FANTA: Fallow-land Algorithm based on Neighborhood and Temporal Anomalies to map planted versus fallowed croplands using MODIS data

DOI WATERSMART FUNDED RESEARCH

WRRC Brown Bag
April 26, 2018

Cynthia SA Wallace
USGS Research Geographer
Western Geographic Science Center

USGS
science for a changing world
U.S. Geological Survey
U.S. Department of Interior

Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

Study Area

Data sets and Derivatives

1. MODIS Data
2. Cultivated Mask Layer (Universe)
3. Climate Divisions (Neighborhoods)
4. Field Data for Validation

Methods

1. Temporal Anomalies
2. Spatial Anomalies
3. FANTA model: 4 questions

Results

Application to Central Valley Wetlands Study

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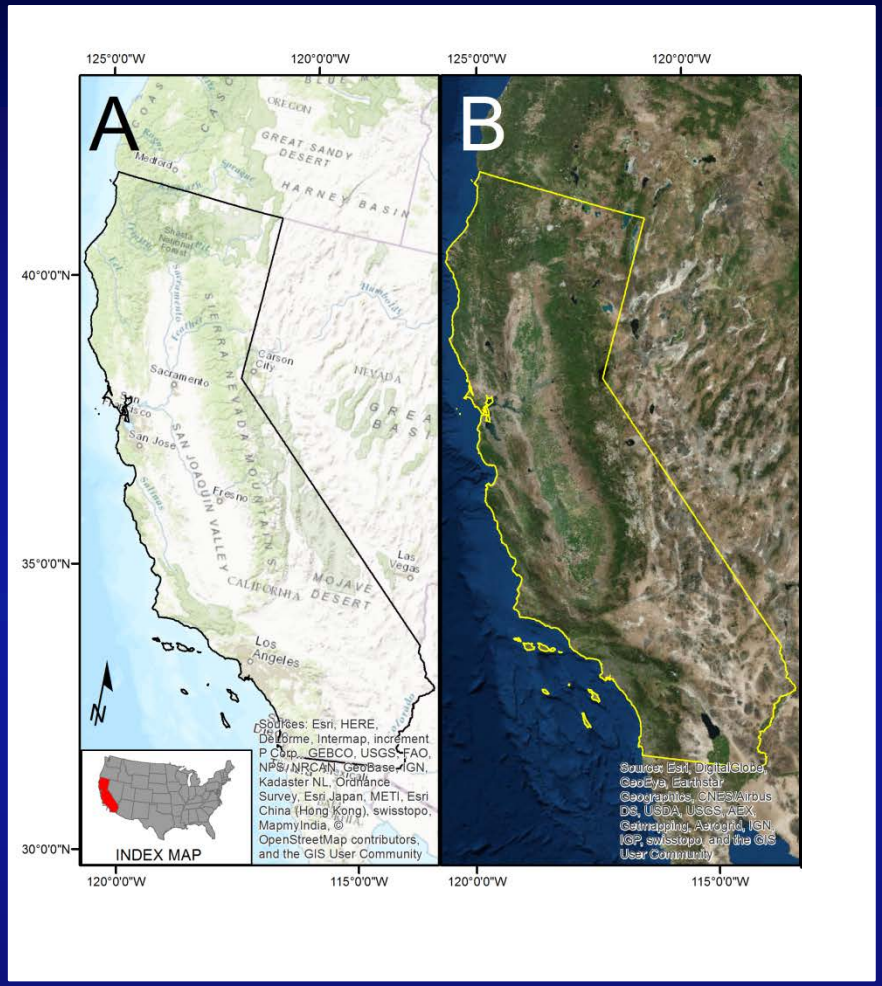
California's Central Valley:

- Produces over 25% of the nation's food
- Over 250 different crops are grown
- Contains 17% of the Nation's and 75% of California's irrigated lands
- Over 80% of human water use in CA is for irrigating crops



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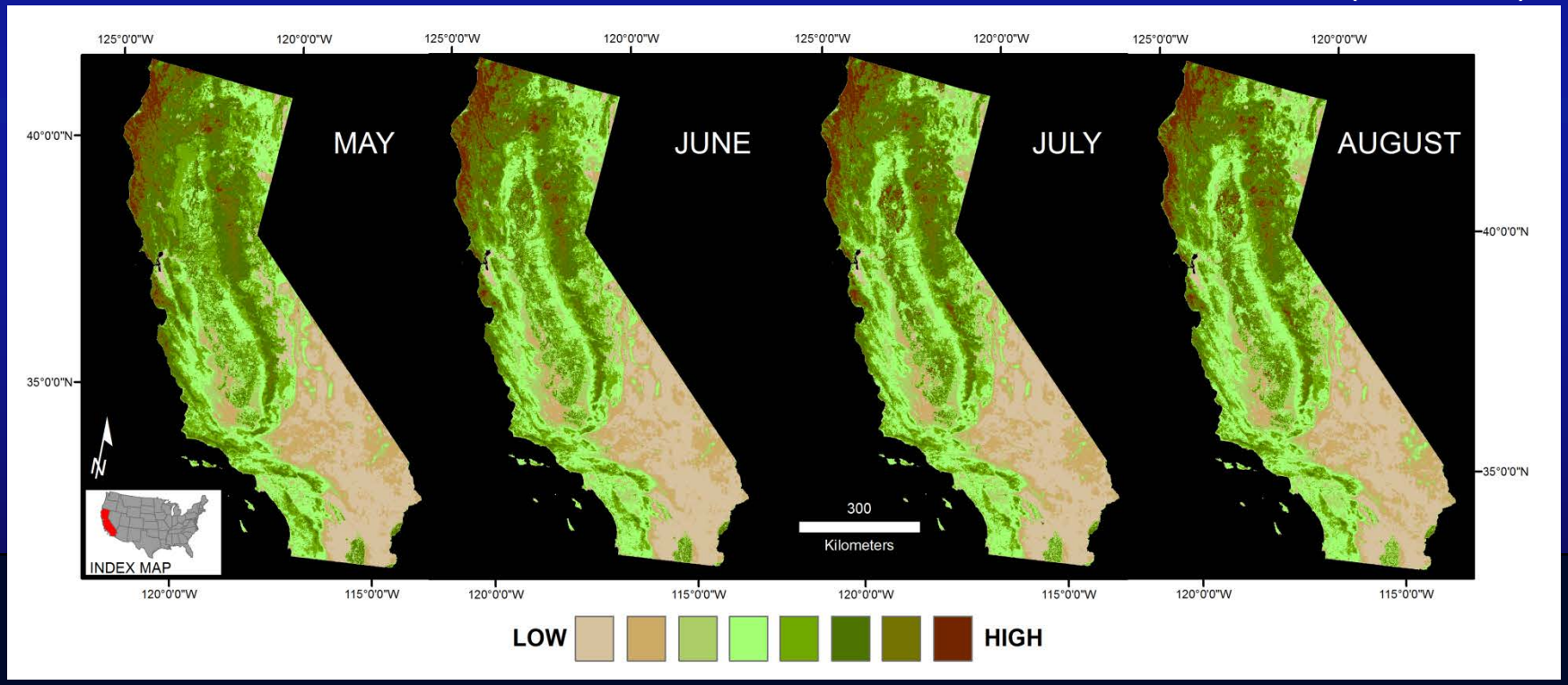
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

