Detecting and Tracking Shifts in National Vegetation Composition

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Science Questions

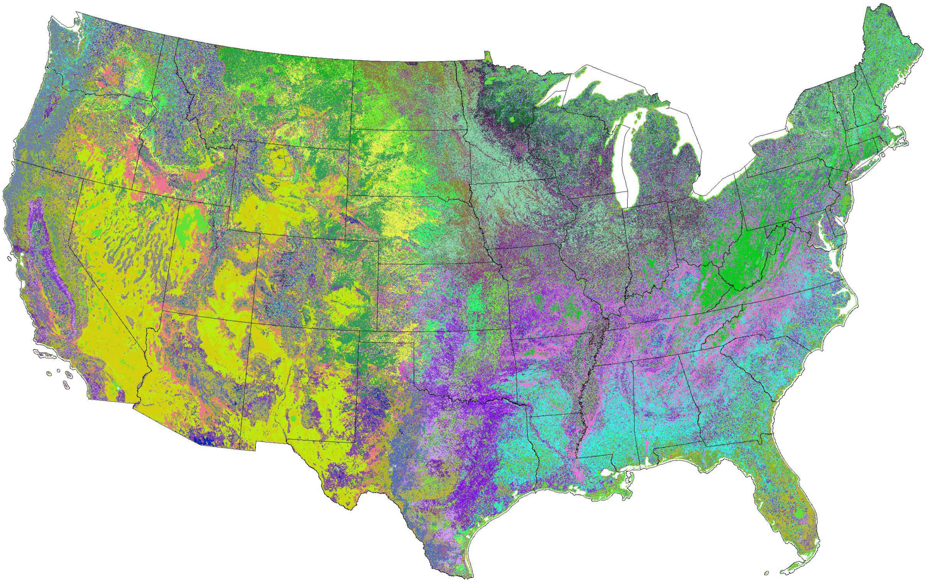
1. Can we use moderate-resolution satellite NDVI imagery to detect and characterize vegetation change at a continental scale?

2. What challenges are there to routine monitoring and tracking of shifts in vegetation composition using NDVI?

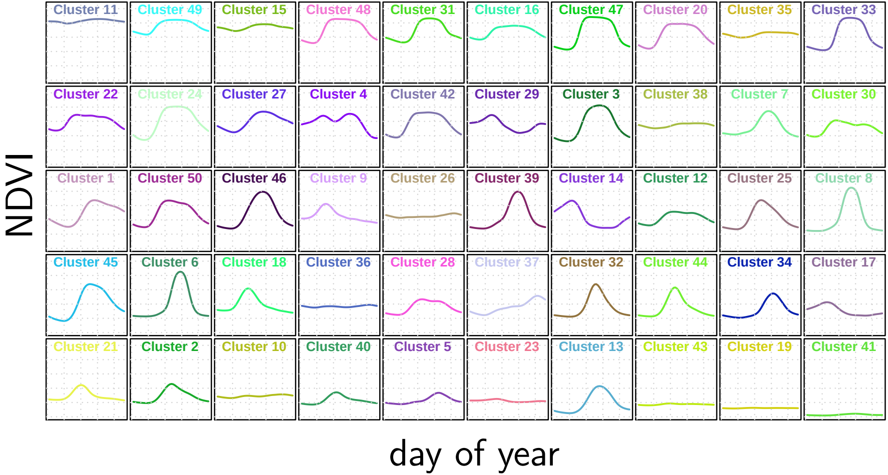
Clustering MODIS NDVI to Produce Phenoregions

- 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.

