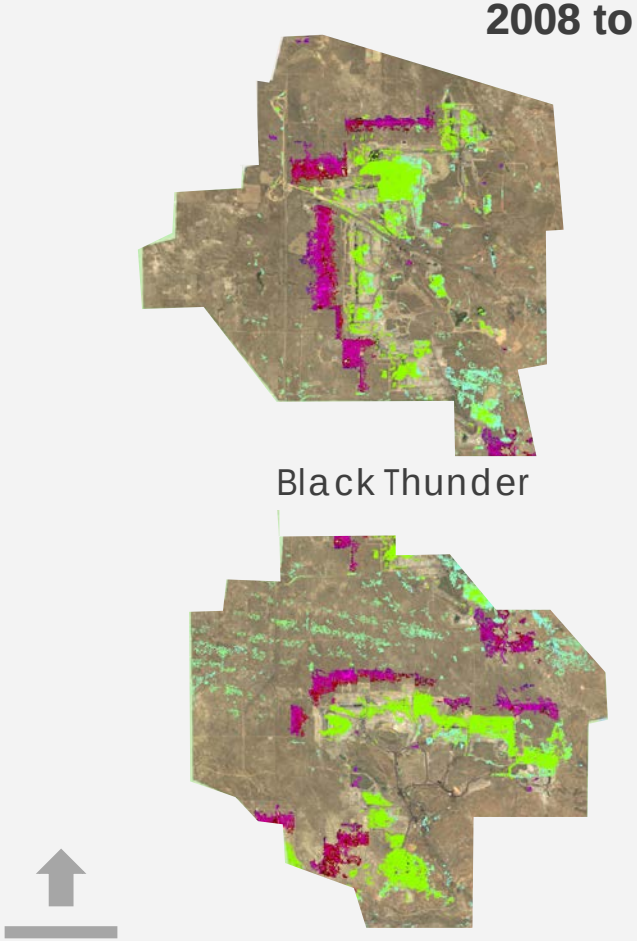
1985 to 1995



1996 to 2007



2008 to 2018



Disturbance

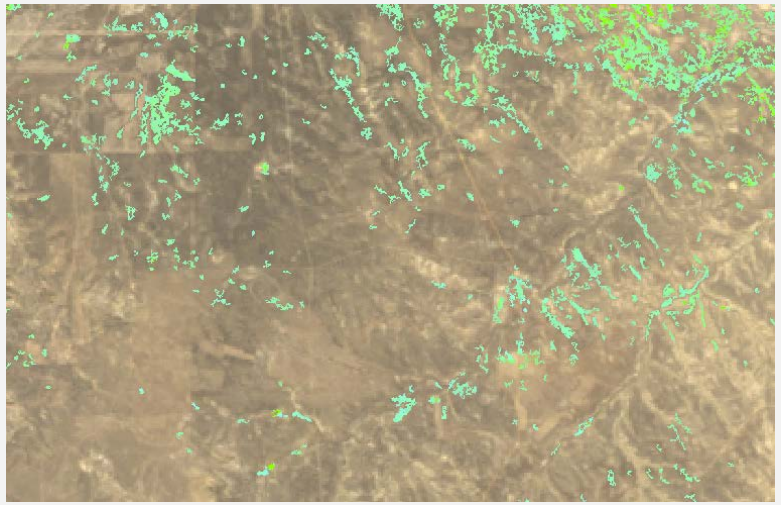
lower higher

Reclamation

lower higher

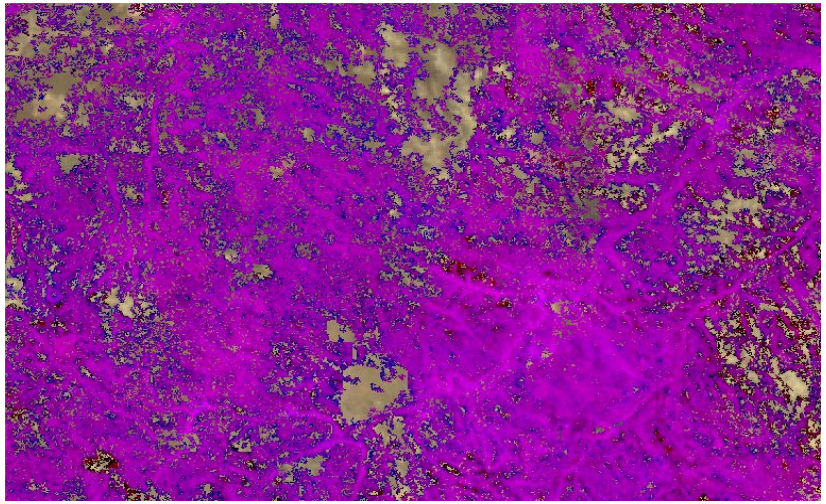
Changes in Land Cover – Southern Reference Site