1. MODIS Data

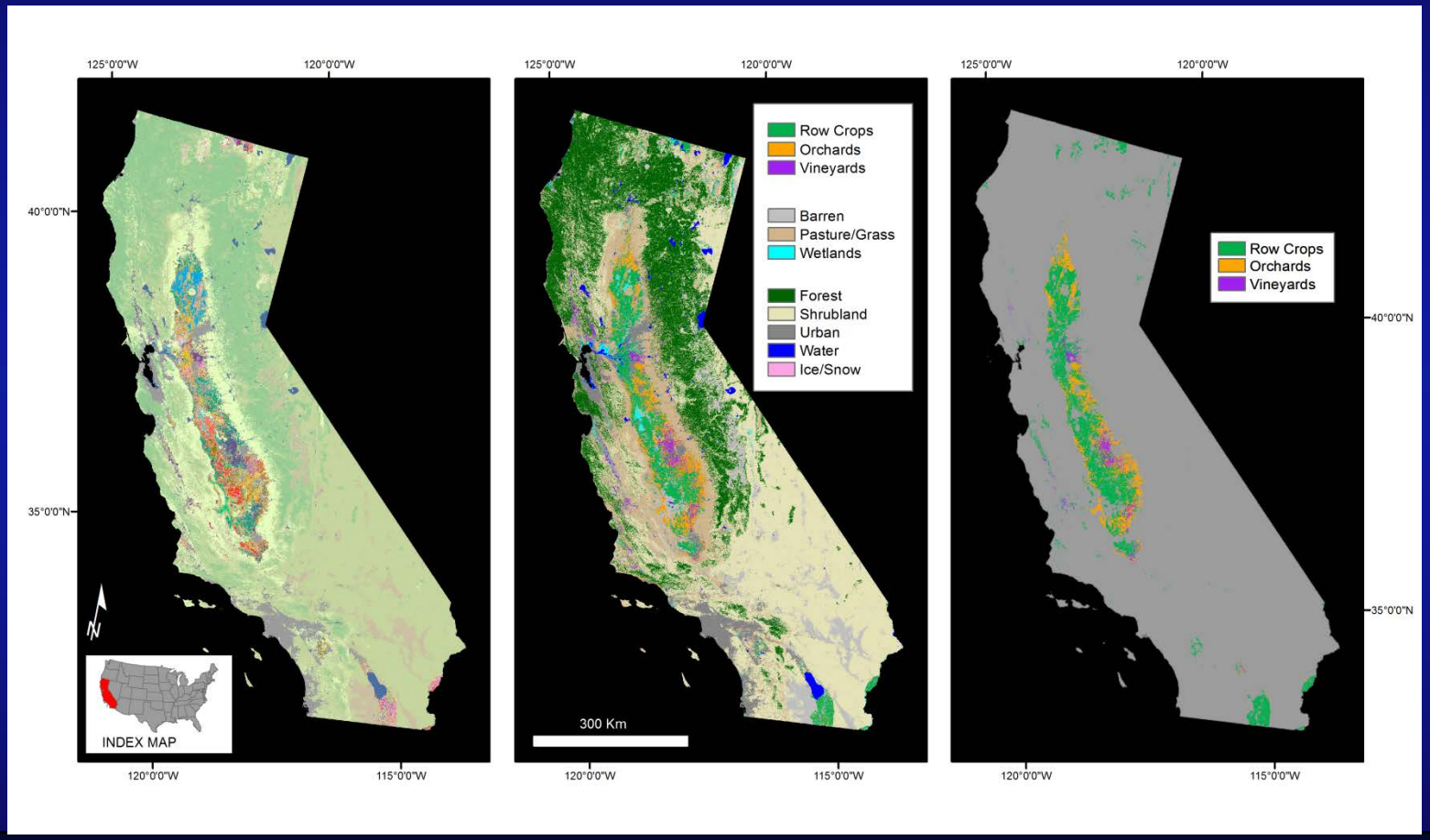
- MODIS 8-day composite reflectance data (red, NIR)
- Calculate NDVI 2001 to present
- Assemble best 4 composites representing each month
- Calculate Monthly NDVI and Monthly statistics (NDVI Min, Max, Range)
- Calculate Historic NDVI Statistics for each Month Based on 13 Years (2001-13)



