Detecting and Tracking Shifts in National Vegetation Composition Across the MODIS Era

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Introduction

Forested landscapes are ecologically and economically important, and understanding their dynamics is important for land–management decision making. Forest ecosystems are also under stress, and may be changing due to interannual variability and long term change in climate, natural and anthropogenic disturbance, including human use and management. **Detecting and tracking shifts** in vegetation is important for land–management, conservation planning, monitoring recovery, managing and monitoring forest structure and composition, maintaining species and habitat diversity and many other purposes.

We demonstrate a **full-circle national-scale accounting system** which can track not only area changes in land cover classes, but can show which other compensatory land cover class area changes accompanied them. Area **changes in the vegetation distributions**, as well as **compensatory gains, losses, and trades in area** of other land cover types, were mapped and tracked annually during 2000–2013 period at MODIS resolution.

For any particular "focus" land cover type, results show which other land covers were **donors or recipients** of area changes, showing ecologists and land managers alike what vegetation types were given up or gained to offset particular increases or losses.

Clustering MODIS NDVI into Phenoregions

- A multi-variate clustering approach using high performance computing was employed to analyze the entire body of the high resolution MODIS NDVI record for the CONUS (2000–2013).

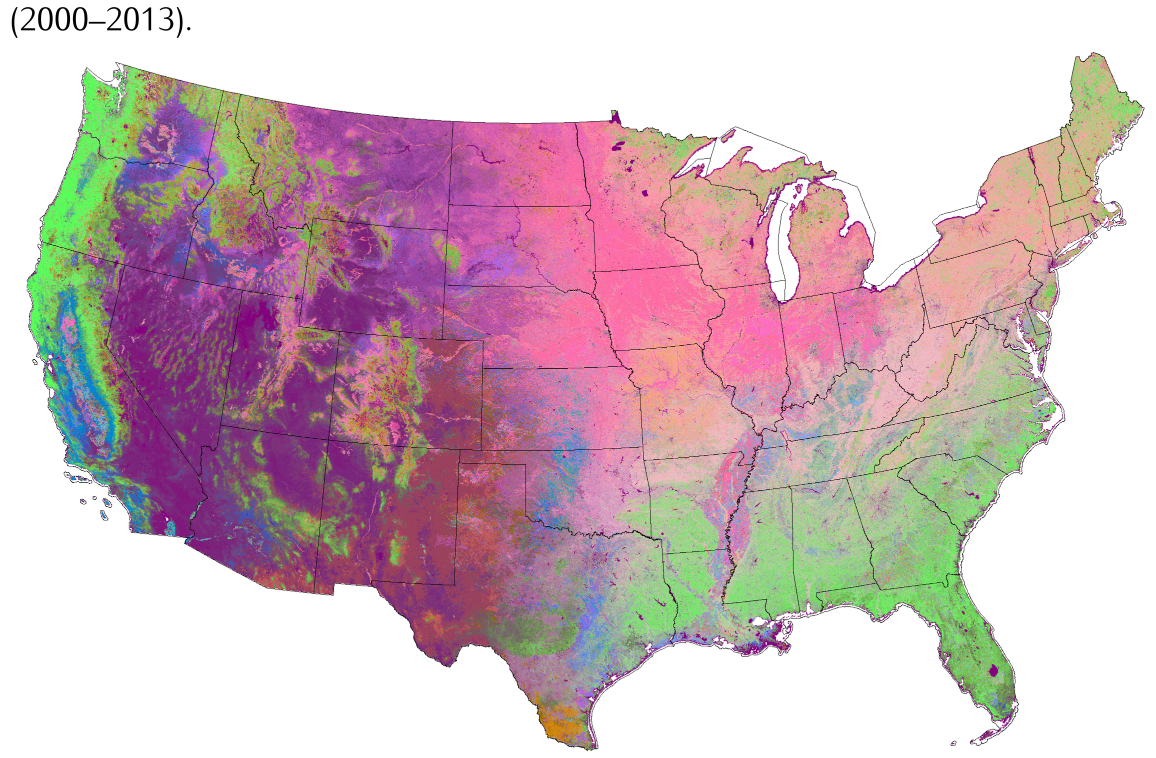


Figure 1: *50 phenoregions, derived from 14 years of MODIS NDVI (2000–2013).*

- The annual traces of NDVI for every year and map cell were combined into one ~380 GB single-precision binary data set of 46-dimensional observation vectors.

