Phenological Classification and Atmospheric Drought Response of Riparian Vegetation in Drylands of the Southwestern United States

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Abstract

Access to groundwater leaves riparian plants in drylands resistant to atmospheric drought but vulnerable to changes in climate or water use that reduce streamflow and groundwater tables. Despite the vulnerability of riparian vegetation to water balance changes few extensible methods have been developed to automatically map riparian plants at the scale of individual stands or stream reaches, to assess their response to changes in moisture due to drought and climate change, and to contrast those responses across plant functional types. We used LiDAR and a sub-annual timeseries of NDVI to map vegetation and then assessed drought response by comparing a drought index to variation in a remotely sensed metric of plant health. First, a random forest model was built to classify vegetation communities based on phenological changes in Sentinel-2 NDVI. This model produced community classes with an overall accuracy of 97.9%; accuracy for the riparian vegetation class was 98.9%. Following this initial classification, LiDAR measurements of vegetation height were used to split the riparian class into structural subclasses. Multiple Endmember Spectral Mixture Analysis was applied to a timeseries of Landsat imagery from 1984 to 2018, producing annual sub-pixel fractions of green vegetation, non-photosynthetic vegetation, and soil. Relationships were assessed within structural subclasses between mid-summer green vegetation fraction (GV) and the Standardized Precipitation-Evapotranspiration Index (SPEI), a measure of soil moisture drought. Among riparian vegetation subclasses, all groups showed significant positive correlations between SPEI and GV, indicating an increase in healthy plant material during wetter years. However, the relationship was strongest for herbaceous plants (Rˆ2=0.509, m=0.0278), intermediate for shrubs (Rˆ2=0.339, m=0.0262), and weakest for the largest trees (Rˆ2=0.1373, m=0.0145). This implies decoupling of larger riparian plants from the impacts of atmospheric drought due to subsidies provided by groundwater resources. Our method was extended successfully to multiple climatically-dissimilar dryland systems in the American Southwest, and the results provide a basis for ongoing studies on the fine-scale drought response and climatic vulnerability of riparian woodlands.

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AGU FALL MEETING

Research Goals

1) Delineate riparian vegetation on landscape scale
2) Assess interannual response to water availability