Example of Monthly NDVI images from 2014

2. Cultivated Mask Layer

Developed from the USDA Cropland Data Layers (CDL), 2007 to 2013

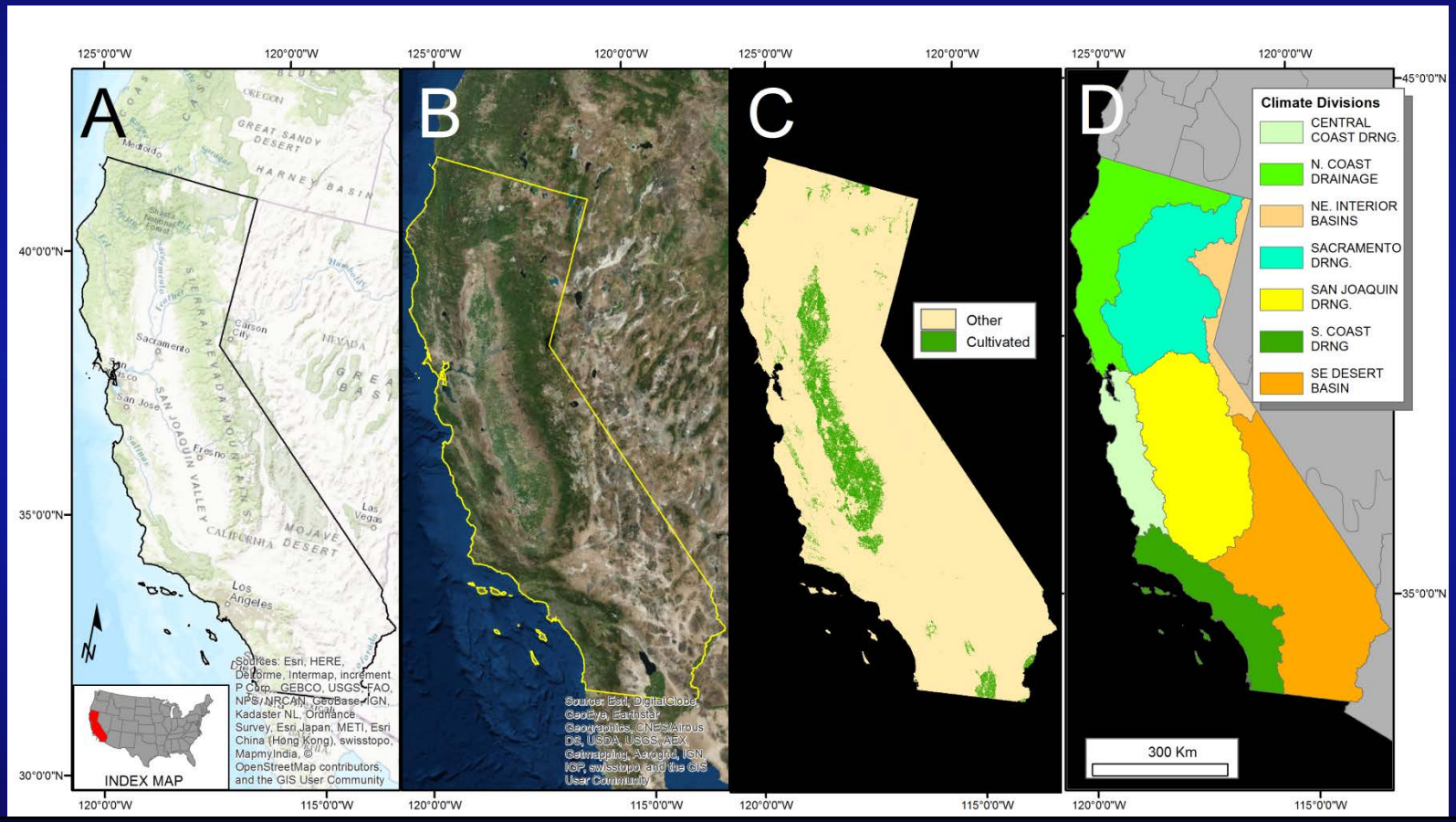


LEFT: USDA CDL map for 2013 with 132 classes. CENTER: Simplified classification for 2013, collapsing land cover into 11 classes. RIGHT: Final Cultivated Area Mask.

Pixels classified as Row Crops, Orchards or Vineyards in at least 5 of 7 years are preserved in the final mask.

3. Climate Divisions

NOAA Climate Divisions are used to define Neighborhoods

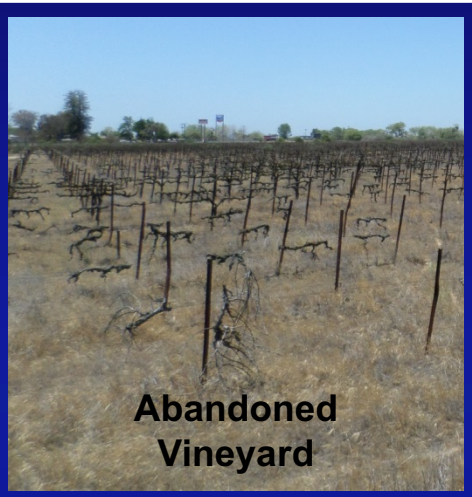


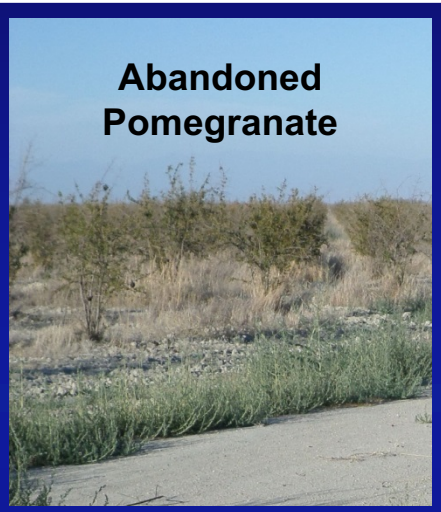
(A) USGS topographic map, (B) Natural color satellite image (C) Cultivated lands derived from USDA-CDL maps (D) Climate Divisions in California from NOAA

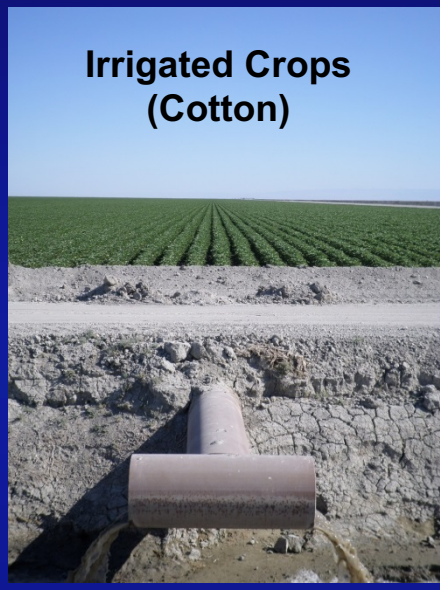
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

4. Field Data

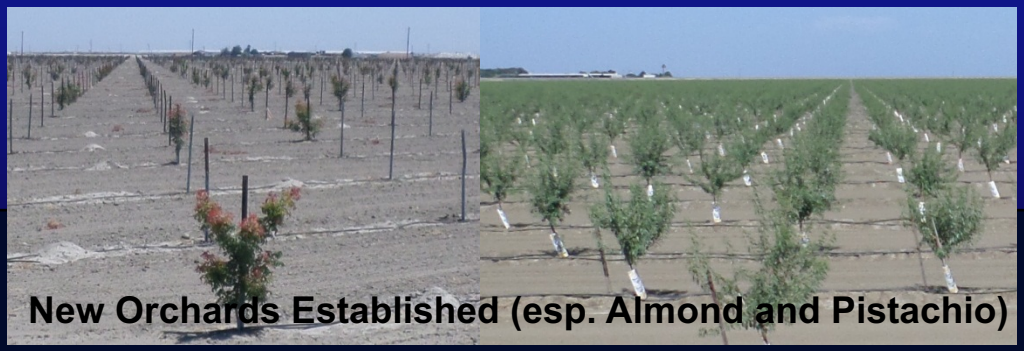
Field data collected July 2014 are used to validated FANTA







Impacts of the drought were evident in 2014 and include abandoned perennial crops, fallowed fields and conversion of row crops to orchards. Many areas maintained healthy crops, with evidence that pre-1914 water rights determined viable acreage.



