Applying a Big Data Approach to Detecting Fire Disturbances and Recovery at a Continental Scale Using Satellite Remote Sensing

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Science Questions

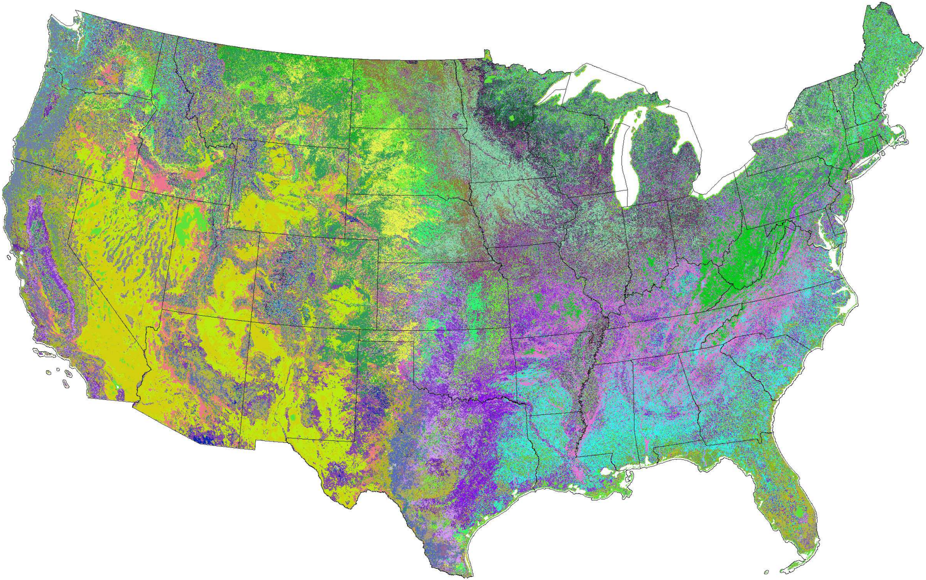
1. Can we use moderate-resolution satellite NDVI imagery to detect and characterize fire disturbances *en masse* in an automated way?

2. What challenges are there to routine monitoring of burned area and fire emissions using NDVI?

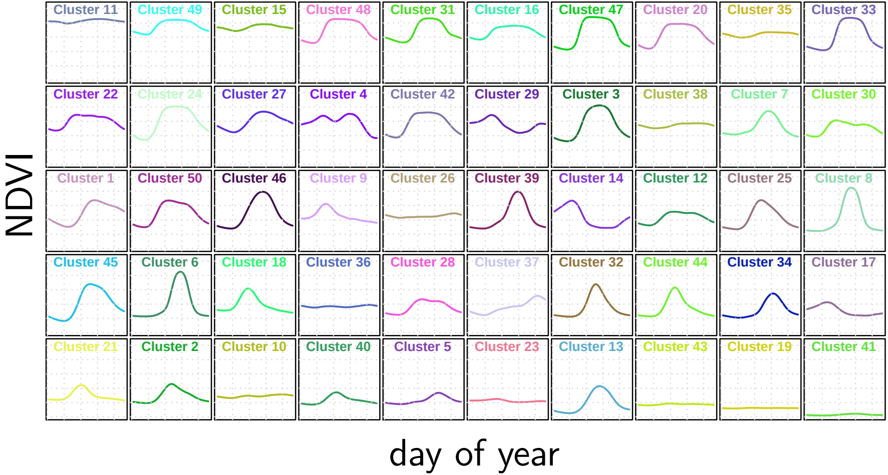
Clustering MODIS NDVI to Produce Phenoregions

- Hoffman and Hargrove previously used *k*-means clustering to detect brine scars from hyperspectral data (Hoffman, 2004) and to classify phenologies from monthly climatology and 17 years of 8 km NDVI from AVHRR (White et al., 2005).
- This data mining approach requires high performance computing to analyze the entire body of the high resolution MODIS NDVI record for the continental U.S.
- $>$101B NDVI values, consisting of $\sim$146.4M cells for the CONUS at 250 m resolution with 46 maps per year for 15 years (2000–2014), analyzed using *k*-means clustering.
- The annual traces of NDVI for every year and map cell are combined into one 395 GB single-precision binary data set of 46-dimensional observation vectors.
- Clustering yields 15 phenoregion maps in which each cell is classified into one of *k* phenoclasses that represent prototype annual NDVI traces.