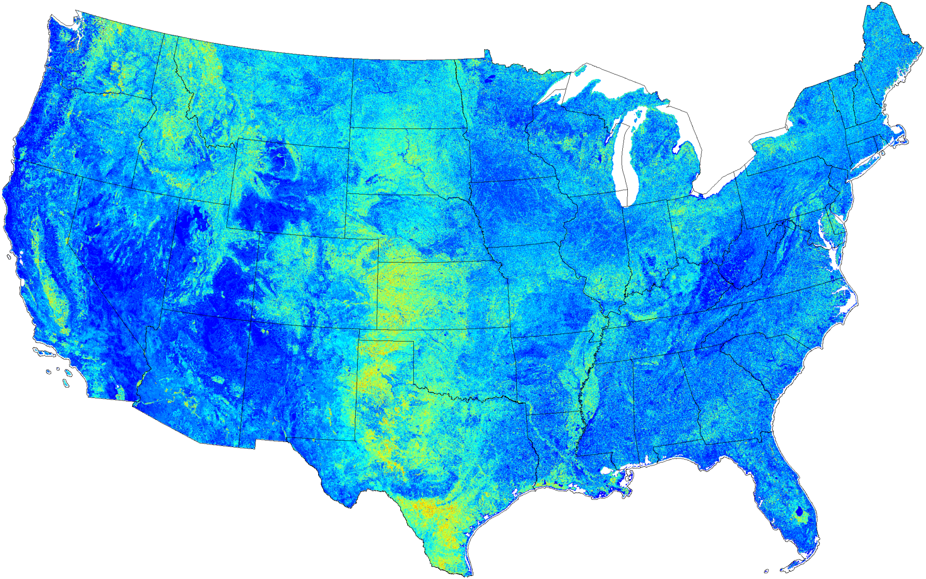
50 Phenoregions for year 2012 (Random Colors)



50 Phenoregion Prototypes (Random Colors)

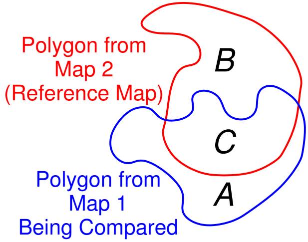


50 Phenoregions Persistence



Mapcurves: A Method for Comparing Categorical Maps

- Hargrove et al. (2006) developed a method for quantitatively comparing categorical maps that is
  - independent of differences in resolution,
  - independent of the number of categories in maps, and
  - independent of the directionality of comparison.

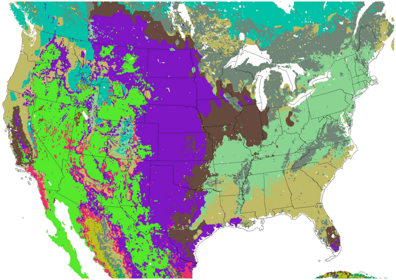


Goodness of Fit (GOF) is a unitless measure of spatial overlap between map categories:

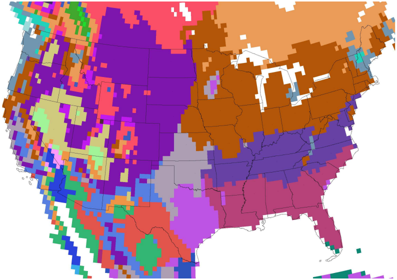
$$\mathrm{GOF} = \sum_{\text{polygons}} \frac{C}{B+C} \times \frac{C}{A+C}$$

- GOF provides "credit" for the area of overlap, but also "debit" for the area of non-overlap.
- Mapcurves comparisons allow us to reclassify any map in terms of any other map (*i.e.*, color Map 2 like Map 1).
- A greyscale GOF map shows the degree of correspondence between two maps based on the highest GOF score.

Expert-Derived Land Cover/Vegetation Type Maps



Foley Land Cover

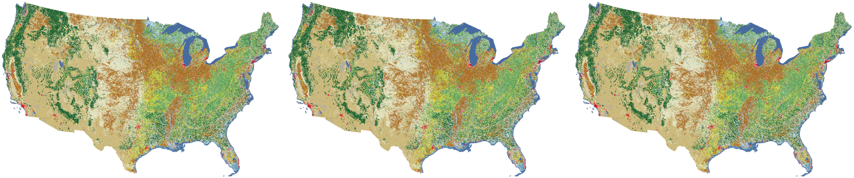


Holdridge Life Zones

	Expert Map	# Cats
1.	DeFries UMd Vegetation	12
2.	Foley Land Cover	14
3.	Fedorova, Volkova, and Varlyguin World Vegetation Cover	31
4.	GAP National Land Cover	578
5.	Holdridge Life Zones	25
6.	Küchler Types	117
7.	BATS Land Cover	17
8.	IGBP Land Cover	16
9.	Olson Global Ecoregions	49
10.	Seasonal Land Cover Regions	194
11.	USGS Land Cover	24
12.	Leemans-Holdridge Life Zones	26
13.	Matthews Vegetation Types	19
14.	Major Land Resource Areas	197
15.	National Land Cover Database 2006	16
16.	Wilson, Henderson, & Sellers Primary Vegetation Types	23
17.	Landfire Vegetation Types	443

Label Stealing: Having your cake and eating it too!