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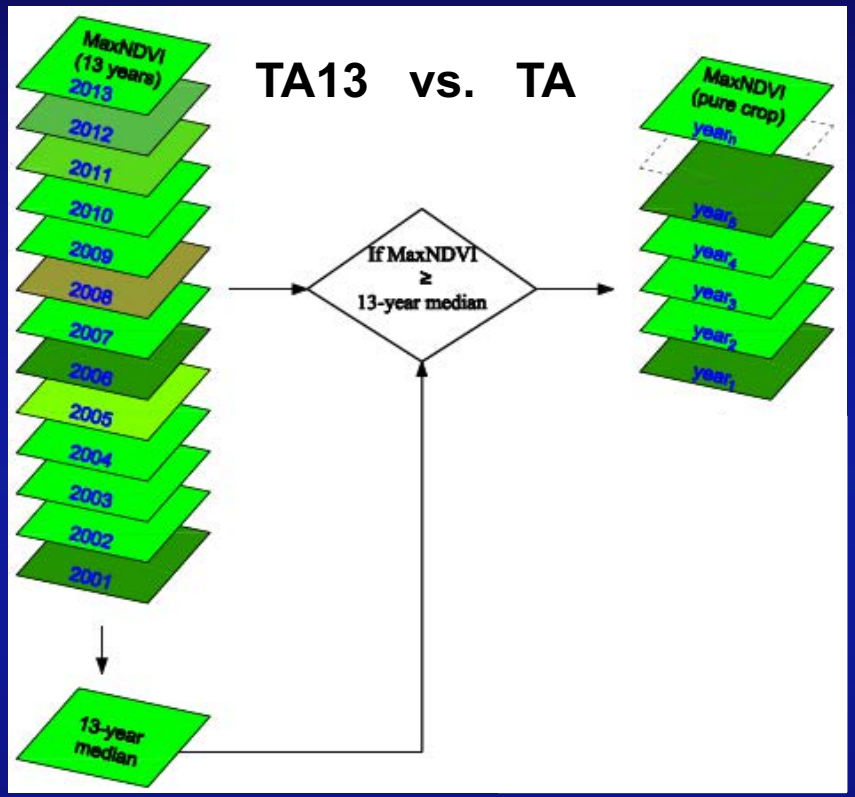
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

1. Temporal Anomalies

Monthly Greenness and Range Anomalies relative to Historical Values:

1. For all years
2. For a Pure Crop signal (subset of years with greenness > median greenness)
3. Over all of California as well as subset by cultivated type



All Years Pure Crop

1. Temporal Anomalies

Monthly Greenness and Range Anomalies relative to Historical Values:

1. For all years
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3. Over all of California as well as subset by cultivated type

$$TA13\_NDVI\ (month) = \frac{NDVI\ (month) - Mean\_NDVI\ (all\ years)}{SD\_NDVI\ (all\ years)} \quad [1]$$

Where:

- TA13_NDVI (month) = the Temporal Anomaly based on 13 years of data of NDVI for the month in the year of interest.
- NDVI (month) = the NDVI value for the month in the year of interest.
- Mean_NDVI (all years) = the mean NDVI value observed at the pixel between 2001-2013.
- SD_NDVI (all years) = the standard deviation of the 13 NDVI values observed at the pixel between 2001-2013.

1. Temporal Anomalies

Monthly Greenness and Range Anomalies relative to Historical Values:

1. For all years
2. For a Pure Crop signal (subset of years with greenness > median greenness)
3. Over all of California as well as subset by cultivated type

$$TA\_NDVI\ (month) = \frac{NDVI\ (month) - Mean\_NDVI\ (pure\ crop\ )}{SD\_NDVI\ (pure\ crop)} \quad [2]$$

$$TA\_NDVIrange\ (month) = \frac{NDVIrange(month) - Mean\_NDVIrange(pure\ crop\ )}{SD\_NDVIrange(pure\ crop)} \quad [3]$$

Where:

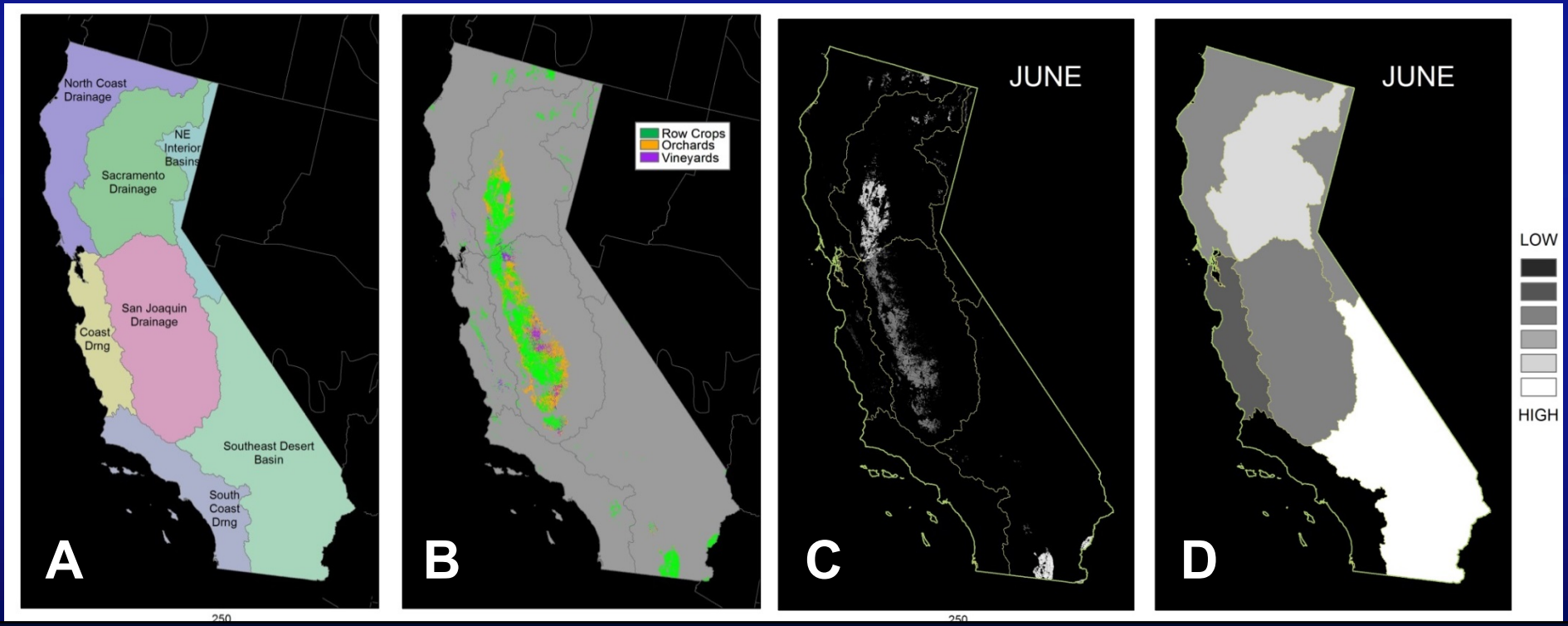
- TA_NDVI (month) / TA_NDVIrange (month) = the Temporal Anomaly based on “pure crop” subset of data of NDVI / NDVIrange for the month in the year of interest.
- NDVI (month) = the NDVI value for the month in the year of interest.
- Mean_NDVI (pure crop) / Mean_NDVIrange (pure crop) = the mean NDVI / NDVIrange value observed at the pixel in the “pure crop” subset of data between 2001-2013.
- SD_NDVI (pure crop) / SD_NDVIrange (pure crop) = the standard deviation of the NDVI values observed at the pixel in the “pure crop” subset of data between 2001-2013.

Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

2. Spatial Anomalies

Monthly Greenness and Range Anomalies relative to Neighborhood Values:
For all Row Crops within each climate zone, calculate:

1. Median Monthly Range (Middle Dynamics Value of the Neighborhood)
2. Median Monthly NDVI (Middle Absolute Greenness Value of the Neighborhood)



A: Climate Divisions. B: Cultivated Mask. C: Median NDVI/Range D: Median extrapolated

The FANTA model examines the values at each pixel and asks how they compare to its neighbors, both in terms of greenness and dynamics during the growing season.

2. FANTA model: 4 Questions

1. "Does it LOOK like a crop based on its history?"
   How does the relative greenness of the pixel compare to a "pure crop" signal from its 13-year history between 2001 and 2013? **(TEMPORAL)**
2. "Does it ACT like a crop based on its history?"
   How does the dynamic range of the pixel compare to a "pure crop" signal from its 13-year history between 2001 and 2013? **(TEMPORAL)**
3. "Does it LOOK like a crop compared to its neighbors?"
   How does the absolute greenness of the pixel compare to other cultivated pixels within its Climate Division? **(SPATIAL)**
4. "Does it ACT like a crop compared to its neighbors?"
   How does the dynamic range of the pixel compare to other cultivated pixels within its Climate Division? **(SPATIAL)**

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2. FANTA model: 4 Questions

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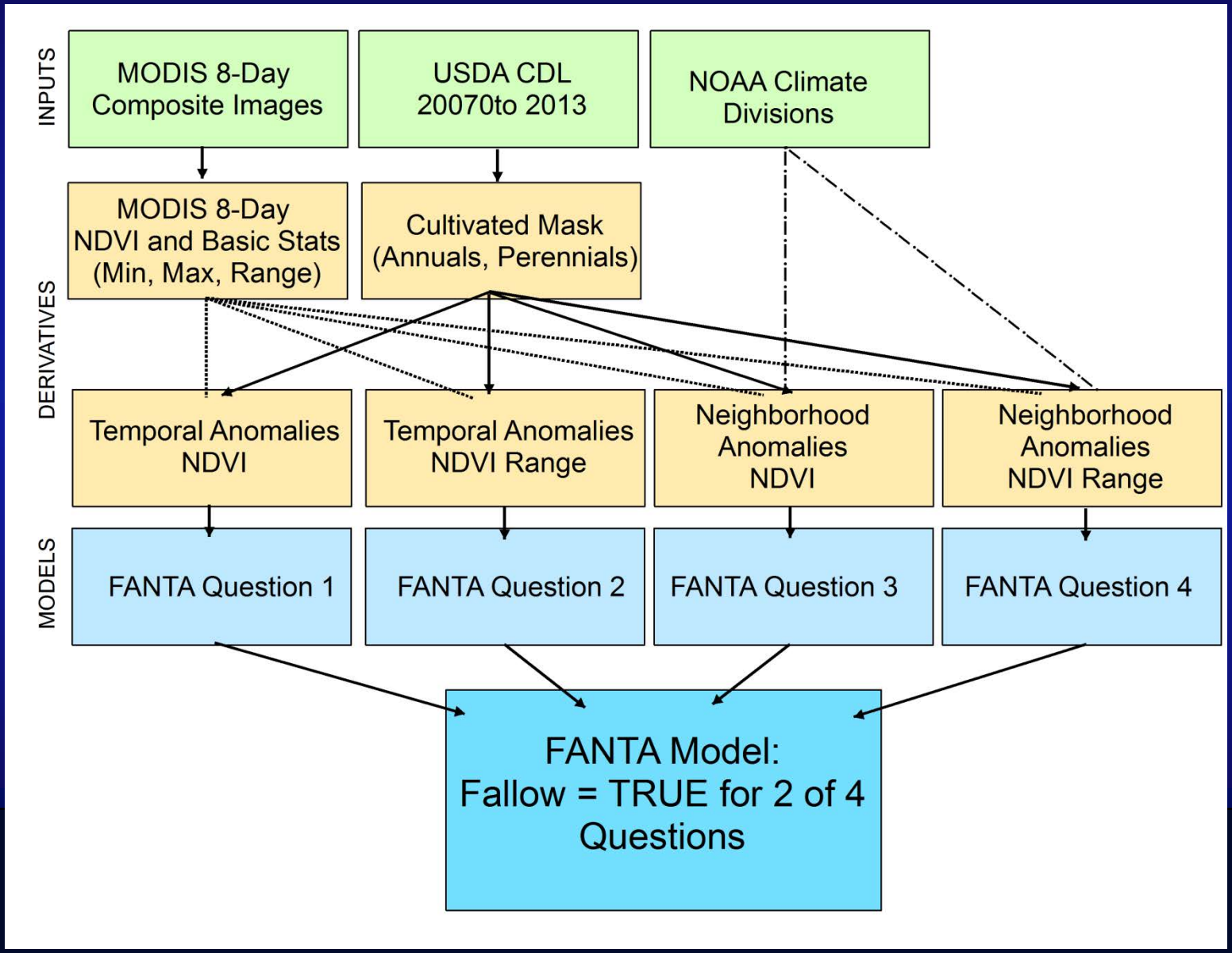
3. "Does it LOOK like a crop compared to its neighbors?"
   How does the absolute greenness of the pixel compare to other cultivated pixels within its Climate Division? **(SPATIAL)**
4. "Does it ACT like a crop compared to its neighbors?"
   How does the dynamic range of the pixel compare to other cultivated pixels within its Climate Division? **(SPATIAL)**

FALLOW = TRUE IF The answer to 2 of the questions is "NO"