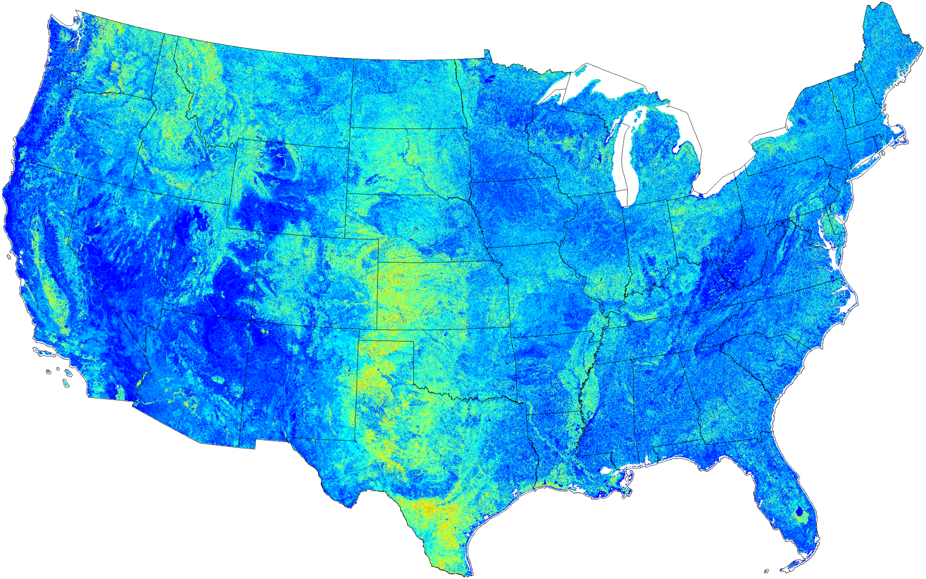
50 Phenoregions for year 2012 (Random Colors)



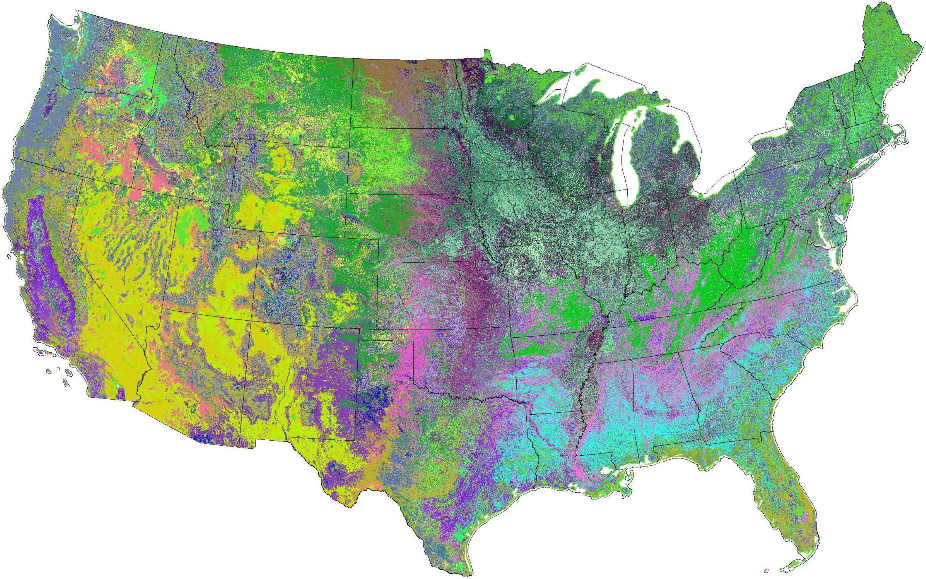
50 Phenoregion Prototypes (Random Colors)