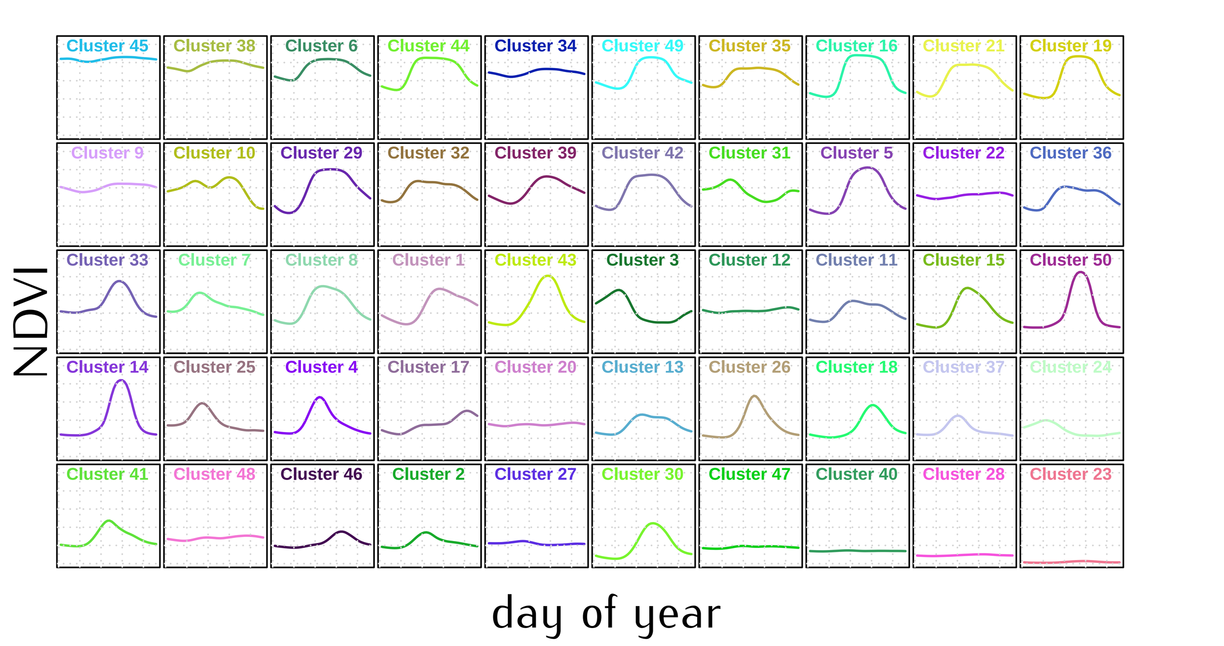
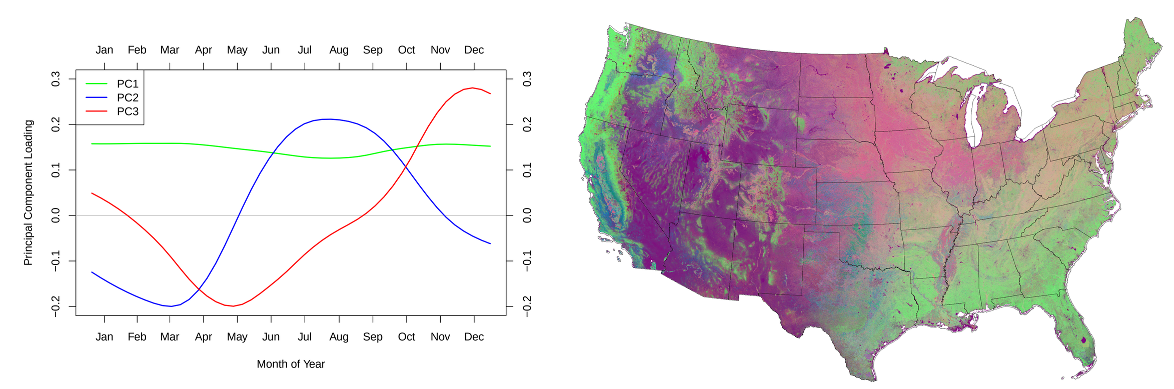


Figure 2: *The corresponding 50 phenoclass trajectory prototypes sorted by area under the curve.*

- Clustering yields 14 phenoregion maps in which each cell is classified into one of k phenoclasses that represent prototype annual NDVI traces.
- "Phenoregions" are statistically defined based solely on landsurface phenology.