- Clustering is an unsupervised classification technique, so phenoregions have no descriptive labels like **Deciduous Forest**.
- **Label stealing** allows us to perform automated "supervision" to "steal" the best human-created descriptive labels to assign to phenoregions.
- We employ the **Mapcurves GOF** to select the best ecoregion labels from land cover maps constructed by human experts.



(a) 2001 (b) 2006 (c) 2011

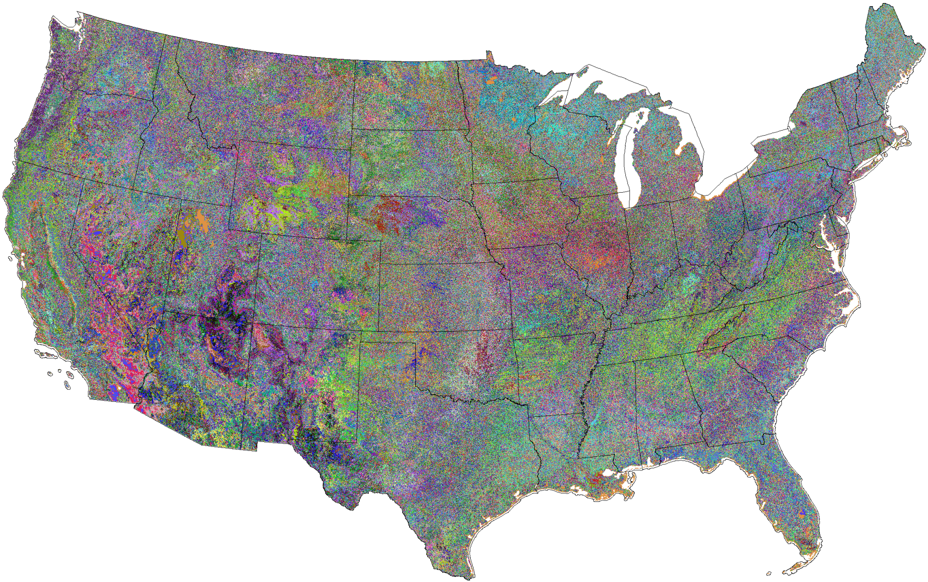
Figure: The National Land Cover Database (NLCD) provides land cover maps at 30 m resolution updated every 5 years.

Areas from the National Land Cover Database (NLCD)