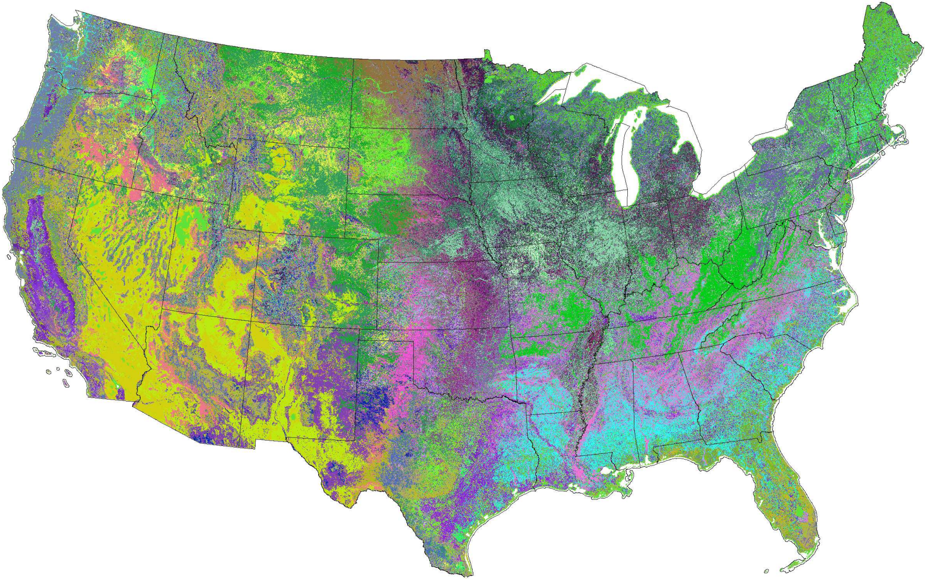
50 Phenoregions Persistence



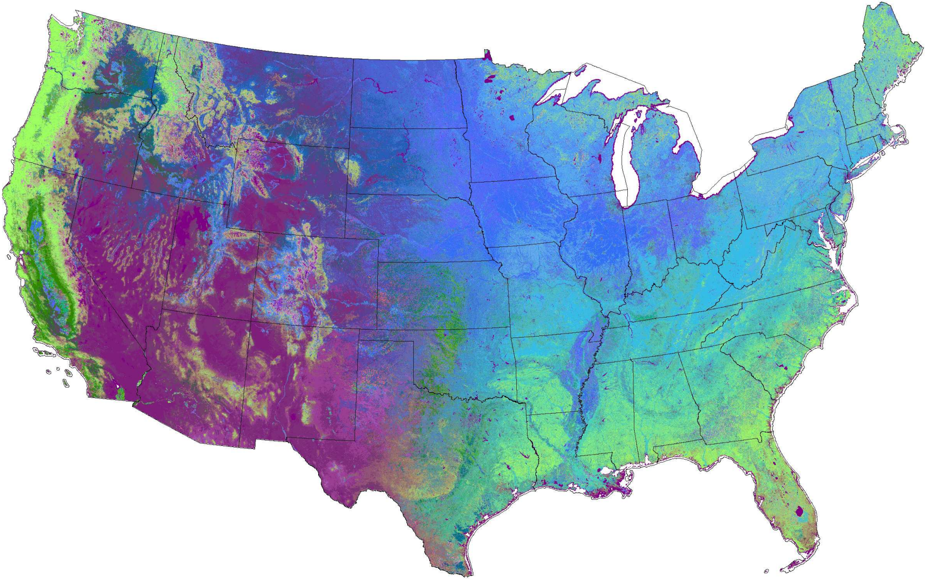
50 Phenoregions Mode (Random Colors)



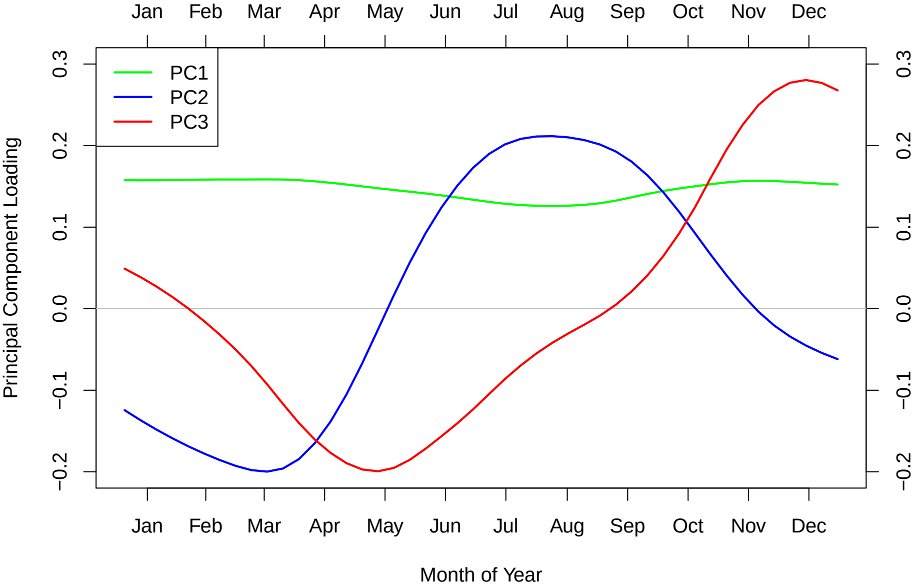
50 Phenoregions Max Mode (Random Colors)



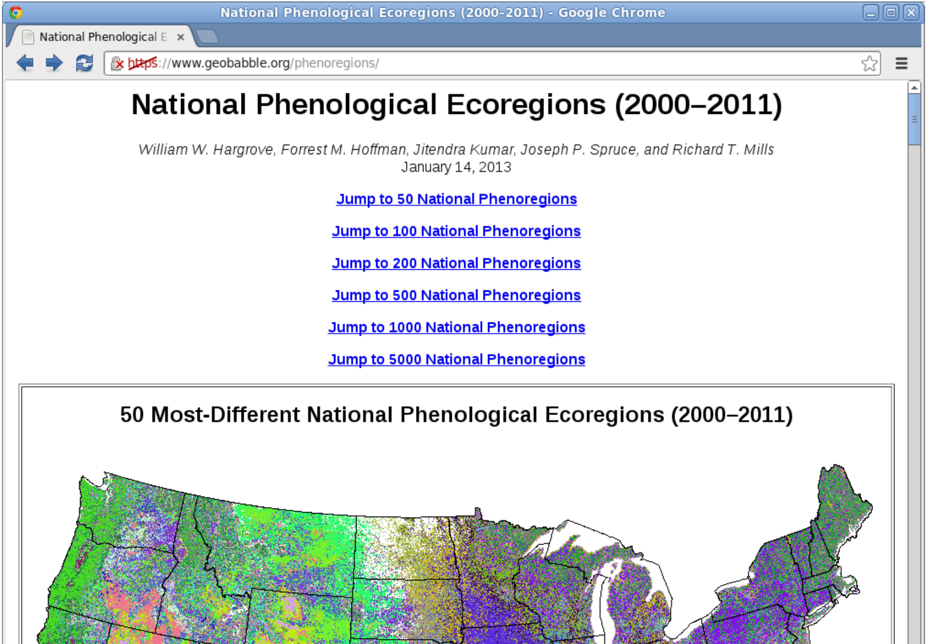
50 Phenoregions Max Mode (Similarity Colors)



50 Phenoregions Max Mode (Similarity Colors Legend)



Phenoregions Clearinghouse



National Phenological Ecoregions (2000–2011)

William W. Hargrove, Forrest M. Hoffman, Jitendra Kumar, Joseph P. Spruce, and Richard T. Mills
January 14, 2013