2. FANTA model: Flow Chart



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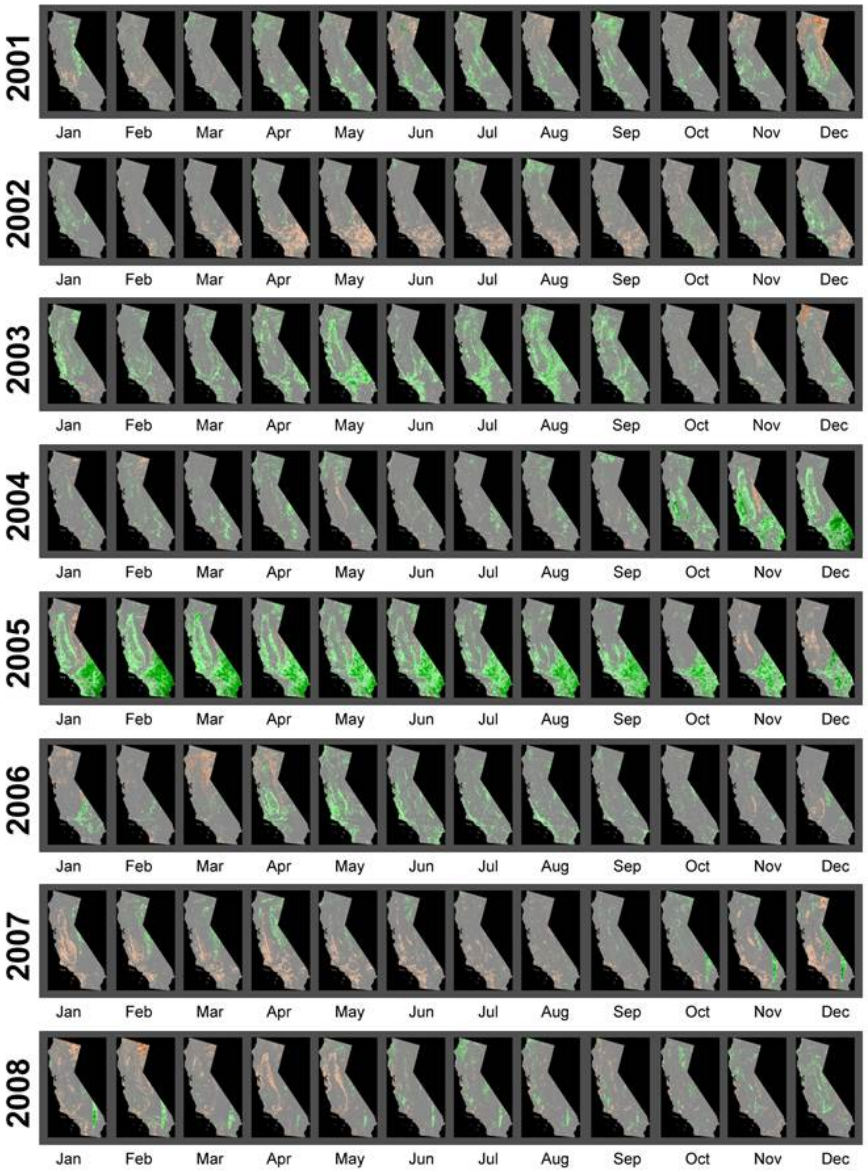
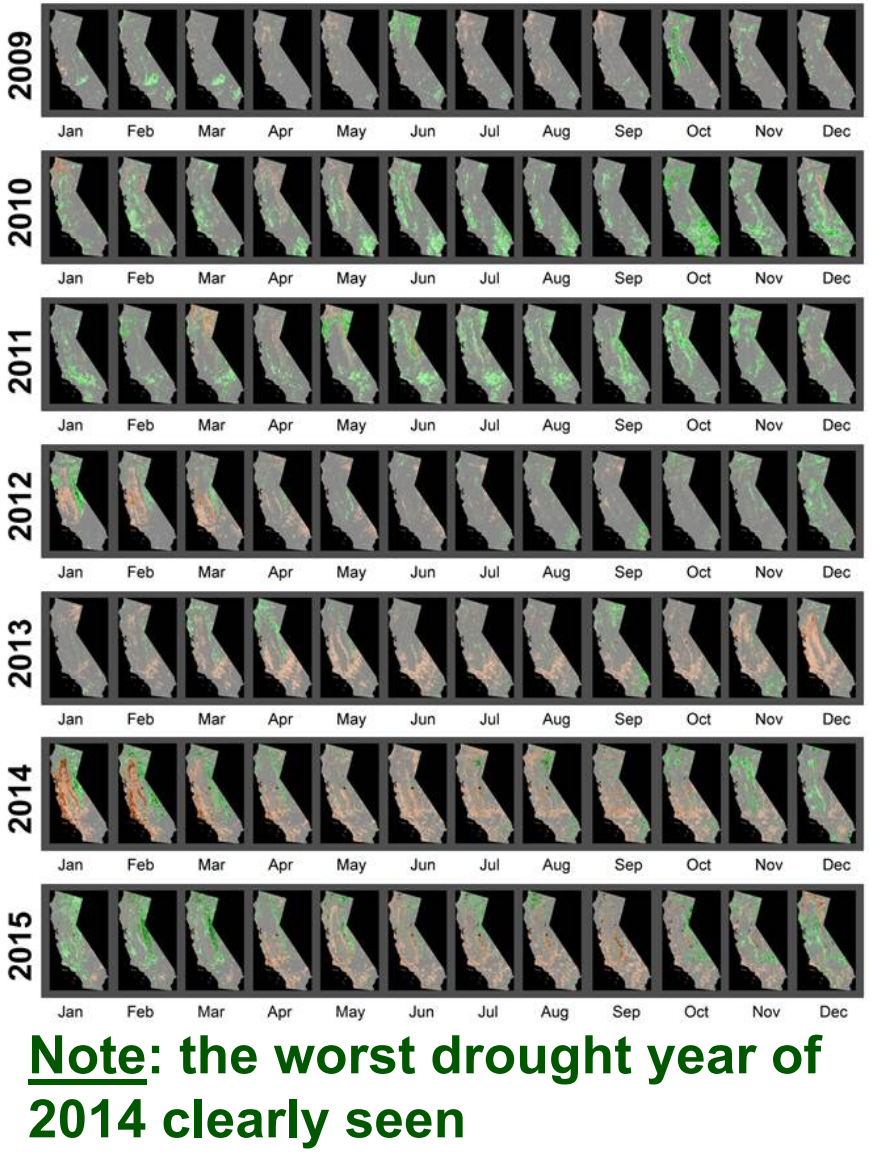
Temporal Anomalies: California Monthly NDVI (TA13_NDVI), 2001 to 2015