(a) Principal components trajectories (similarity colors legend)

(b) Max mode map of 5000 phenoregions (similarity colors map)

Figure 3: *The mode map shows the phenoregion most frequently occupied in all 14 years. Principal components analysis (PCA) was used to obtain the three most dominant annual trajectories of NDVI, and these PCs were assigned to the green, blue, and red colors to produce the similarity colors map. PC1 appears to correspond to evergreen vegetation, PC2 appears to correspond to deciduous forests and crops, and PC3 appears to correspond to drought deciduous vegetation.*

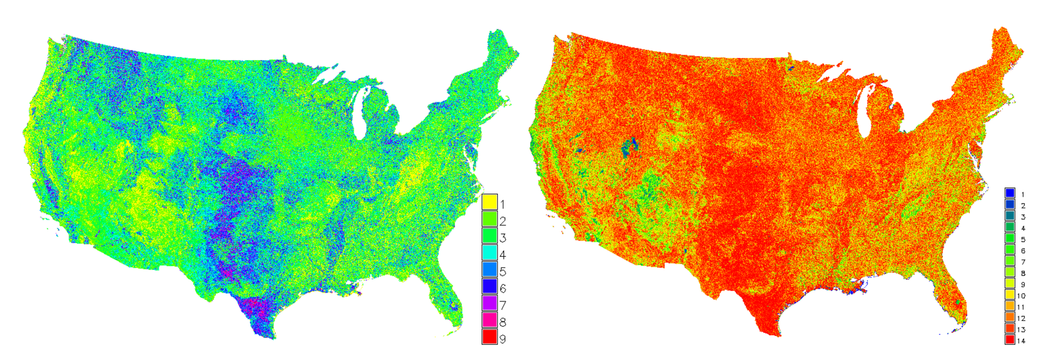
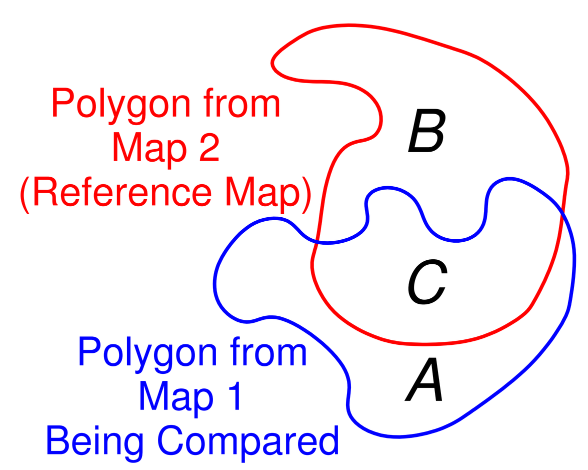


Figure 4: *Persistence of phenological classification for 50 (left) and 5000 (right) phenoregions across all 14 years of MODIS NDVI (2000–2013). Blue regions are classified into the same phenoclass almost every year, while yellow to red regions are classified into different phenoclasses almost every year.*

Mapcurves

- "Mapcurves" is a method for quantitatively comparing categorical maps that is 1) independent of differences in resolution, 2) independent of the number of categories in maps, and 3) 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).