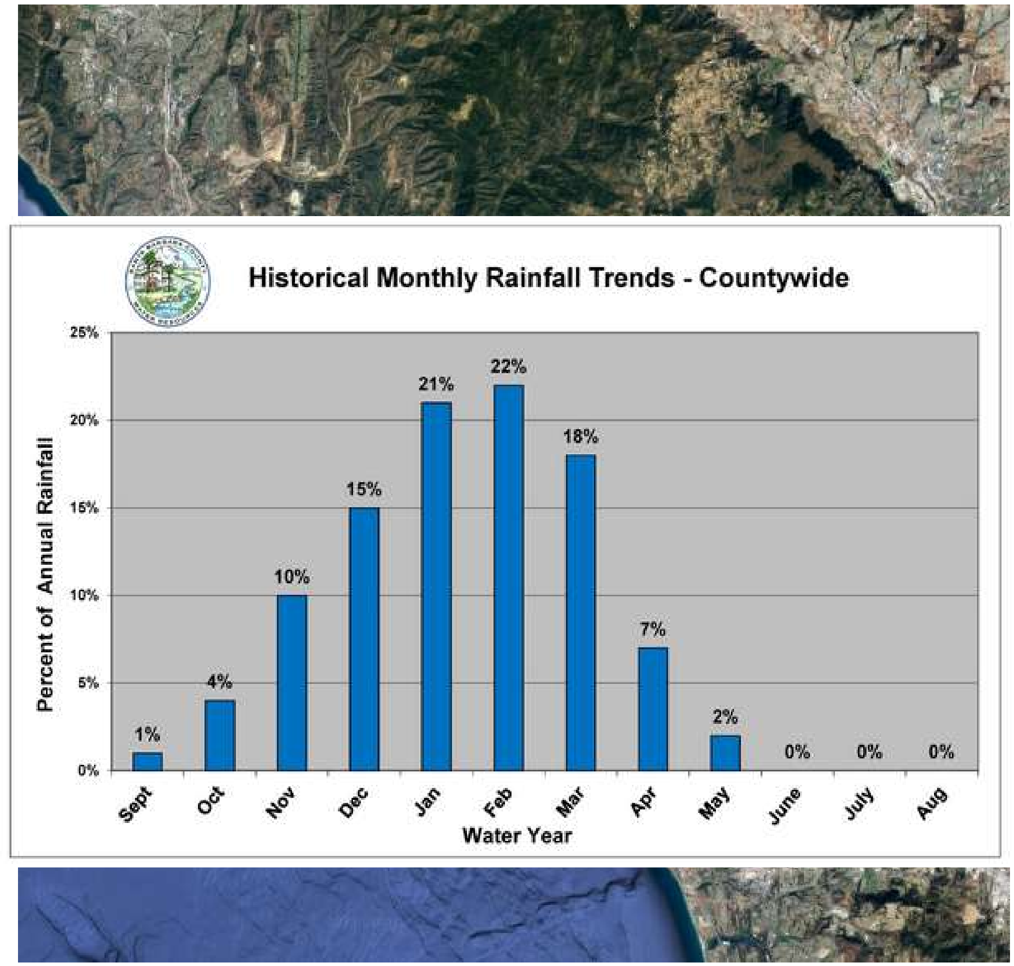


Riparian Zones in US Southwest

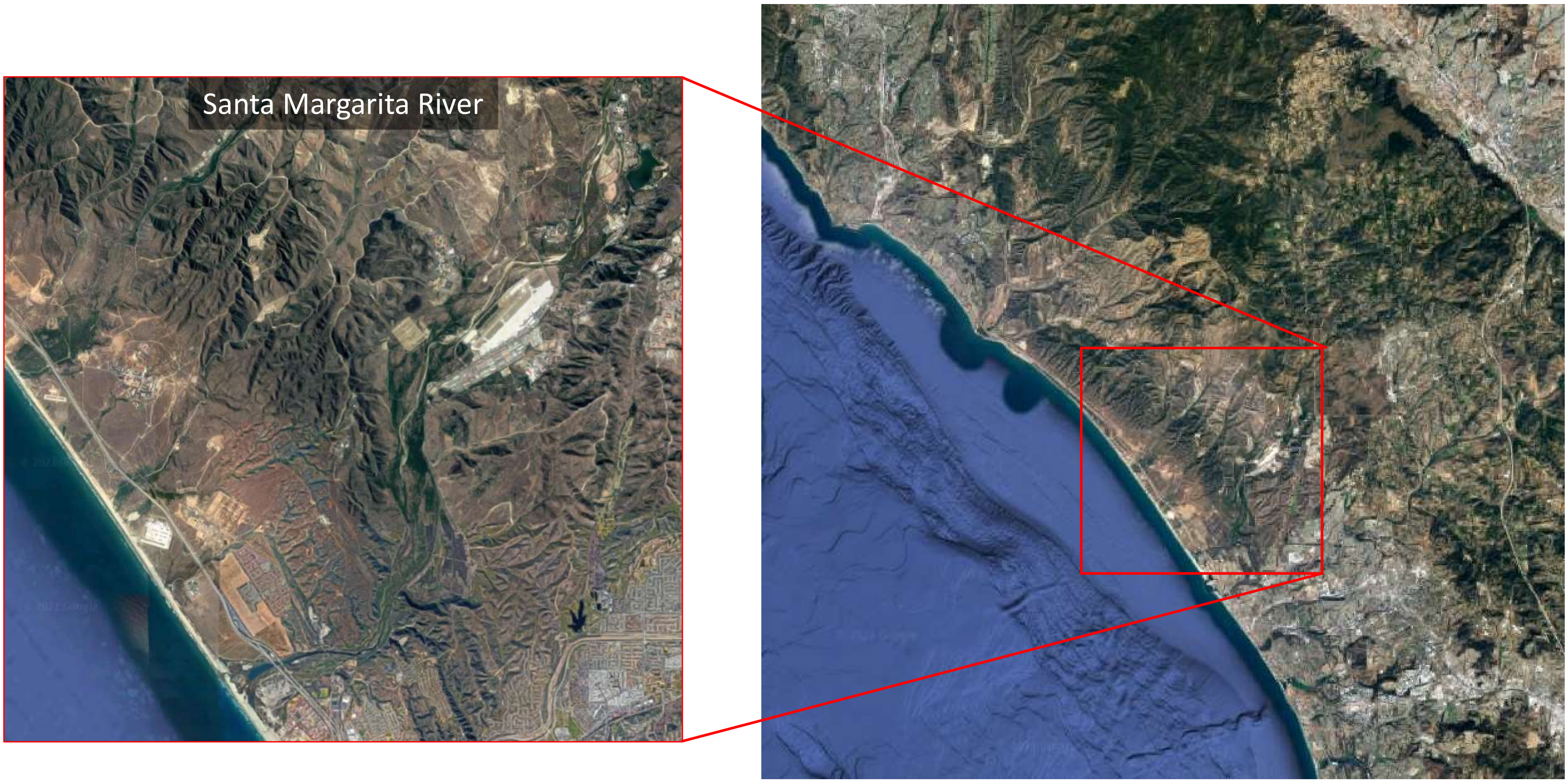
- Perennial water access
- Small fraction of land area (< 10%)
- Extremely Important
  - Diverse refugia for plants/animals
  - Large fraction of landscape productivity
  - Channel water during flood events
- Often Threatened
  - Conflict for water with agriculture
  - Conflict for land with development

Marine Corps Base Camp Pendleton

- Vegetation Types
  - Willow Riparian Woodland
  - Coastal Sage Scrub
  - Oak Woodland
  - Annual Grassland
- Mediterranean Climate
  - Wet, cool winters
  - Dry, mild summers



Marine Corps Base Camp Pendleton

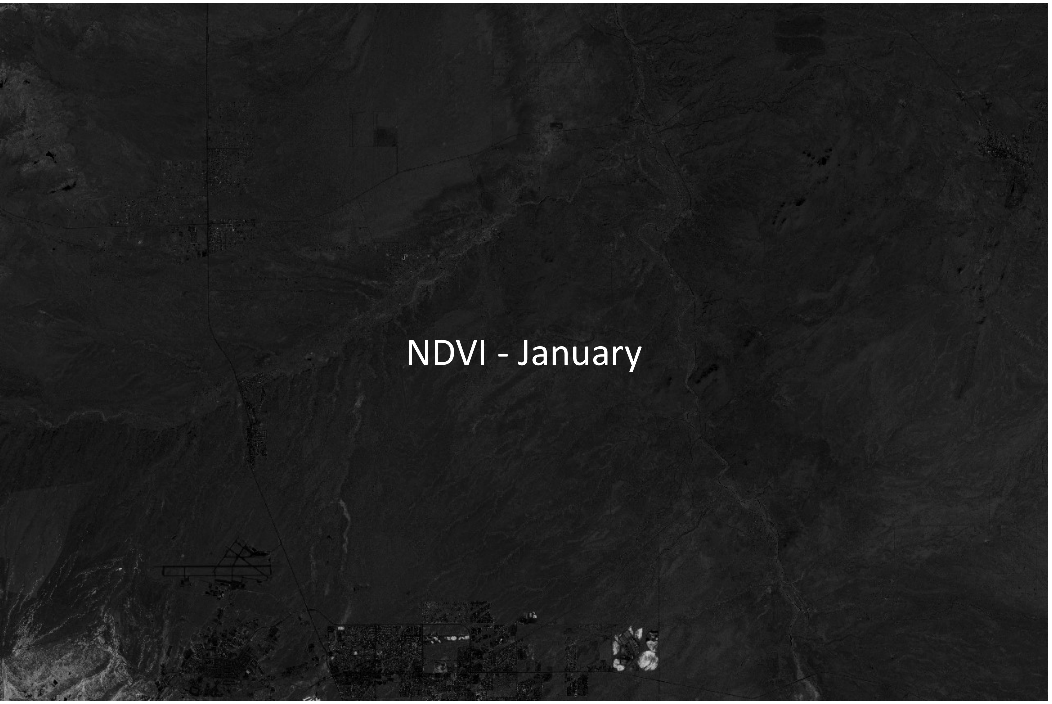


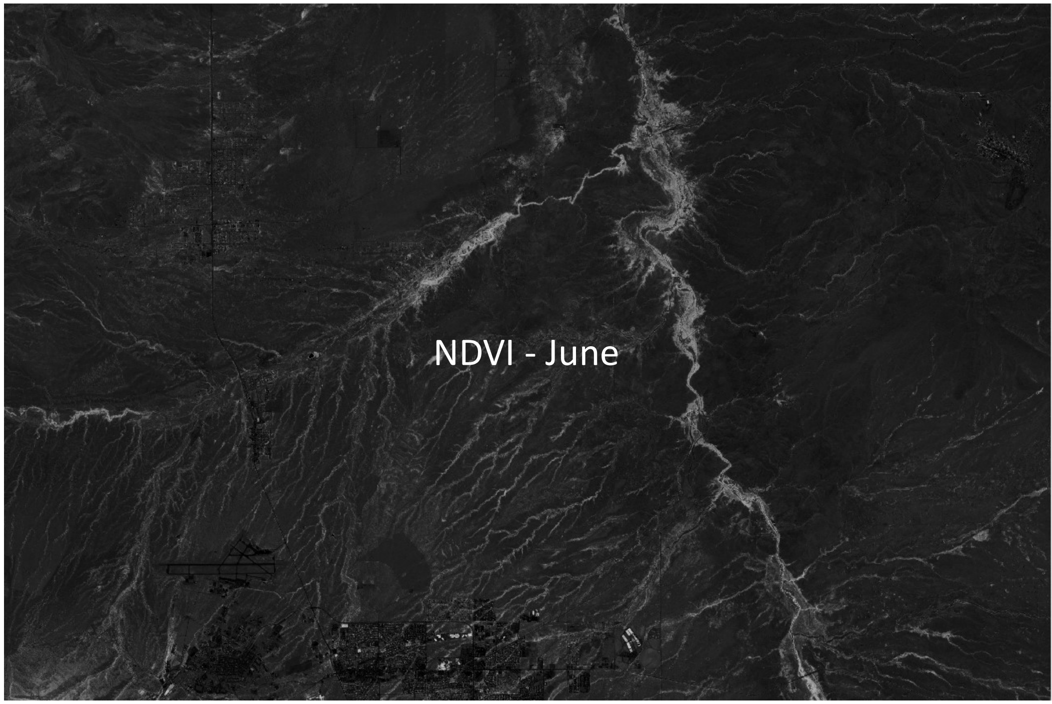
What is Riparian?