[Jump to 50 National Phenoregions]

[Jump to 100 National Phenoregions]

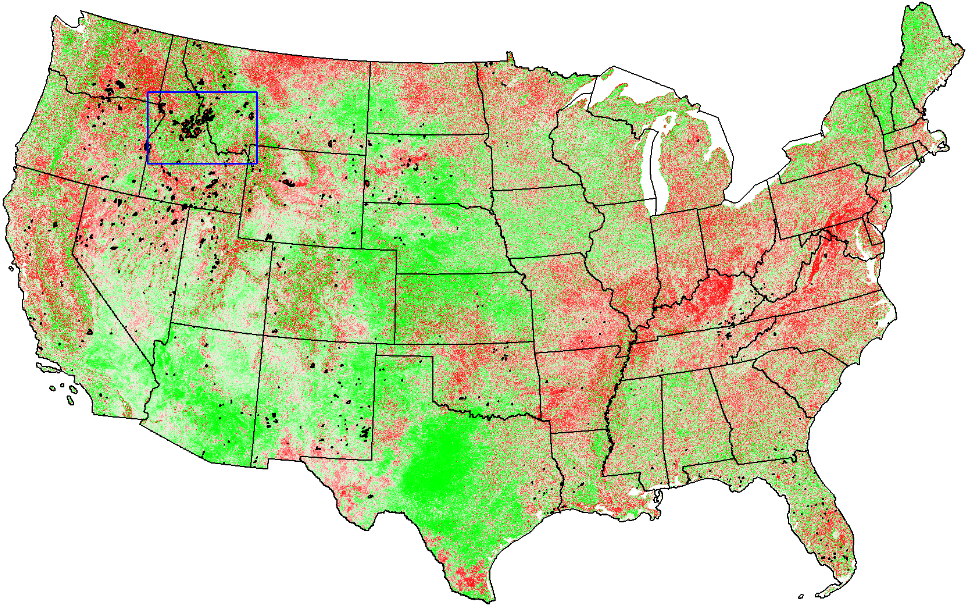
[Jump to 200 National Phenoregions]

[Jump to 500 National Phenoregions]

[Jump to 1000 National Phenoregions]

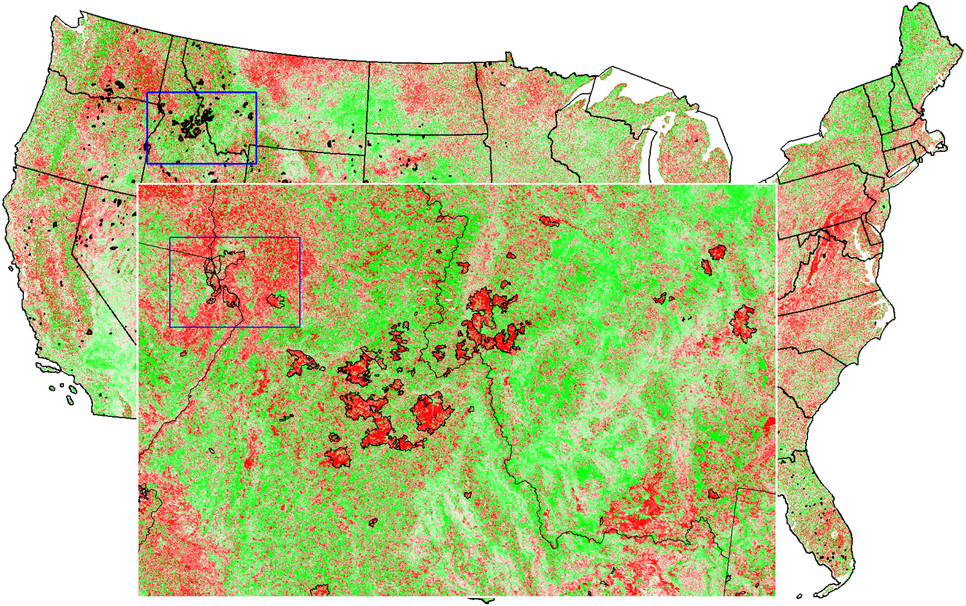
[Jump to 5000 National Phenoregions]