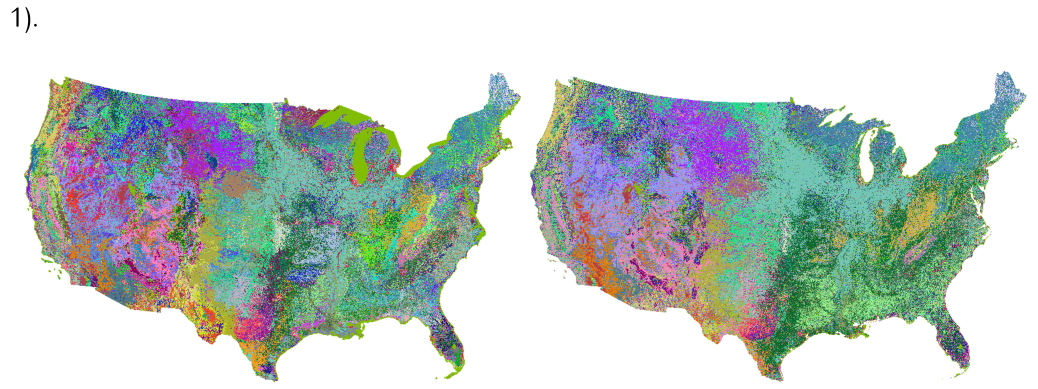
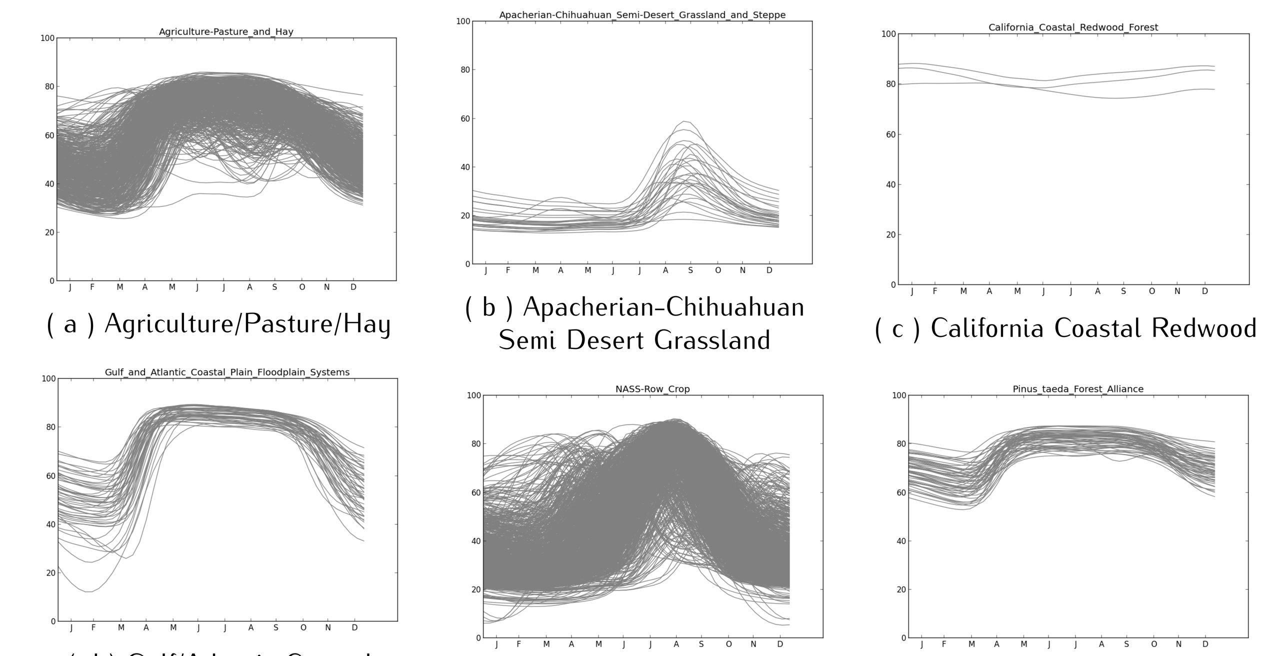


Figure 5: *Landfire Existing Vegetation Type (EVT) map (Left); K=5000 Phenoregions map reclassed to Landfire EVT map (Right).*