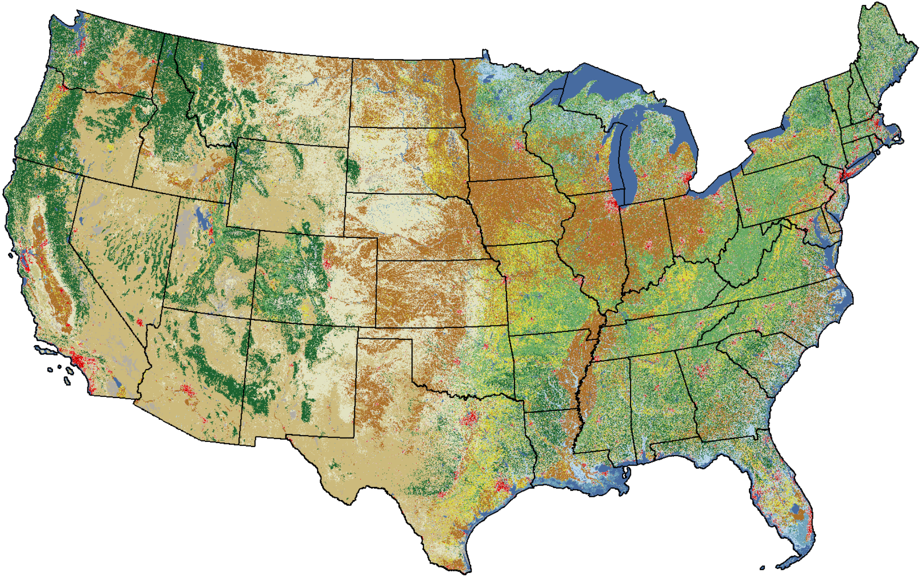
Land Cover Type	2001	2006	2011
11-Open Water	103.770	103.210	103.210
12-Perennial Ice Snow	0.355	0.355	0.355
21-Developed Open Space	64.117	64.750	64.750
22-Developed Low Intensity	28.162	28.826	28.826
23-Developed Medium Intensity	10.980	12.324	12.324
24-Developed High Intensity	3.916	4.404	4.404
31-Barren Land	23.891	24.419	24.419
41-Deciduous Forest	220.317	218.936	218.936
42-Evergreen Forest	240.573	235.658	235.658
43-Mixed Forest	42.449	41.302	41.302
52-Shrub/Scrub	423.604	426.936	426.936
71-Grassland Herbaceous	284.981	287.860	287.860
81-Pasture Hay	135.133	133.563	133.563
82-Cultivated Crops	309.648	309.078	309.078
90-Woody Wetlands	77.921	77.811	77.811
95-Emergent Herbaceous Wetlands	25.062	25.448	25.448

Units of millions of acres

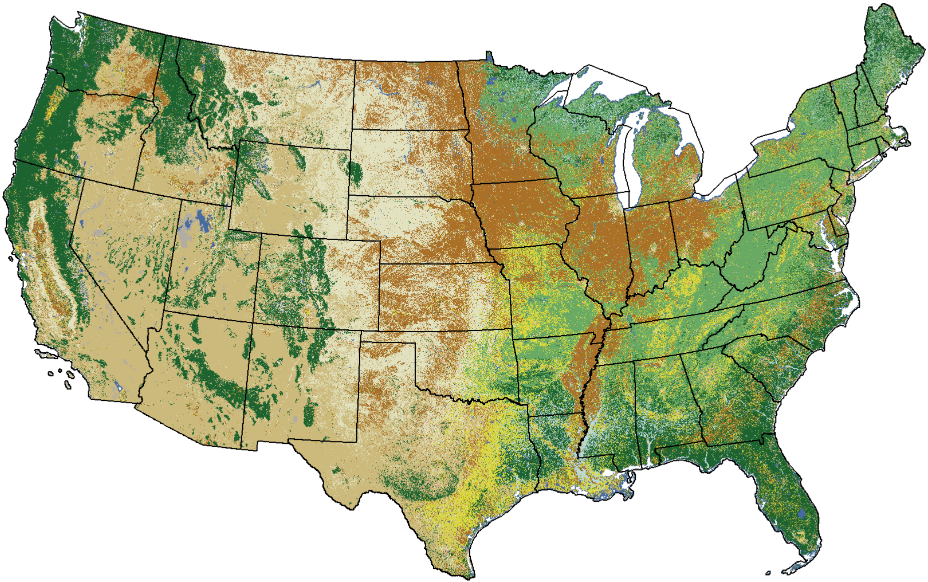
1000 Phenoregions Max Mode (Random Colors)