50 Most-Different National Phenological Ecoregions (2000–2011)

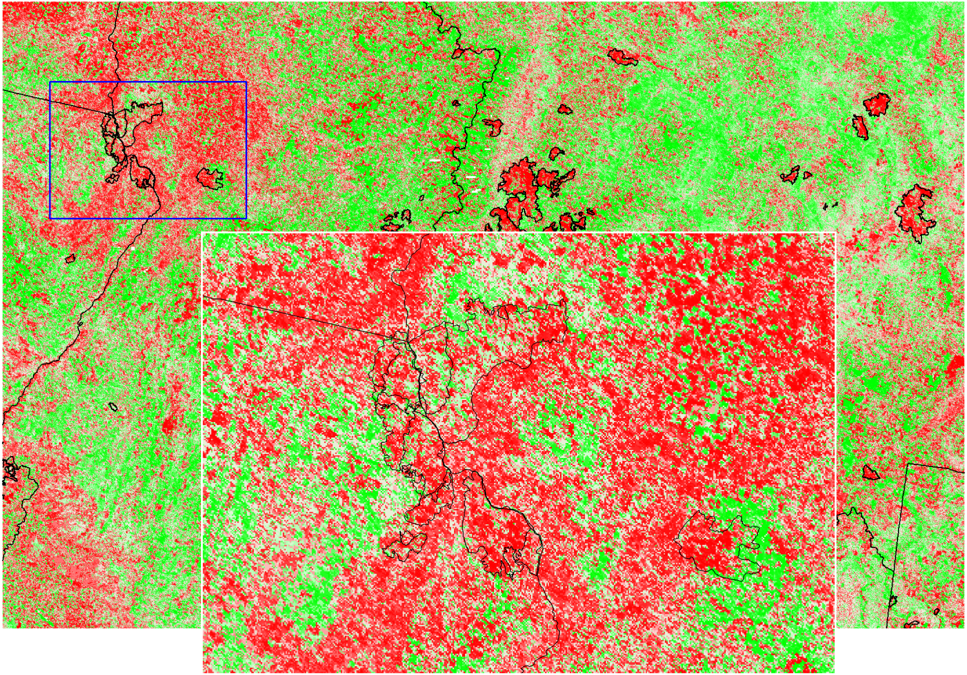


Magnitude of NDVI Change (Disturbance) Map (2000–2001)

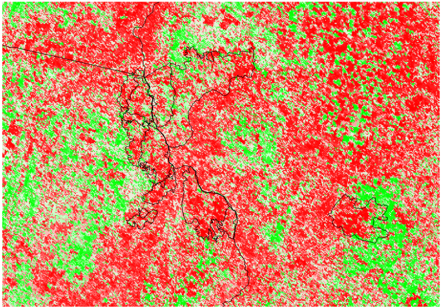
Red: NDVI decrease; Green: NDVI increase; Black vectors: 2000 burn perimeters from Monitoring Trends in Burn Severity (MTBS) Dataset



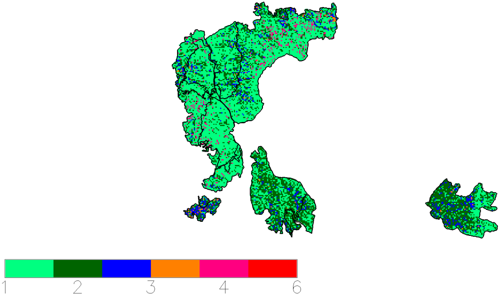
We observe large magnitude of change within most burn perimeters, but we also see reductions outside of burn perimeters and mixed differences within some burn perimeters.



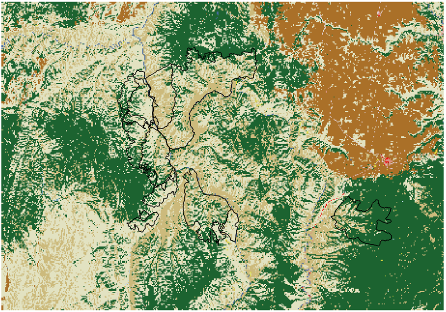
What accounts for mixed changes in NDVI within known fire boundaries?



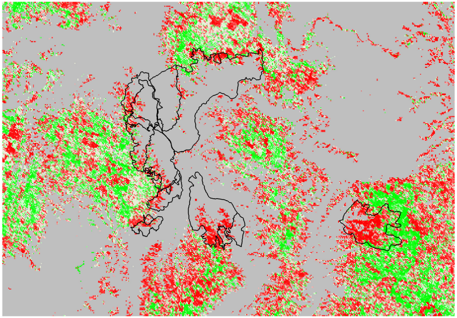
Disturbance Map



MTBS Burn Severity



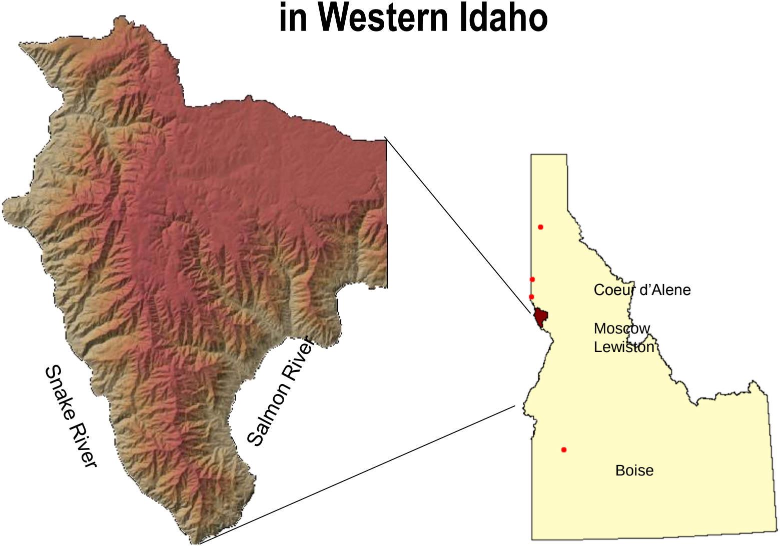
NLCD Vegetation Map



Disturbance Map (Forest only)

Low severity fires in mixed grasslands with sparse open forests are less likely to show strong, homogeneous reductions in NDVI.