Riparian Plant Phenology

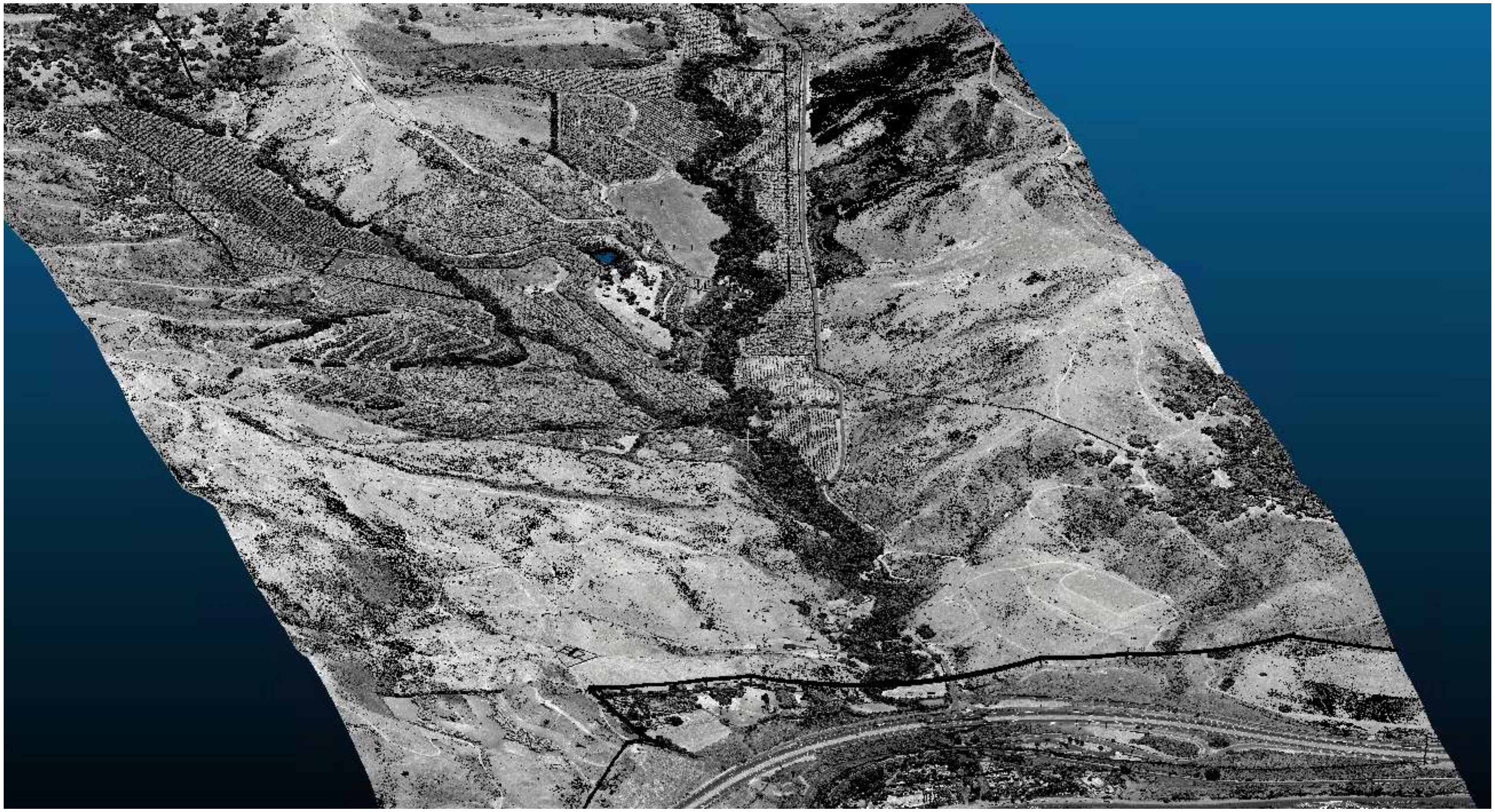
- Phenology – seasonal cycles of natural phenomena
- Deciduous plants undergo annual leaf cycles
  - **Leaf flush** in spring
  - **Leaf senescence** and drop in fall