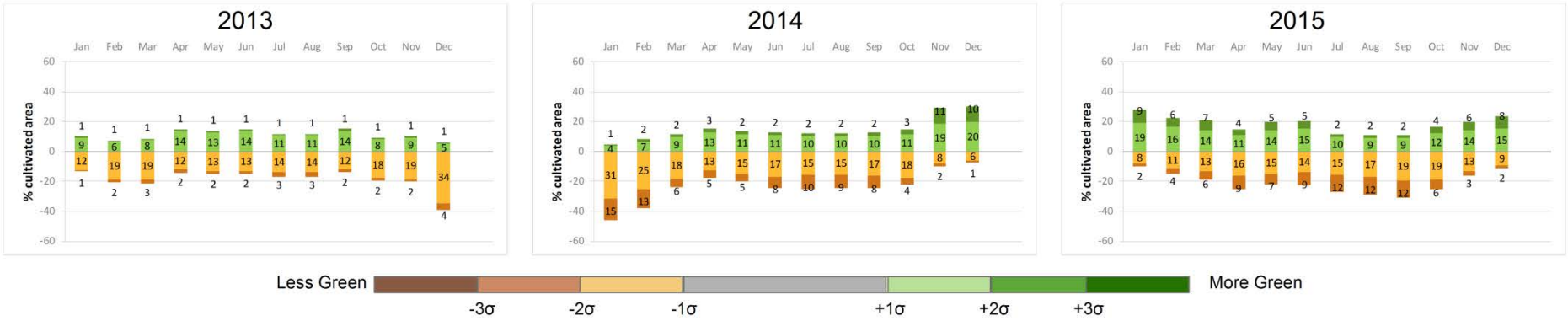




Note: the worst drought year of 2014 clearly seen

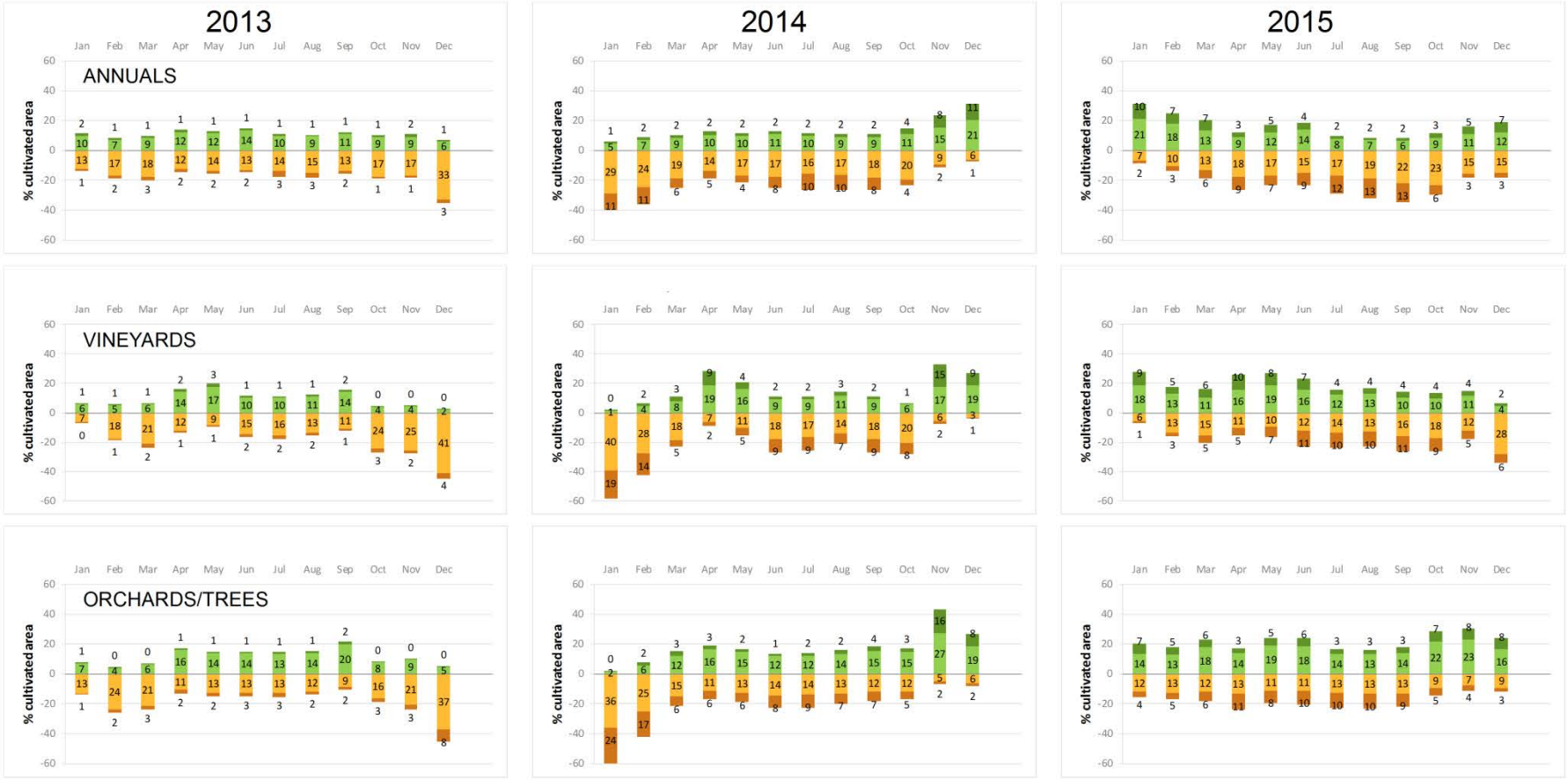
Temporal Anomalies

Monthly Greenness and Range Anomalies relative to Historical Values:
For a Pure Crop signal



Temporal Anomalies

Monthly Greenness and Range Anomalies relative to Historical Values:
For a Pure Crop signal subset by cultivated type