Craig Mountain Wildlife Management Area in Western Idaho



Craig Mountain Vegetation Characteristics

Forests are interspersed with canyon grasslands at high to middle elevations.
(Top of Coral Creek looking down toward the Snake River)

Craig Mountain Vegetation Characteristics

Douglas-fir and ponderosa pine trees grow with diverse shrubs.
(North-facing slope at middle elevation in Coral Creek)

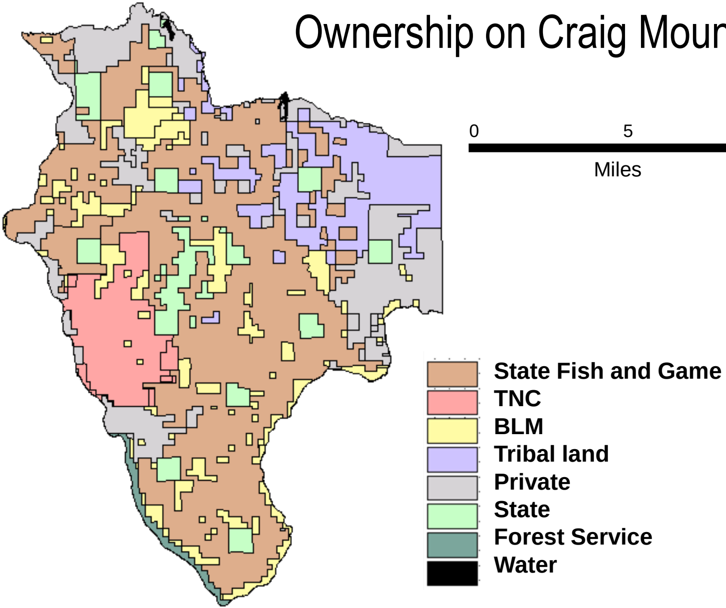
Craig Mountain Vegetation Characteristics

Grasses and weeds (including invasive species) dominate at lower elevations.

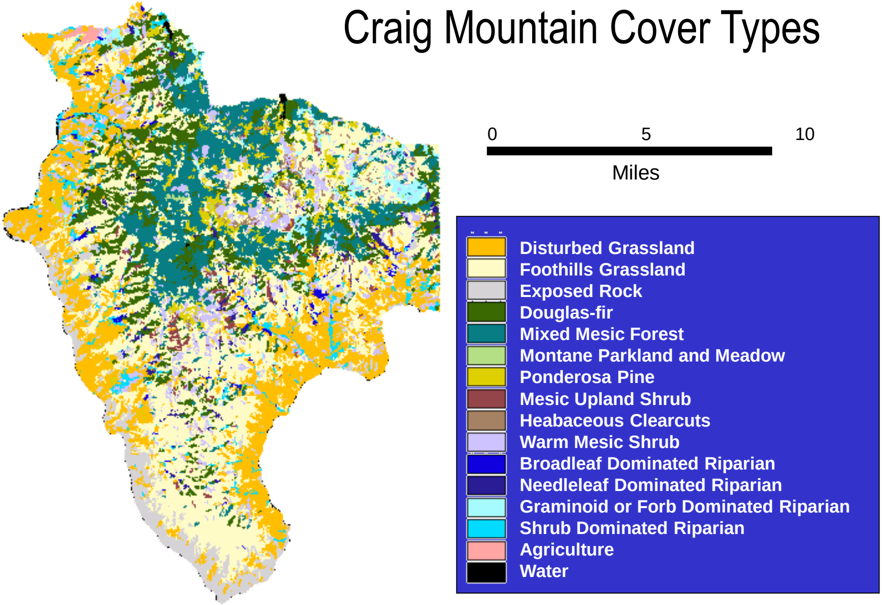
Craig Mountain Vegetation Characteristics

At the lowest elevation, weeds and exotic annual grasses favored by disturbance dominate.