Plant Phenology – Satellite Detection





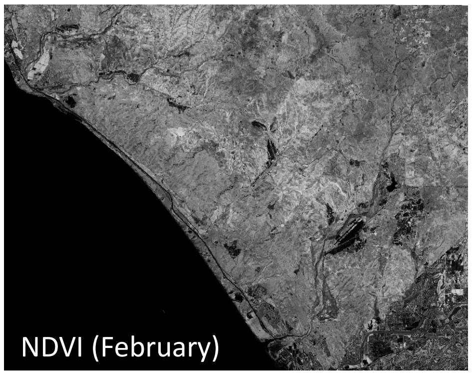
Vegetation Structure - LiDAR

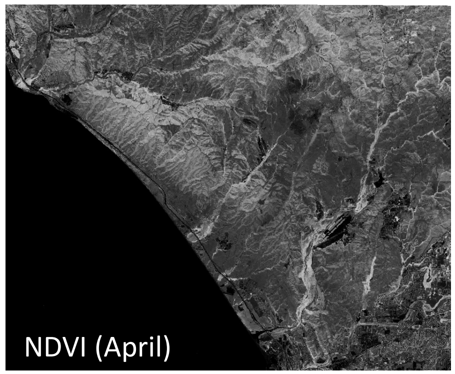


Phenological Classification of Vegetation Types

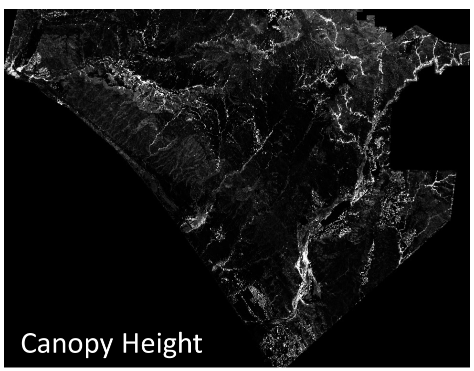
Input Data – 10 m

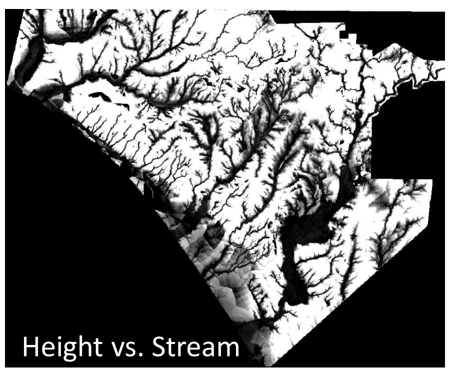
Sentinel-2-derived Phenology





LiDAR-derived Metrics



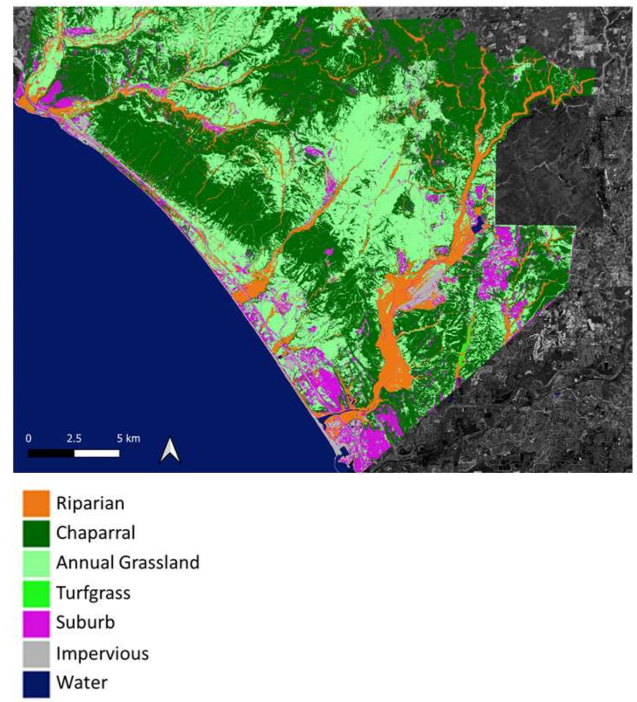


Training/Validation Polygons

Random Forest Classifier