Phenological Signature(s) of Landfire EVT Types



(a) Agriculture/Pasture/Hay

(b) Apacherian-Chihuahuan Semi Desert Grassland

(c) California Coastal Redwood

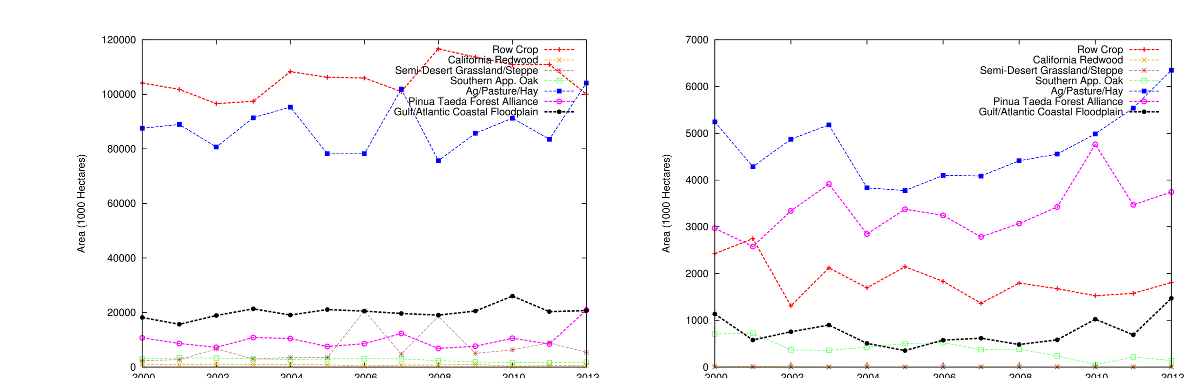
(d) Gulf/Atlantic Coastal Plain Floodplain

(e) NASS Row Crop

(f) Pinus Taeda Forest

Figure 6: *Land surface phenological signatures associated with Landfire EVT types.*

Tracking Changes in Vegetation Composition

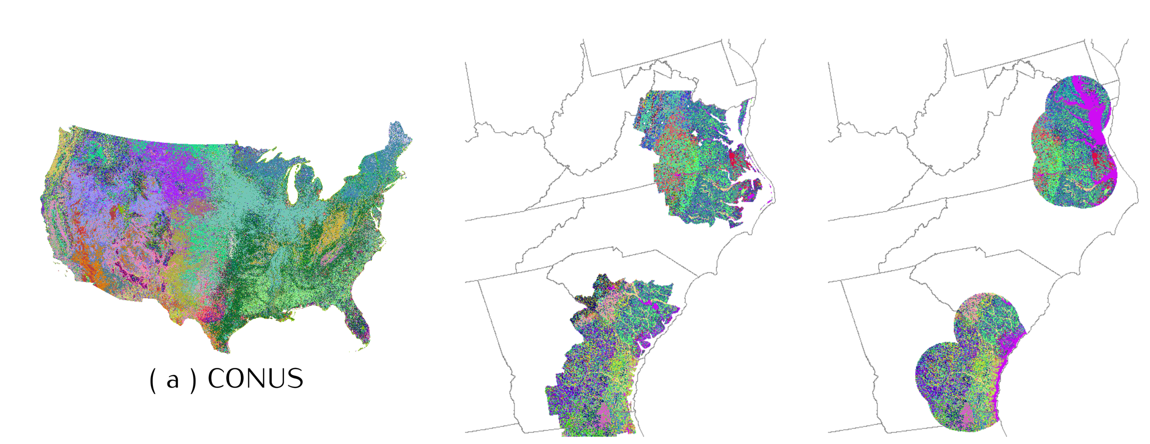


(a) CONUS

(b) 185 Southeast Counties

Figure 7: *Changes in area (1000-hectares) occupied by various vegetation types during period 2000–2012 for CONUS and 185 Southeastern counties.*

Recipients and Donors



(a) CONUS

(b) 185 SE Counties

(c) SE Pellet Mills

Table 1: *Area occupied by Southern Oak Forest decreased from 3010.89 to 1622.87 (CONUS), 374.23 to 215.46 (183 SE Counties), 269.94 to 159.01 (SE Pellet Mills Region) during 2007-2011. Shown below are the recipient (**Winners**) Land Cover classes to replace Southern Oak Forest during this period. (Area Unit: 1000-hectares)*