NLCD 2006



Reclassed 1000 Phenoregions Max Mode

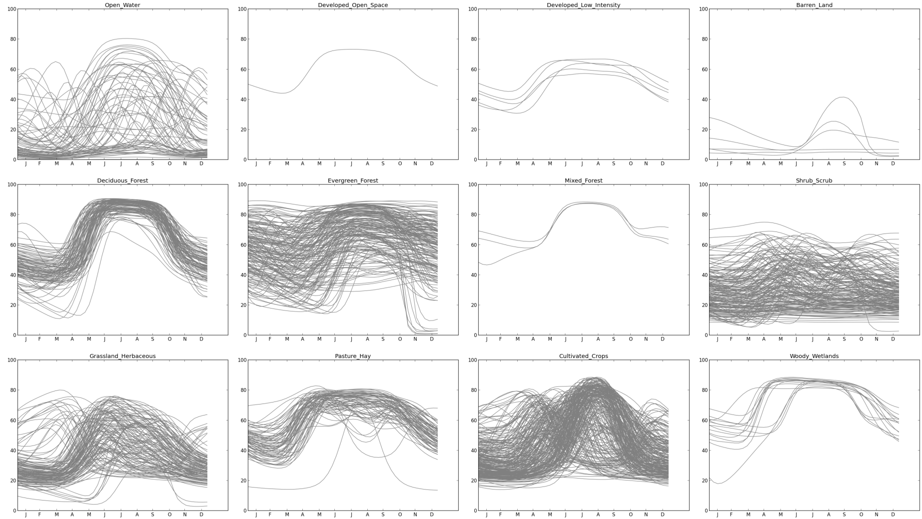


Areas for Stolen Labels on 1000 Phenoregions

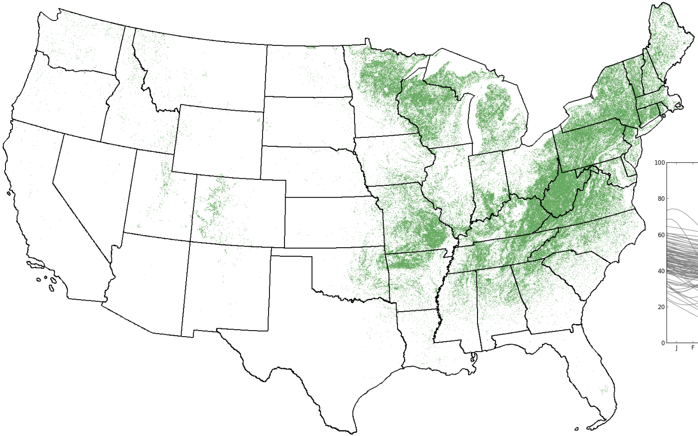
Land Cover Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
11-Open Water	37.0	36.6	37.9	38.0	40.4	41.9	38.7	39.5	41.9	41.1
21-Developed Open Space	3.1	3.0	4.2	2.1	2.5	4.0	3.4	4.1	4.0	2.4
22-Developed Low Intensity	8.6	10.9	18.3	10.7	15.5	12.4	12.8	18.2	13.7	13.1
31-Barren Land	9.1	7.6	9.4	9.1	8.8	7.1	7.7	8.3	9.3	9.6
41-Deciduous Forest	254.0	270.0	256.4	266.8	277.3	269.1	266.5	225.3	269.7	265.0
42-Evergreen Forest	321.6	320.2	357.4	322.1	316.3	326.0	315.8	315.3	328.1	316.1
43-Mixed Forest	10.3	11.6	7.3	7.1	7.4	7.2	8.9	6.5	6.2	6.6
52-Shrub/Scrub	523.1	515.7	558.1	501.7	480.7	469.7	537.6	445.7	487.3	464.6
71-Grassland Herbaceous	251.1	267.1	219.8	276.2	251.8	305.6	270.5	332.8	280.9	314.0
81-Pasture Hay	142.6	147.3	141.6	155.9	166.2	138.9	132.1	190.4	127.7	136.1
82-Cultivated Crops	347.2	323.5	304.1	318.1	342.2	332.9	318.8	319.9	347.9	348.6
90-Woody Wetlands	33.4	27.8	26.9	33.3	32.1	26.4	28.6	35.1	24.6	24.1