1985 to 1995



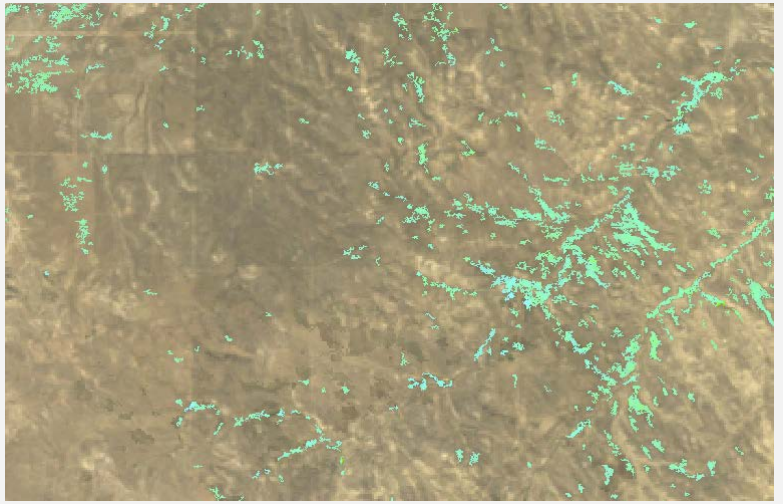
1 mi

1996 to 2007



1 mi

2008 to 2018



1 mi

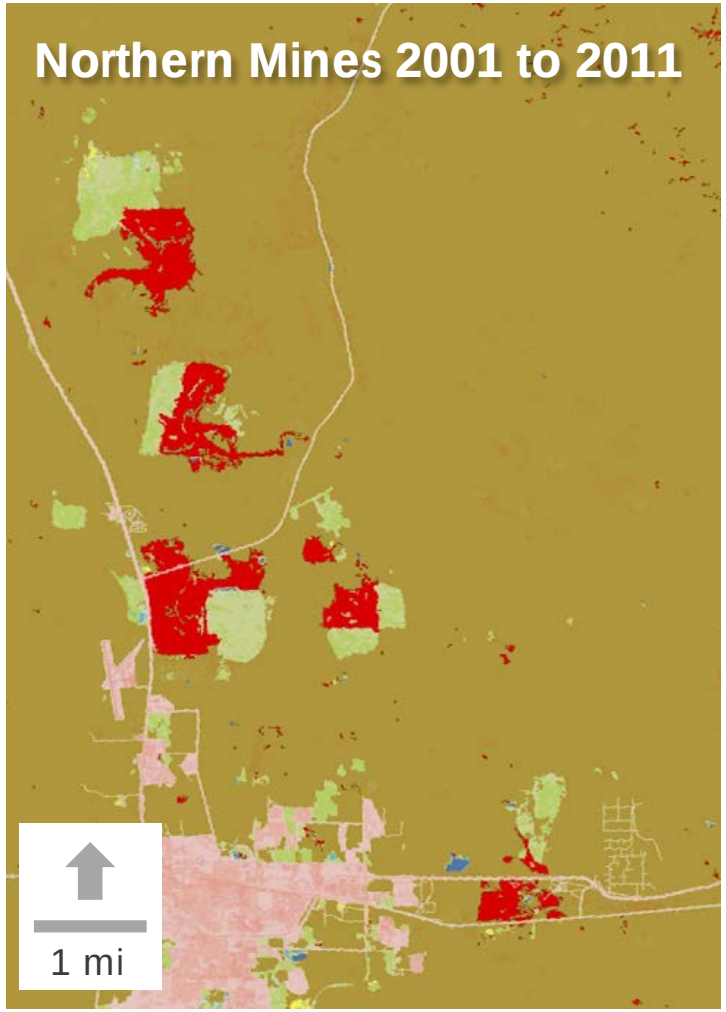
Disturbance

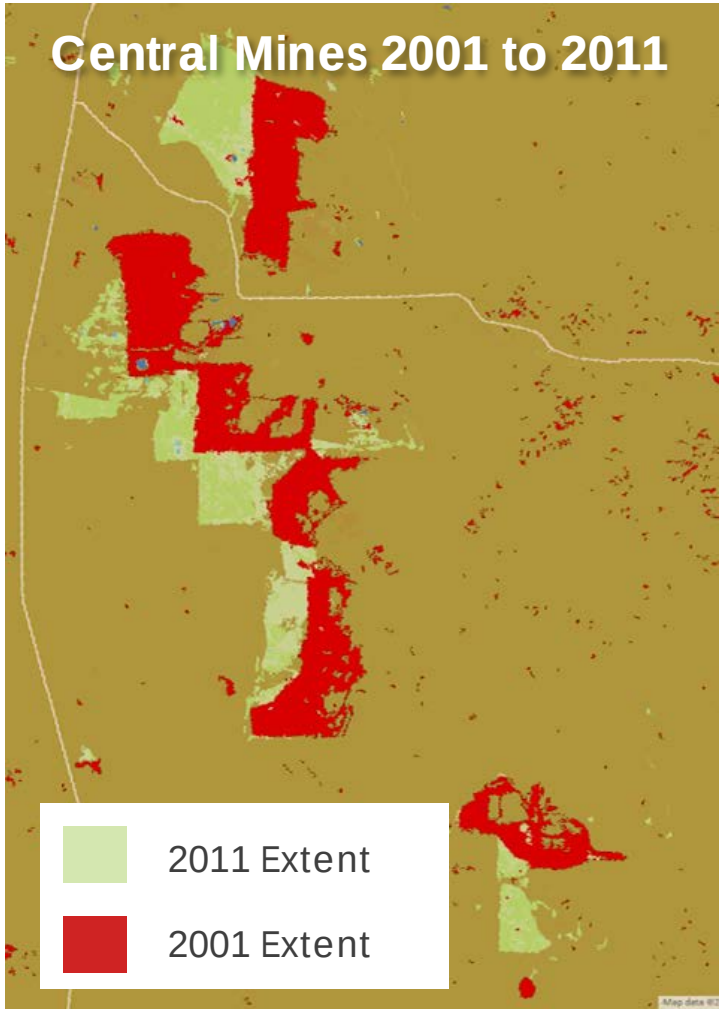
lower higher

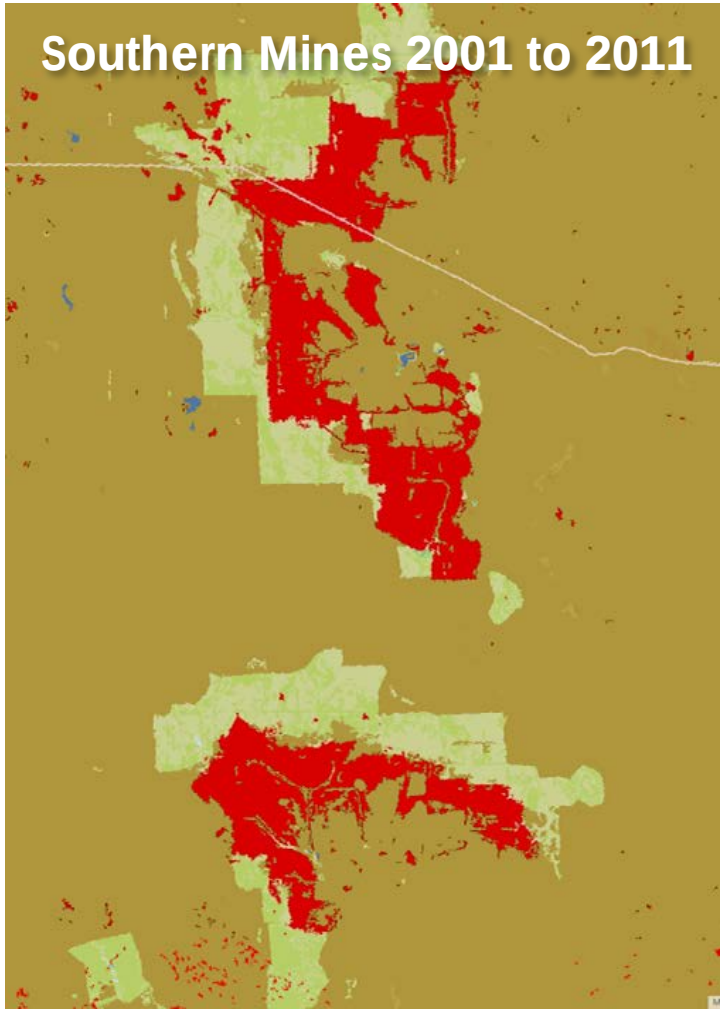
Reclamation

lower higher

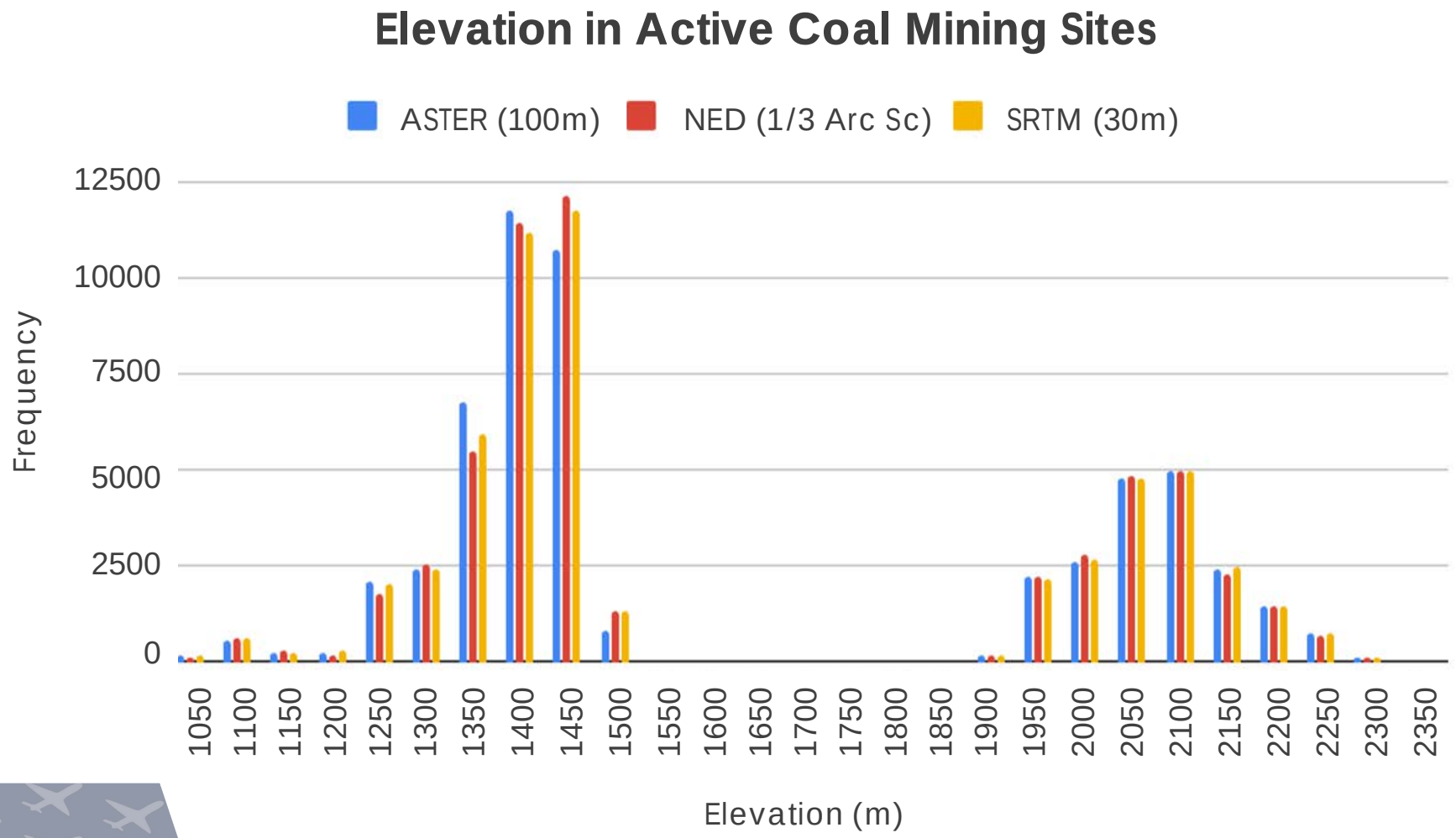
Changes in Land Cover - NLCD

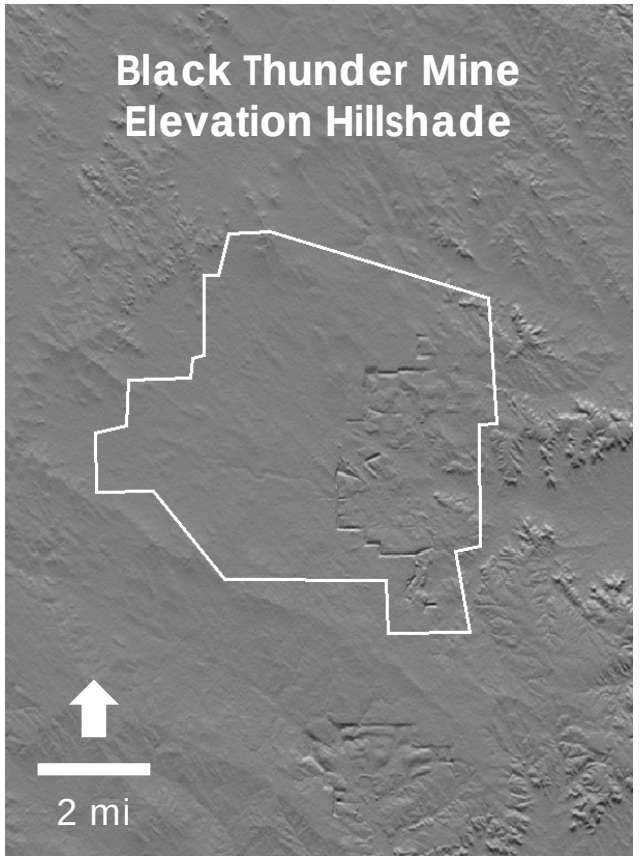






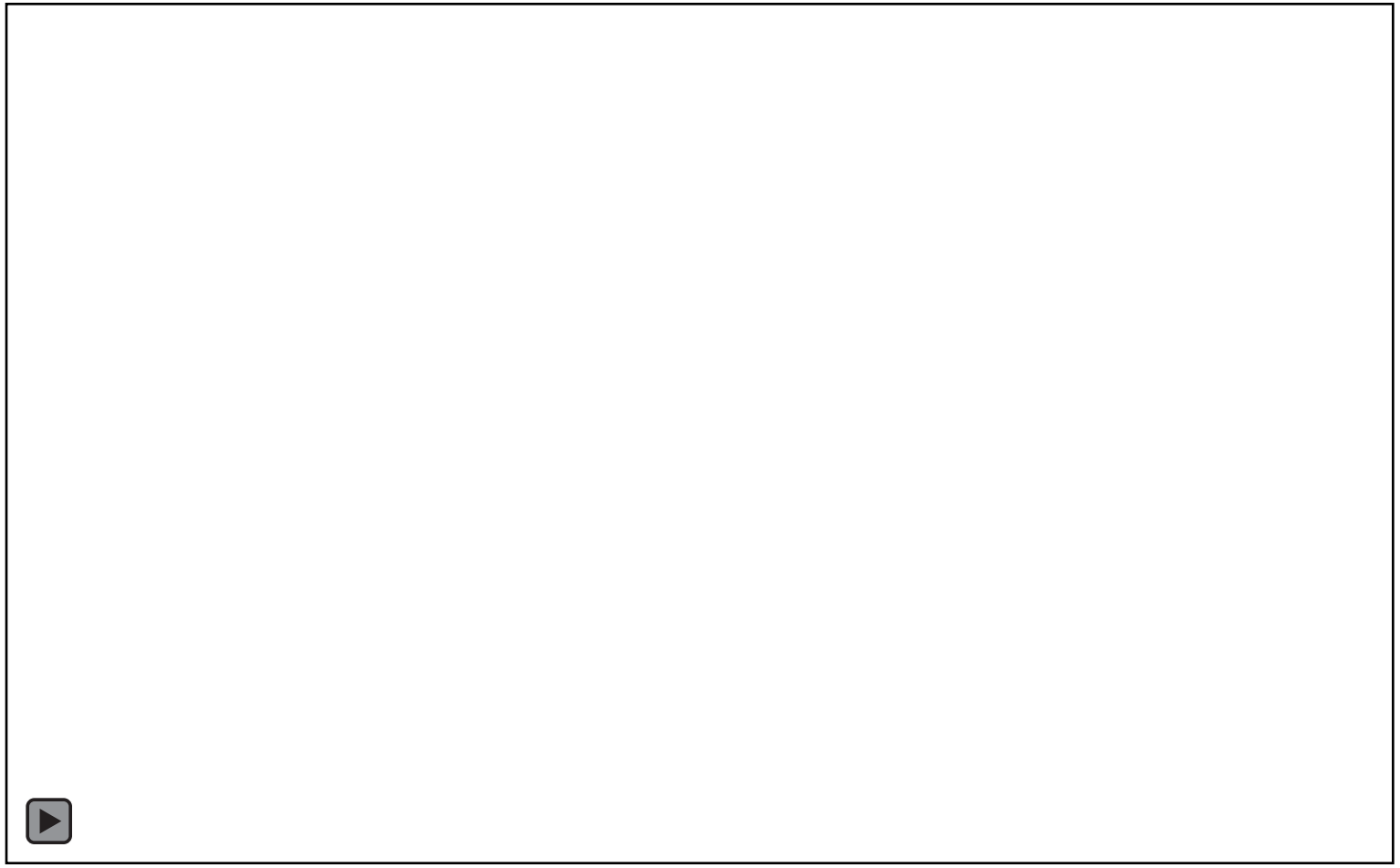
Elevation Change





Coal Mining Assessment Tool (CMAT)

- Built in Google Earth Engine, assesses changes in land cover from 1985 to 2018