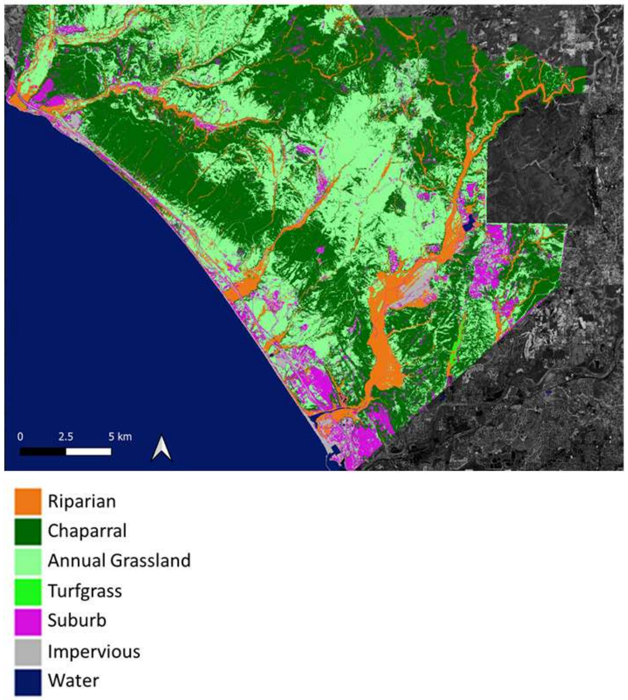
Output Classification

Camp Pendleton

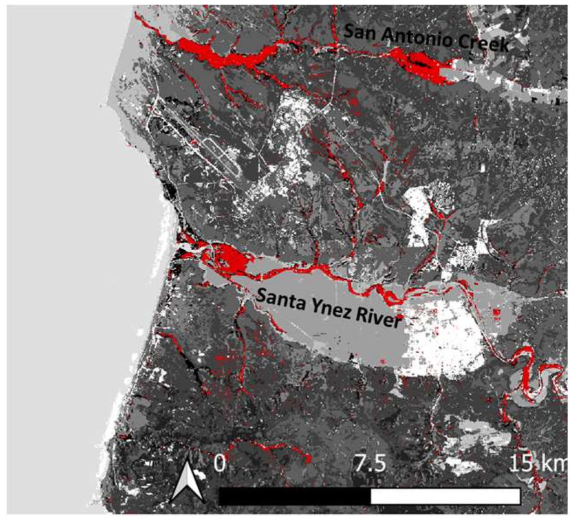


Phenological Classification of Vegetation Types

Camp Pendleton

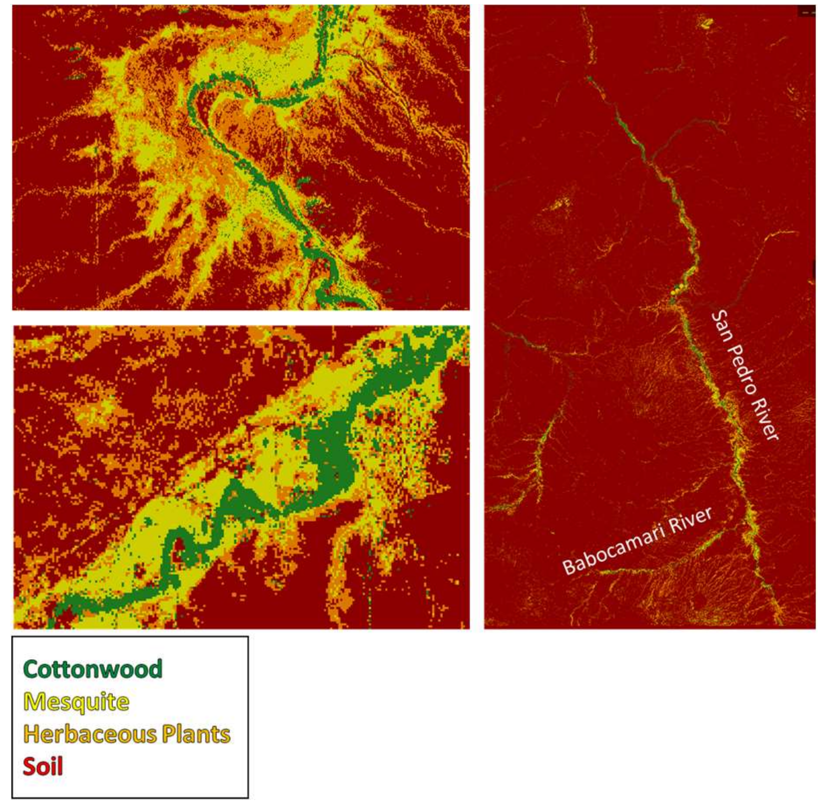


Vandenberg Air Force Base

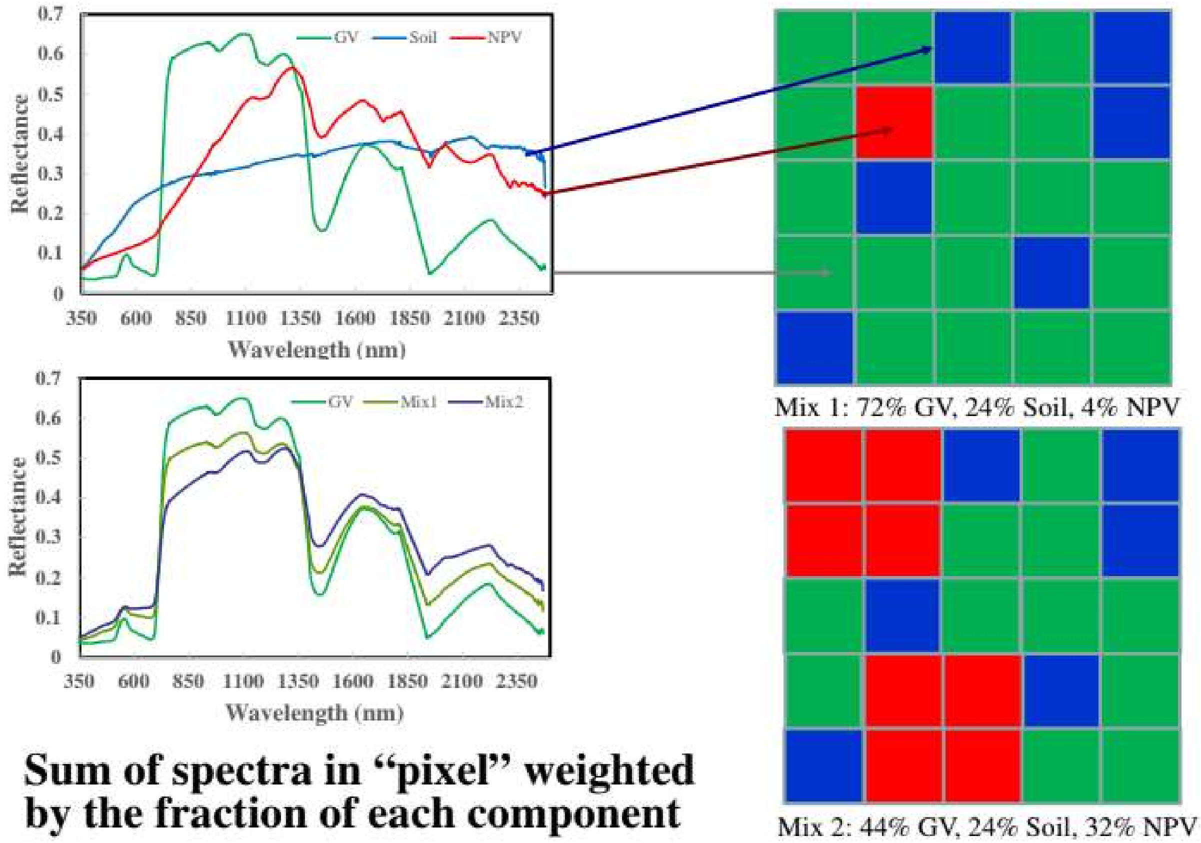


Riparian Communities in Red

San Pedro and Babocomari Rivers



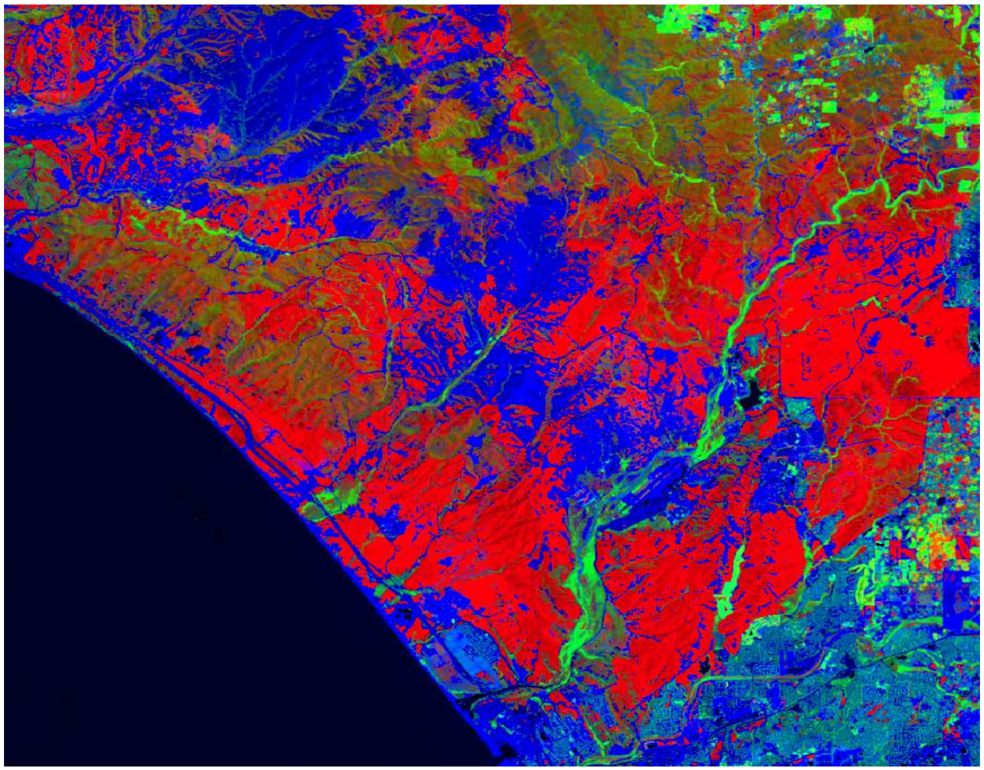
Multiple Endmember Spectral Mixture Analysis