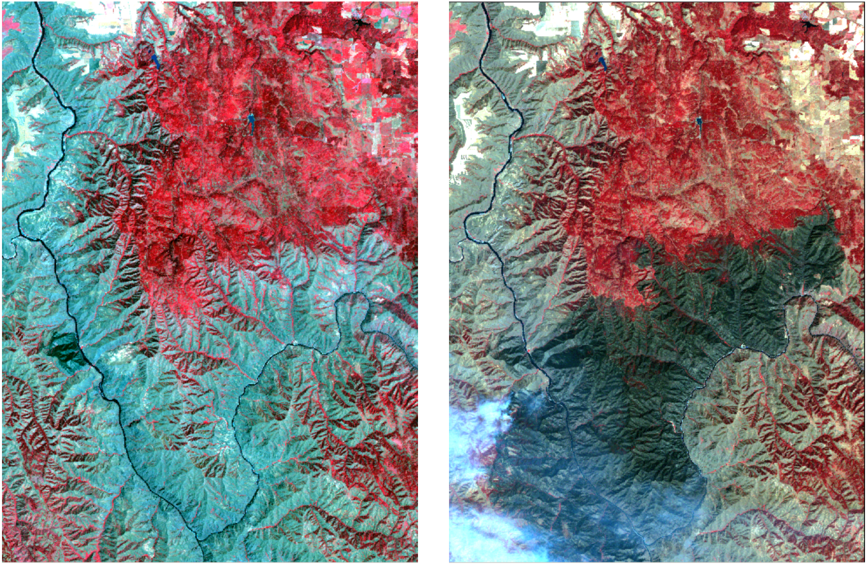
Ownership on Craig Mountain



Craig Mountain Cover Types



Craig Mountain area before and after Maloney Creek Fire

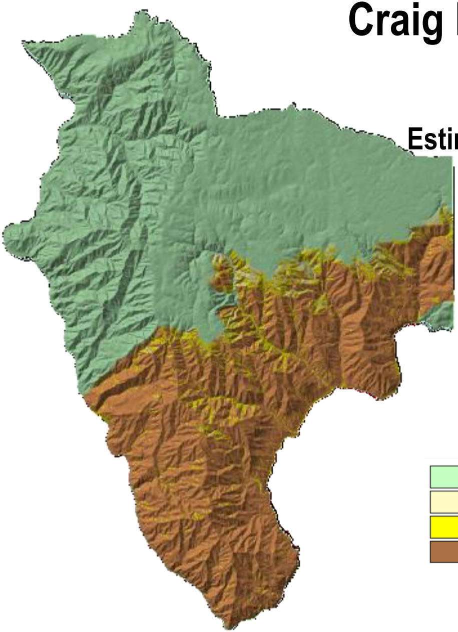


July 27, 2000

August 28, 2000

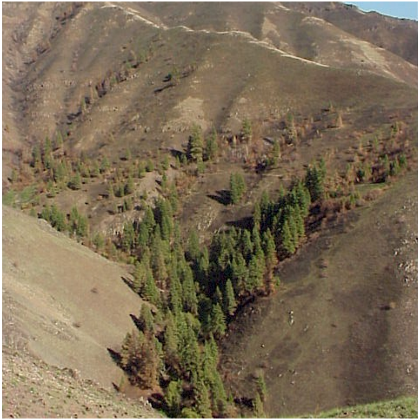
Craig Mountain Burn Severity

for the Maloney Creek fire
August 2000
Estimated from Landsat 7 imagery



Maloney Creek Fire

- Started during a dry lightning storm August 10, 2000, and covered 74,000 acres.
- Declared 100% contained August 29. 12 structures lost. $4.3M fire suppression costs (Morrison et al., 2000).
- History of frequent fires; highly flammable; constrained by exposed rock; quick regeneration.
- In the forests, much of the overstory trees survived (low severity).
- In the grasslands, much of the overstory was burned.



China Garden Creek soon after the burn (September 2000).

Maloney Creek Fire – 3 Weeks Post-burn

September 2000

Maloney Creek Fire – 2 Growing Seasons Post-burn

May 2003

Maloney Creek Fire – 6 Growing Seasons Post-burn

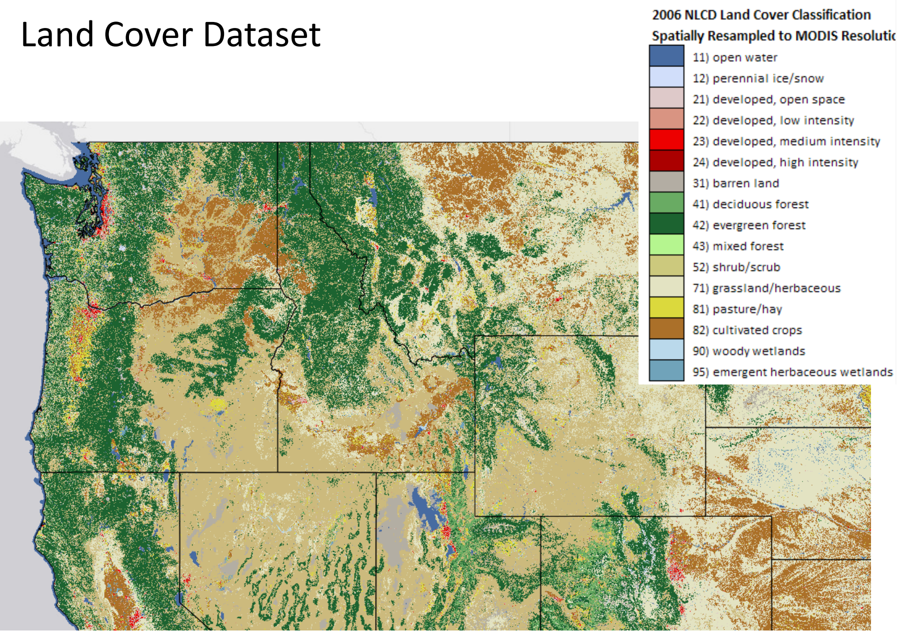
May 2006

What could cause the wide distribution of reductions in NDVI in 2001 outside the Maloney Creek Fire perimeter?