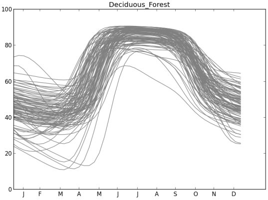
Units of millions of acres

Reclassed Phenoregion Centroid Traces

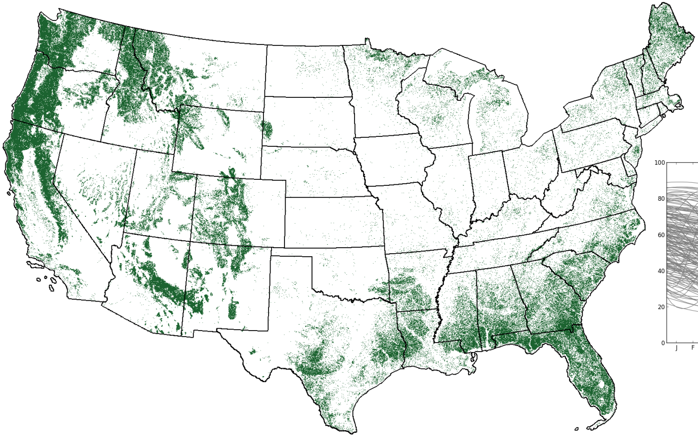


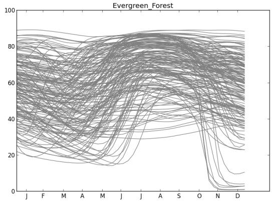
Reclassed Deciduous Phenoregion (Year 2000)



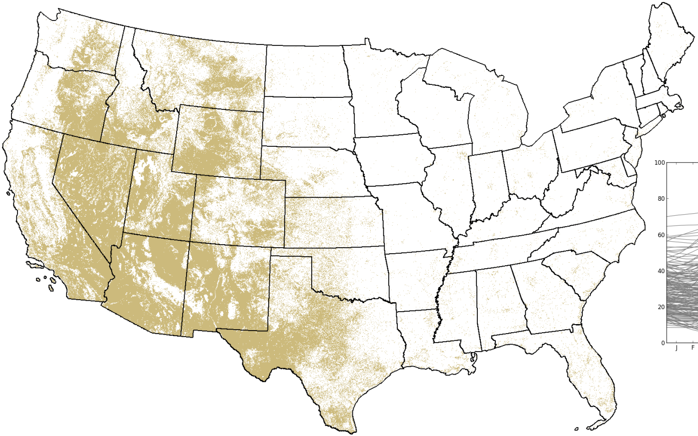


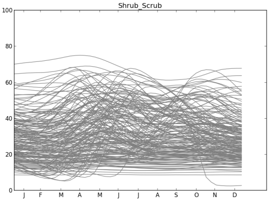
Reclassed Evergreen Phenoregion (Year 2000)



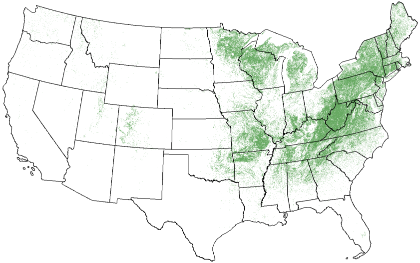


Reclassed Shrub/Scrub Phenoregion (Year 2000)

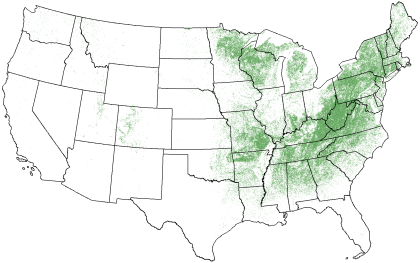




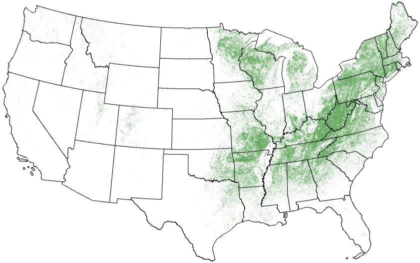
Reclassed Deciduous Phenoregion (Year 2000-2004)



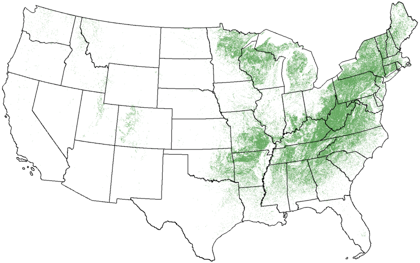
2000



2001



2002



2003

Web Interface for Analyzing Transitions

Historical Trajectories of Vegetation Chance in CONUS – Mozilla Firefox

Historical Trajectories of ...