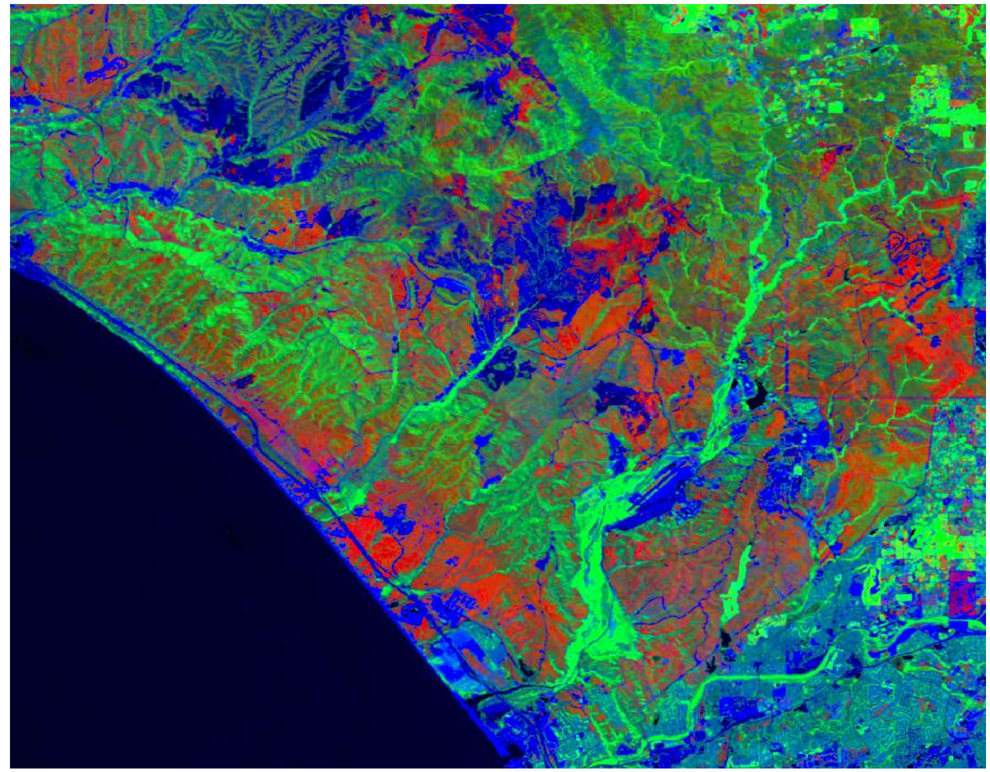


- **Sum of spectra in "pixel" weighted by the fraction of each component**

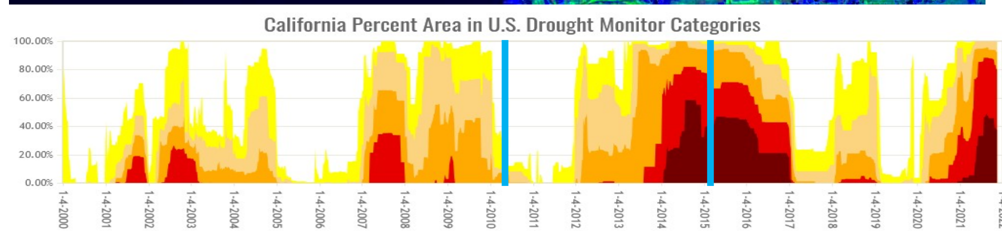
Roberts 2020

Multiple Endmember Spectral Mixture Analysis





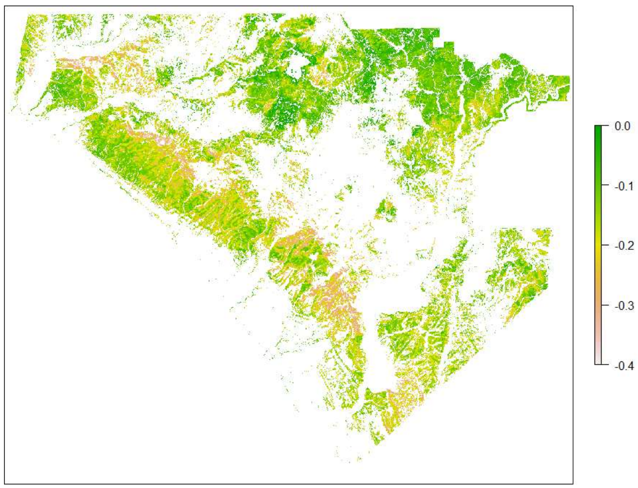
Green – Green Vegetation Fraction
Red – Non-photosynthetic Vegetation Fraction
Blue – Soil Fraction



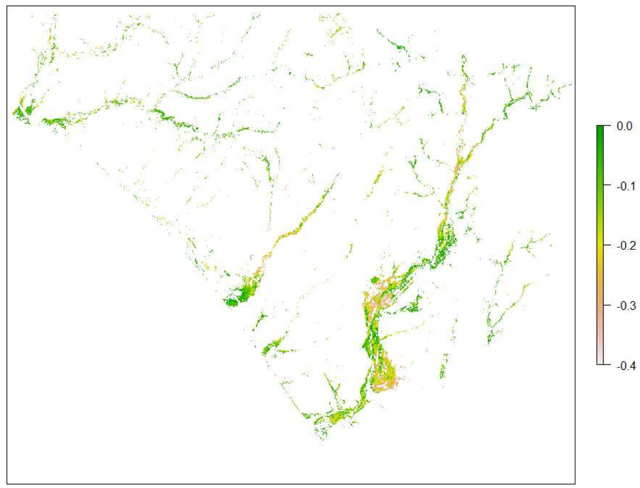
MESMA Case Study Across Camp Pendleton

Drought-induced Loss of Greenness (2015 vs. 2010 comparison)

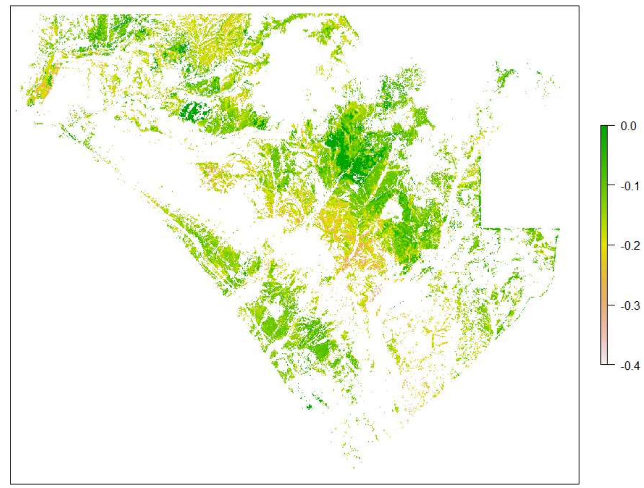
Chaparral



Riparian Woodland



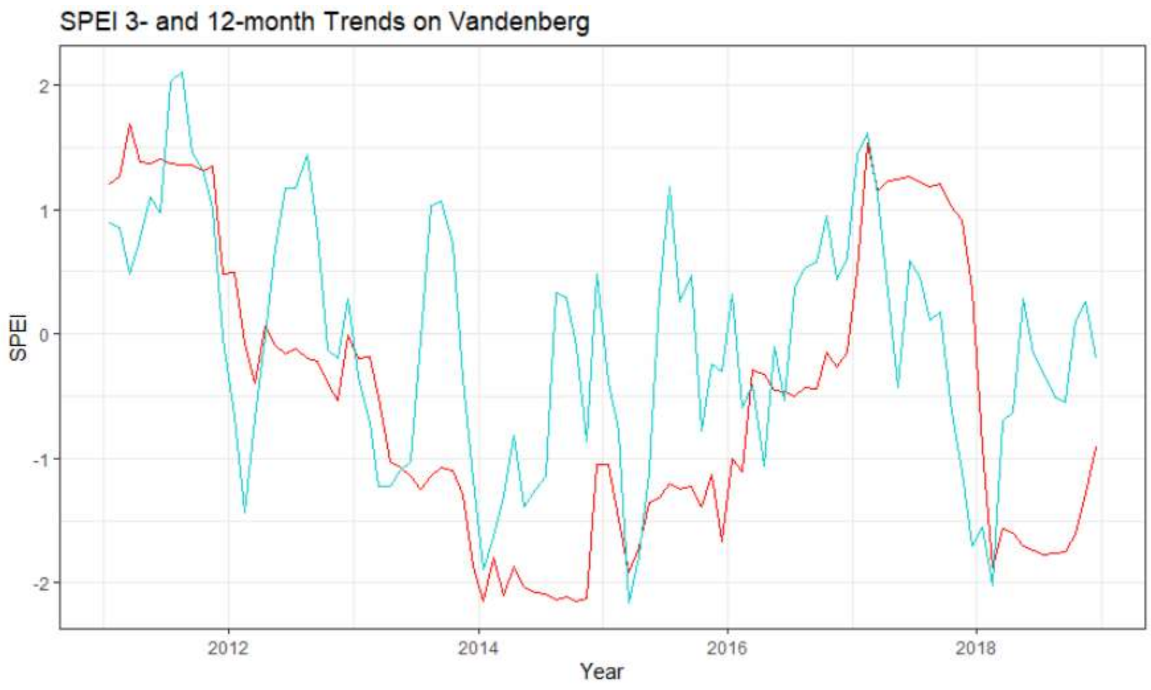
Annual Grassland



More-negative, orange-colored areas correspond to a larger decrease in greenness fraction from before the drought (2010) to during the drought (2015). Green areas showed no change or an increase in greenness under drought.