- Graphical user interface (GUI) provides maps of land disturbance and other analyses
- Can be used for future monitoring with code modifications



Uncertainties and Future Work

- Landsat **spatial resolution is low** for the scale of **individual mines**
- **Small artifacts** in some years
- **Parameters may "even out"** within a single composite image due to contemporaneous reclamation
- **No LiDAR** to measure topographic change over time
- Land classifications to differentiate **barren undisturbed from barren disturbed lands** are extremely difficult - future work could explore this

Image Credit: Google Earth Engine

Conclusions

Summary of Findings

- While NDVI and NDWI can be helpful indices for evaluating land disturbance, the spatial and temporal patterns of mining and reclamation call for **more advanced methods**.

- Tasseled cap greenness and tasseled cap angle values indicate that mines that engage in **thorough contemporaneous reclamation** can restore vegetation **up to 78% faster than other mines.**

- CMAT determines the magnitude and persistence of land change over a 34 year time period, which partner organizations can use to **effectively monitor mining land disturbance and reclamation efforts.**

Overall Project Benefits

Image Credits: EcoFlight

- Build community capacity with Earth observations
- Facilitate monitoring of land disturbance and land reclamation monitoring in mining areas
- A baseline for further analyses on coal life cycles

ACKNOWLEDGEMENTS

Shannon Anderson, Staff Attorney (Powder River Basin Resource Council)

Dan Cohn, Regional Organizer (Western Organization of Resource Councils)

Jason Whiteman, Water and Natural Resources Administrator (Northern Cheyenne Tribe)

Dr. Mik Carbajales-Dale, Director (Clemson Energy-Economy-Environment Systems Analysis Group)

Christian Thomas, Geospatial Engineer (SkyTruth)

Dr. Juan Torres-Perez, Science Advisor (Bay Area Environmental Research Institute, NASA Ames Research Center)

Dr. Kenton Ross, Science Advisor, (NASA Langley Research Center)

John Dilger, Science Advisor (Spatial Informatics Group, LLC)

Farnaz Bayat, NASA DEVELOP Center Lead (NASA Ames Research Center)

Jerrold Acdan, NASA DEVELOP Project Coordination Fellow (NASA Ames Research Center)

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