https://www.climatemodeling.org/veg_trajectories/

Search

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Landcover Changes during period 2000-2012 for CONUS

K = 1000 | NLCD 2006

Landcover Type	NLCD 2001	NLCD 2006	NLCD 2011
11-Open_Water	103.77	103.21	103.21
12-Perennial_Ice_Snow	0.355	0.355	0.355
21-Developed_Open_Space	64.117	64.75	64.75
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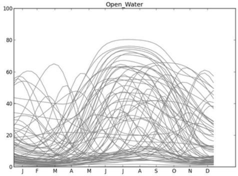
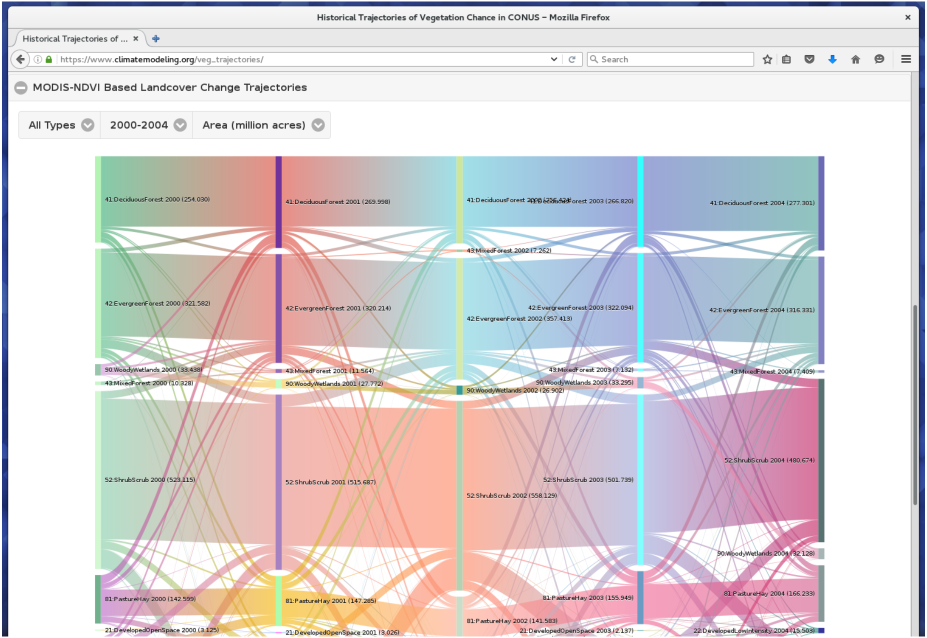
82-Cultivated_Crops	309.648	309.078	309.078
90-Woody_Wetlands	77.921	77.811	77.811
95-Emergent_Herbaceous_Wetlands	25.062	25.448	25.448

Landcover Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
11-Open_Water	36.994	36.628	37.854	37.981	40.443	41.927	38.72	39.55	41.905	41.07
21-Developed_Open_Space	3.125	3.026	4.182	2.137	2.479	3.96	3.36	4.065	3.987	2.3
22-Developed_Low_Intensity	8.609	10.885	18.266	10.735	15.503	12.426	12.761	18.223	13.716	13.12
31-Barren_Land	9.136	7.638	9.403	9.067	8.785	7.097	7.737	8.34	9.306	9.62
41-Deciduous_Forest	254.029	269.997	256.423	266.818	277.299	269.128	266.464	225.317	269.711	264.99
42-Evergreen_Forest	321.58	320.213	357.411	322.092	316.33	325.959	315.795	315.266	328.07	316.09
43-Mixed_Forest	10.328	11.564	7.262	7.132	7.409	7.222	8.934	6.547	6.192	6.61
52-Shrub_Scrub	523.112	515.685	558.126	501.736	480.671	469.668	537.567	445.702	487.276	464.60
71-Grassland_Herbaceous	251.122	267.082	219.766	276.242	251.822	305.643	270.527	332.845	280.885	314.00
81-Pasture_Hay	142.598	147.284	141.582	155.948	166.232	138.872	132.054	190.436	127.713	136.14
82-Cultivated_Crops	347.183	323.482	304.078	318.073	342.154	332.92	318.77	319.91	347.88	348.55
90-Woody_Wetlands	33.438	27.772	26.902	33.294	32.128	26.434	28.565	35.053	24.614	24.07