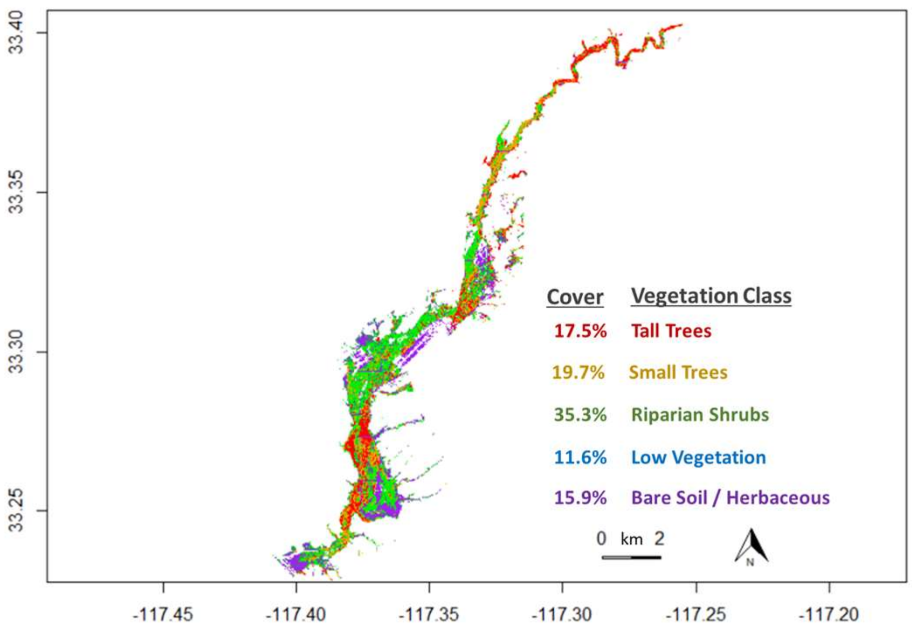
Drought Indicators – SPEI

- Standardized Precipitation-Evapotranspiration Index
- Approximates water availability to shallow-rooted plants
- Multiple temporal scales

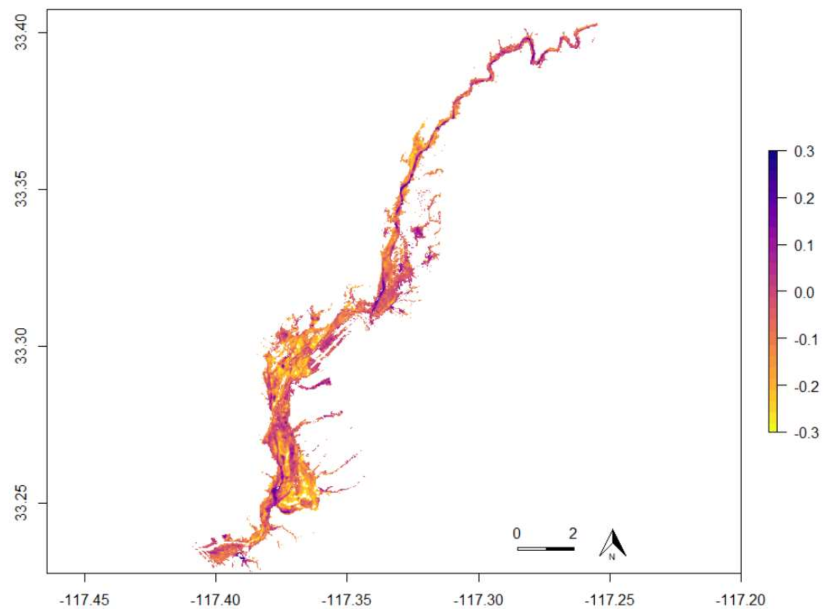


Plant Functional Types on the Santa Margarita

Vegetation Structural Class



Drought-induced Loss of Greenness

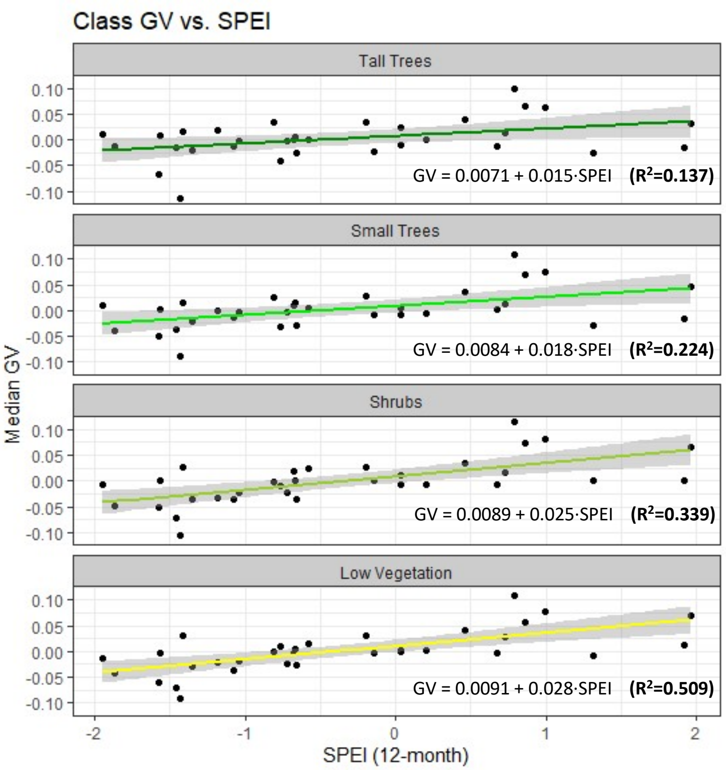


MESMA Case Study on the Santa Margarita River

Riparian GV-SPEI (12) Linear Models

	R	Adj. R^2	Slope	Intercept	P-value
Large Trees	0.4064	0.1373	0.0145	0.0071	0.0210 *
Small Trees	0.4987	0.2236	0.0175	0.0084	0.0037 **
Shrubs	0.6391	0.3887	0.0262	0.0089	8.24e-5 ***
Low Vegetation	0.7247	0.5093	0.0278	0.0091	2.74e-6 ***
Bare / Herbaceous	0.6727	0.4343	0.0259	0.0103	2.46e-5 ***

The relationship between soil moisture drought (SPEI) and greenness becomes progressively weaker for larger riparian plants, implying a subsidy provided by riparian groundwater. Larger, deeper-rooted trees are more readily able to access this subsidy than smaller shrubs and herbaceous riparian vegetation.