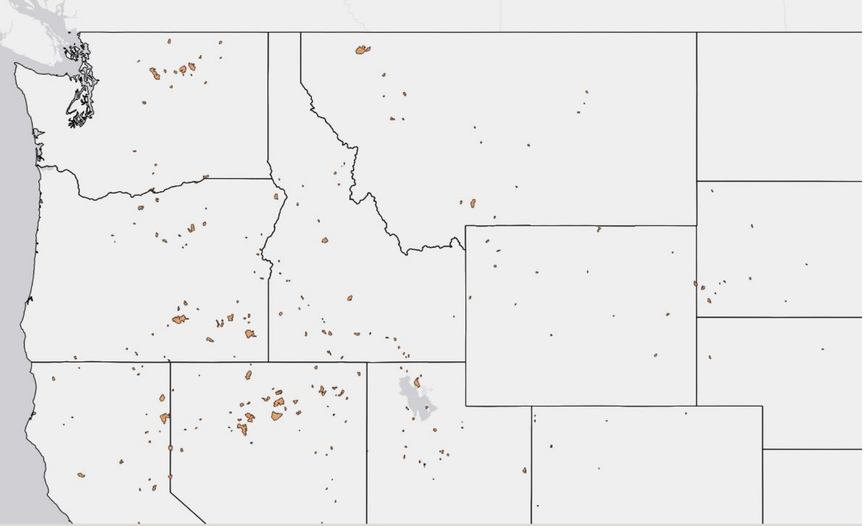
Let's check out relevant data layers in the *ForWarn* system!

`http://forwarn.forestthreats.org/fcav2`

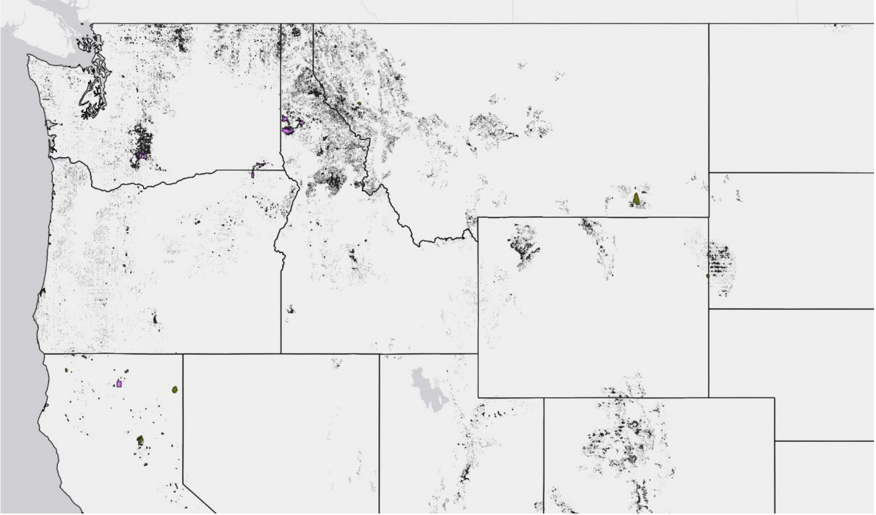
Land Cover Dataset



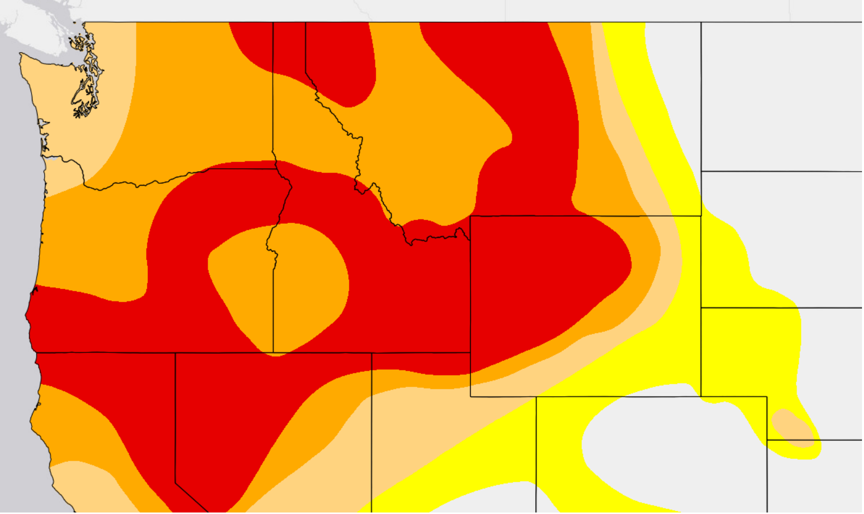
2001 Wildfires
Monitoring Trends in Burn Severity Dataset



2001 Defoliations and tree mortality
Forest Health Protection Insect and Disease Surveys



2001 Drought (late September)
US Drought Monitor



Summary and Conclusions

- **Phenoregions**, delineated annually across the entire MODIS satellite record, provide a nice framework for studying vegetation change.
- Detecting fire disturbances (perimeters and severity) only from changes in NDVI is difficult!
- The good thing is:
  - Changes in satellite NDVI captures all forms of vegetation disturbance.

  The bad thing is:
  - Changes in satellite NDVI captures all forms of vegetation disturbance.
- Challenges include
  - low severity fires,
  - fires in grasslands (fast recovery and/or drought susceptible),
  - fires in frequently burned or highly disturbed areas,
  - fires in mixed grassland, shrubland, and forests.
- *ForWarn* system provides an interface to a variety of geospatial data useful for studying fire and other disturbances at a continental scale.

Acknowledgments

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Craig Mountain and Maloney Creek Fire graphics and photos obtained from Steve Bunting and Penny Morgan at the University of Idaho, who teach a landscape ecology of forests and rangelands course covering the Maloney Creek Fire.

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