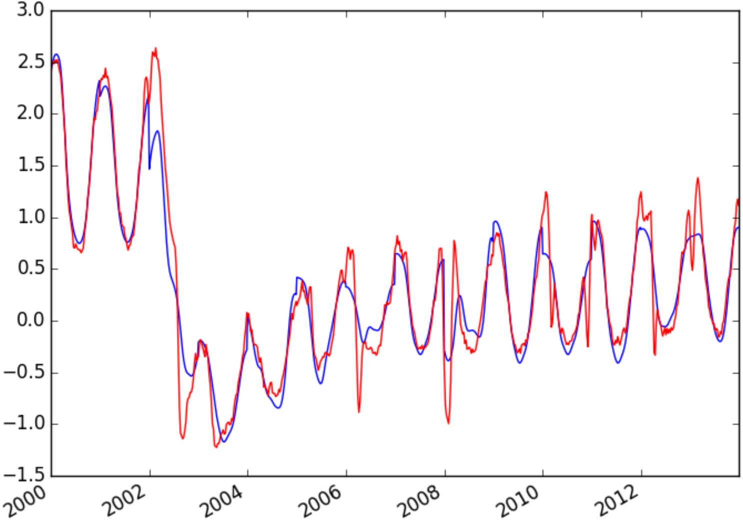


MODIS NDVI Traces associated with selected landcover type regions
(Select landcover type in table to update figure)

Web Interface for Analyzing Transitions

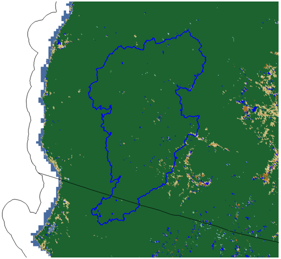


Reconstructed Phenology Curve (Standardized)

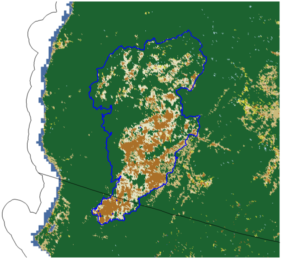


Reconstructed phenological trace for a single "disturbed" pixel in the Western U.S. MODIS in blue and phenoregion centroids in red.

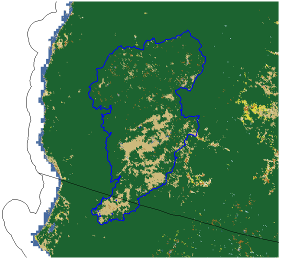
Biscuit Fire



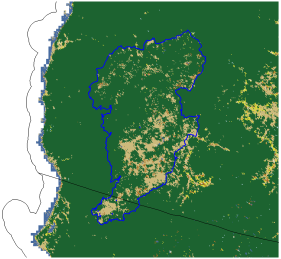
2001



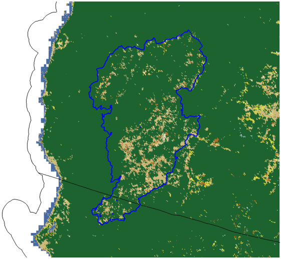
2002



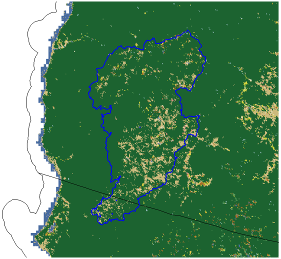
2003



2004



2005



2006

Summary

- Yes, we can detect and characterize at least large disturbances through their NDVI changes and classify recovering vegetation by their annual phenology.
- Challenges include limitations in remote sensing resolution, detail in land cover classifications, and diversity of phenological traces due to interannual variability.

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.

References

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