Major Takeaways

- Dryland PFTs can be delineated using phenology and structure
- Riparian plants respond negatively to drought
- This relationship is weakest for the largest (phreatophytic) trees

Riparian GV-SPEI (12) Linear Models

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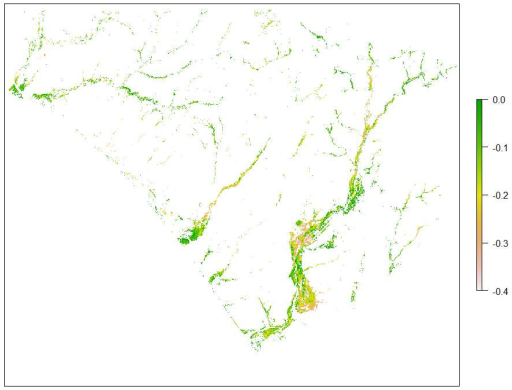
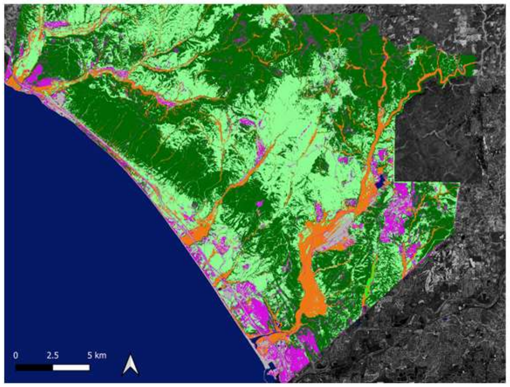
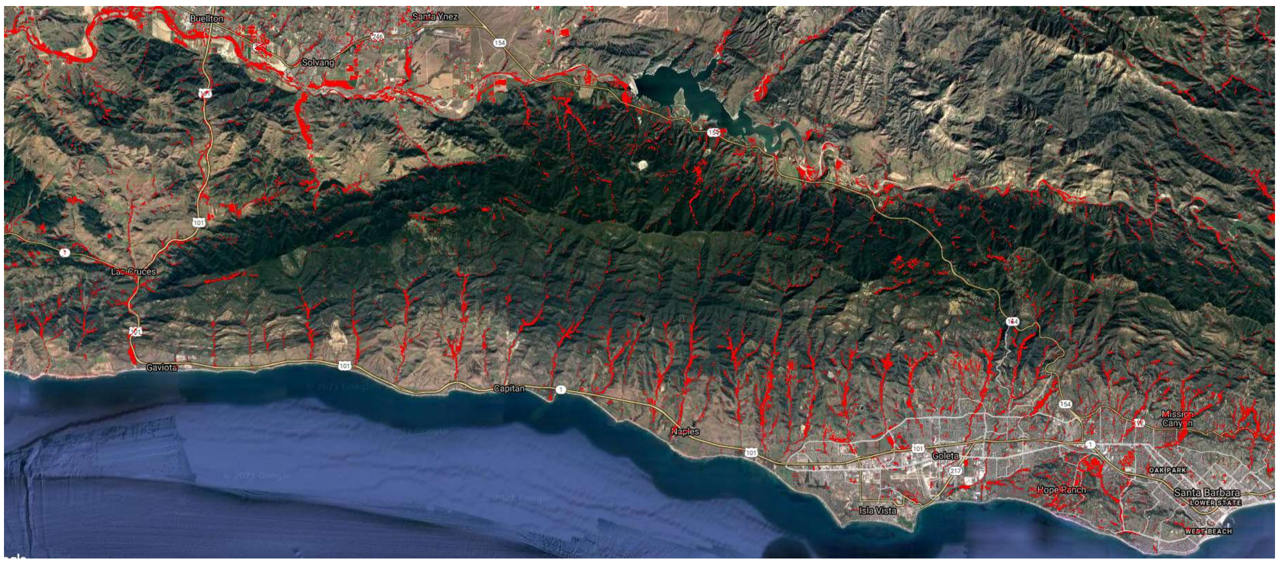
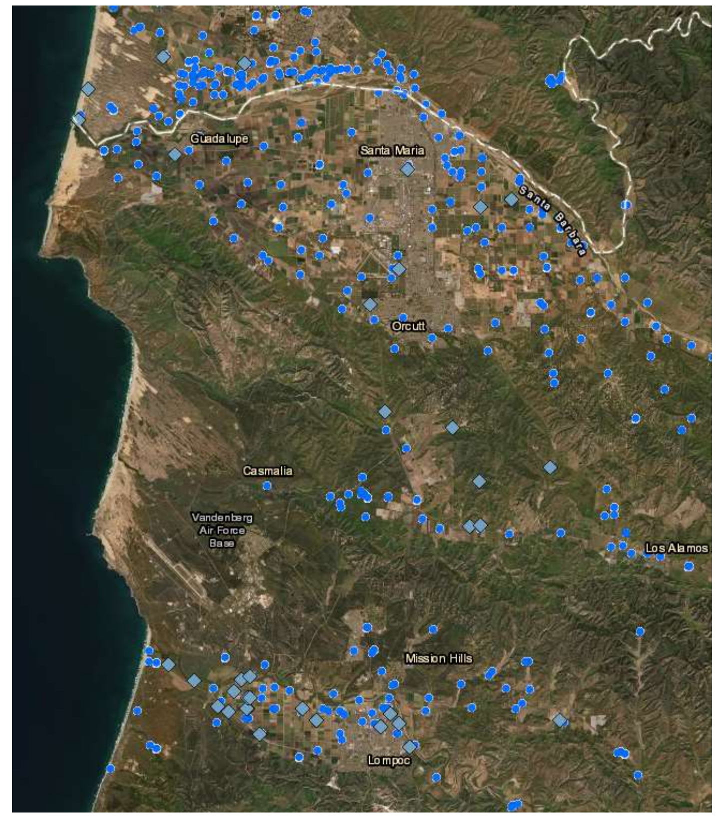




Next Steps

- Groundwater and spatial variability
- Regional analysis (Google Earth Engine)
- Modeling future outcomes



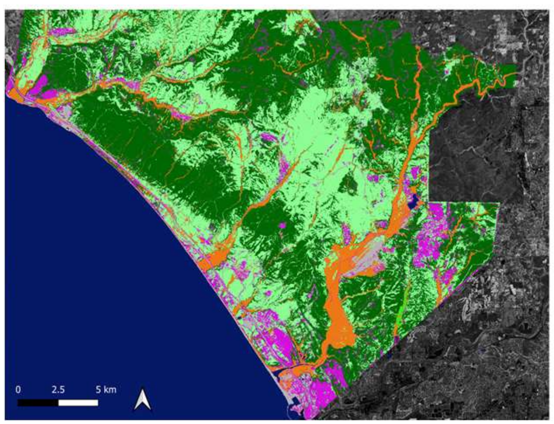


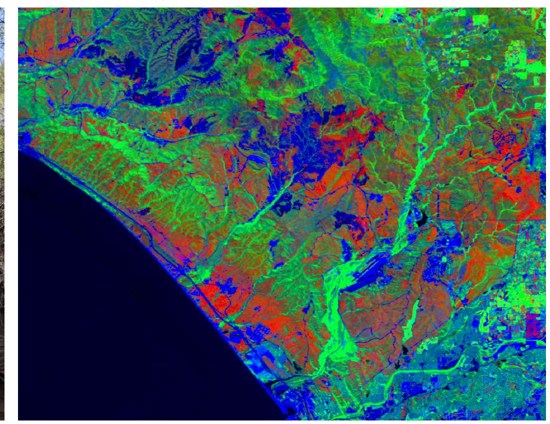
Thank you!

Viper Lab

Advisor: Dar Roberts

Committee: Anna Trugman, Kelly Caylor, Michael Singer, John Stella





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Geography

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