Vegetation Type	CONUS	185 Southeast Counties	SE Pellet Mills Region
Southern Appalachian Oak Forest	35.15	23.93	24.77
Southern Piedmont Dry Oak(Pine) Forest	14.15	33.44	41.73
South-Central Interior Mesophytic Forest	11.60	4.30	1.94
Ozark-Ouachita Dry-Mesic Oak Forest	10.94	5.93	4.18
Laurentian-Acadian Northern Hardwoods Forest	6.40	2.73	1.41
Southern and Central Appalachian Cove Forest	6.20	5.04	1.93
Pinus Taeda Forest Alliance	5.74	9.78	10.22
Southeast Conifer and Hardwood Managed/Plantation	3.60	6.1	7.4

Table 2: *Area occupied by Gulf and Atlantic Coastal Floodplain Systems increased from 8446.95 to 20926.36 (CONUS), 688.34 to 1469.78 (185 SE Counties), 520.74 to 1060.11 (SE Pellet Mills Region) during 2007-2011 Shown below are the donor (**Loosers**) Land Cover classes which were replaced by Gulf and Atlantic Coastal Floodplain Systems. (Area Unit: 1000-hectares)*

Vegetation Type	CONUS	185 Southeast Counties	SE Pellet Mills Region
Gulf and Atlantic Coastal Floodplain	32.28	40.18	42.63
Agriculture-Pasture and Hay	17.05	12.93	11.45
Pinus Taeda Forest Alliance	14.84	24.11	24.56
Ozark-Ouachita Dry-Mesic Oak Forest	11.83	2.94	2.42
Southern Piedmont Dry Oak(Pine) Forest	6.70	9.71	8.90
Southern Interior Low Plateau Dry-Mesic Oak Forest	4.28	3.37	3.24
Rural Upland Tree	1.79	3.14	3.20

Trajectories of Change (Fingerprints of Change)

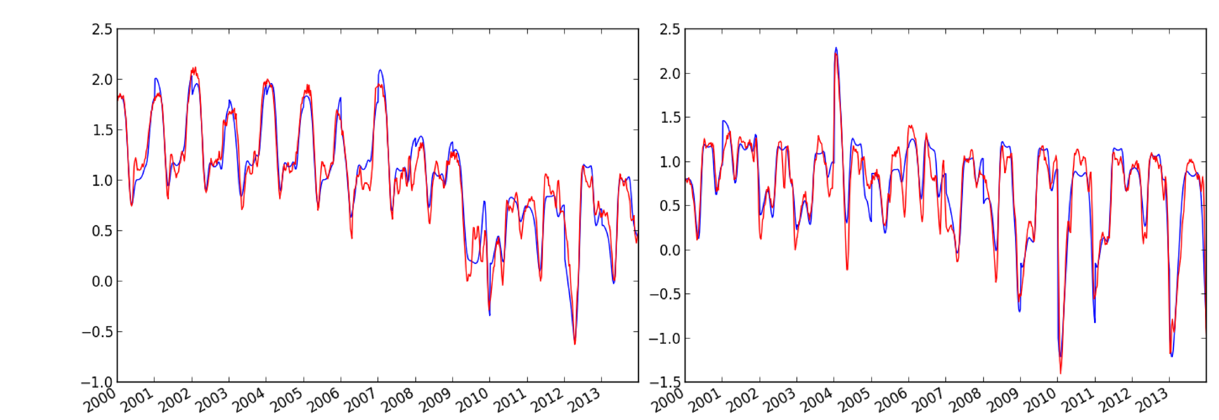


Figure 9: *MODIS NDVI time series (blue) and smoothed Phenoregion-based trajectory (red) at cell. All regions experiencing similar phenological trajectories of changes can be identified to allow tracking and monitoring of changes to assist with land management, conservation planning and decision making.*

Summary

- We developed a method to characterize vegetation classes using remote sensing (based on any desired "definition").
- The method enables us to track changes to the vegetation explicitly in space and time.
- It offers continuous detection of change (at MODIS space and time resolution).
- It provides complete accounting of change (donors and recipients).
- Framework allows inclusion of ancillary biotic and abiotic drivers influencing Phenology. Work is ongoing to understand and attribute the pre-dominant factors leading to change.

Acknowledgments

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