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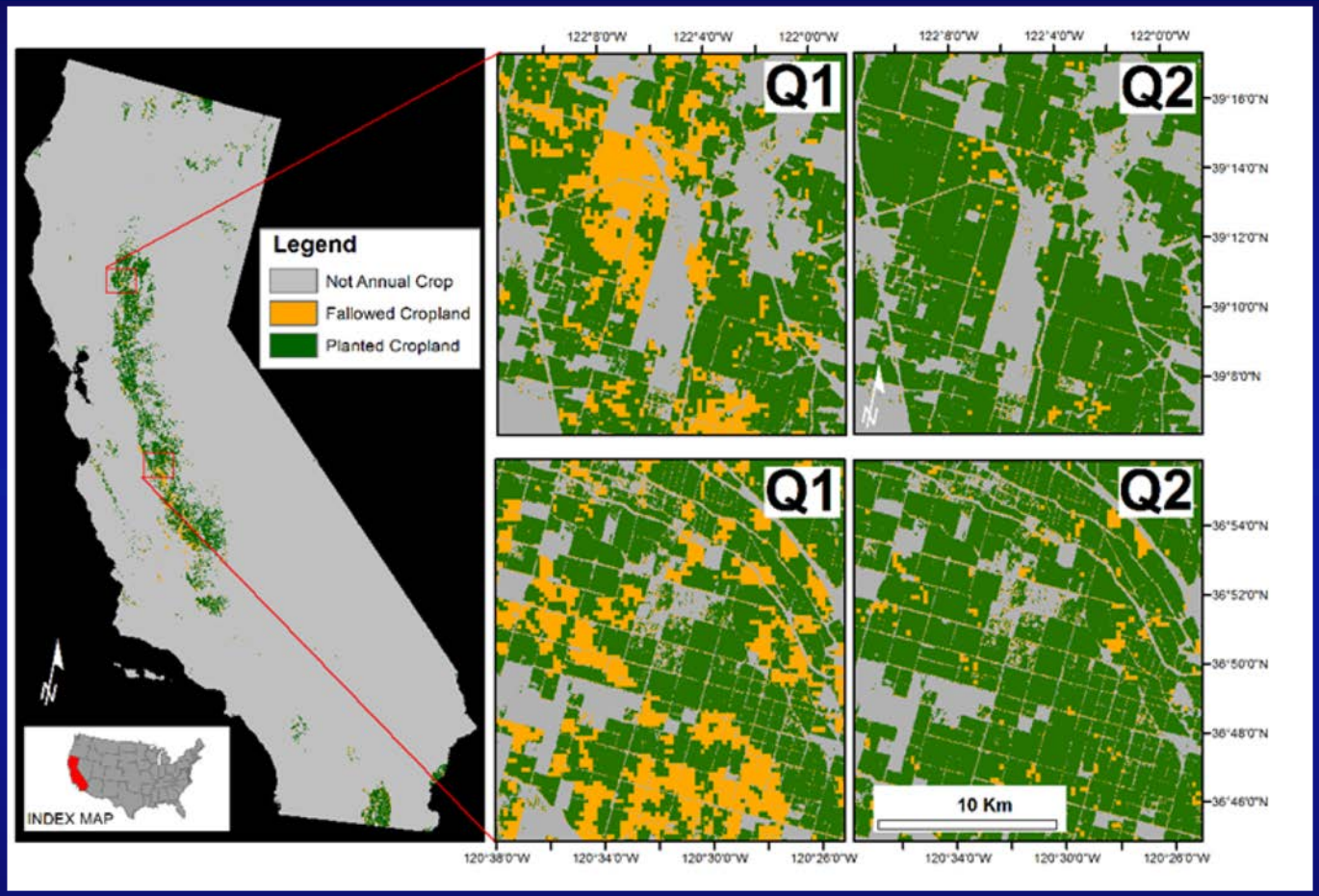
FANTA 2014: 2 Temporal Questions



FANTA 2014 Q1 (Temporal) Q2 (Temporal)

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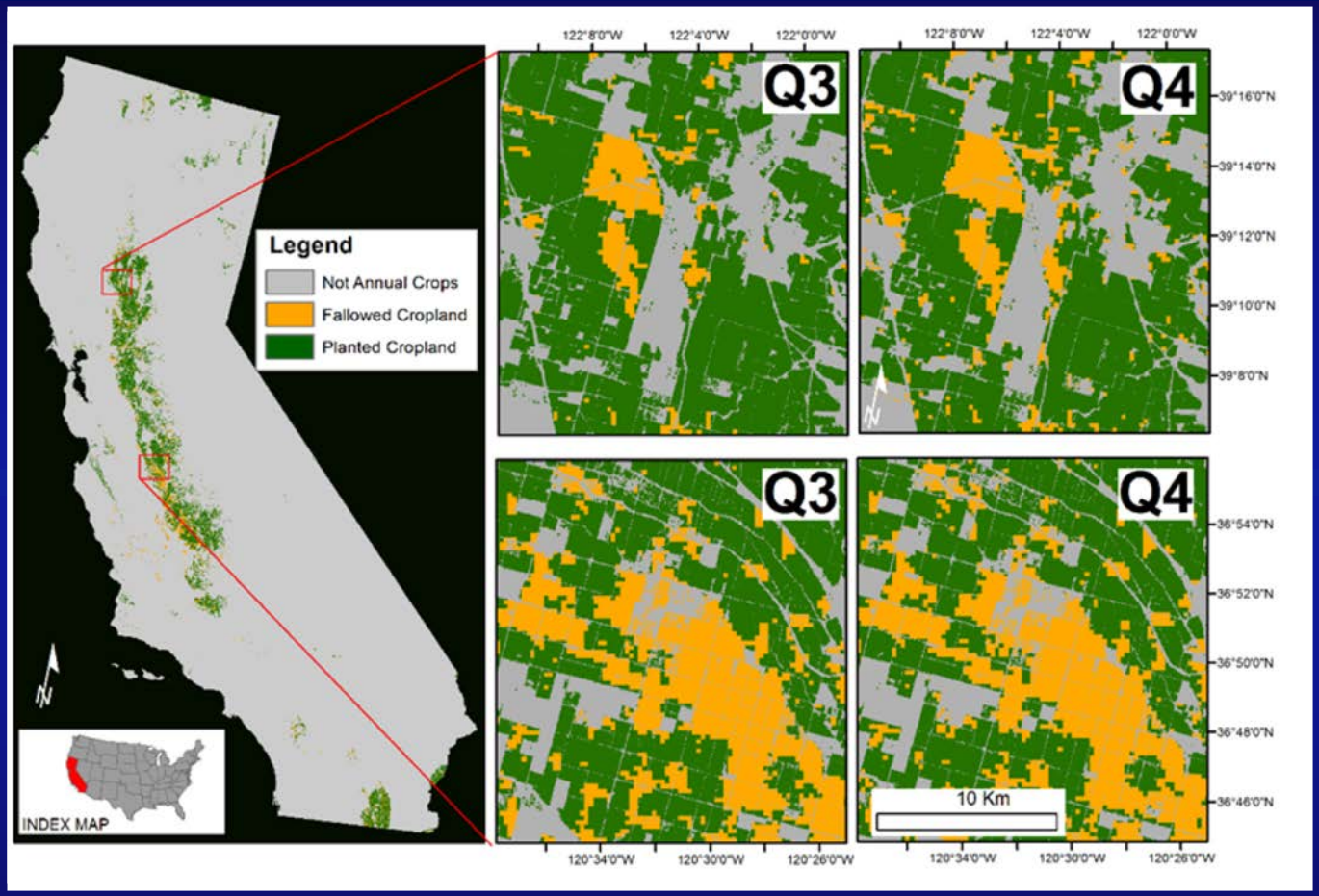
FANTA 2014: 2 Spatial Questions



FANTA 2014 Q3 (Neighbor) Q4 (Neighbor)

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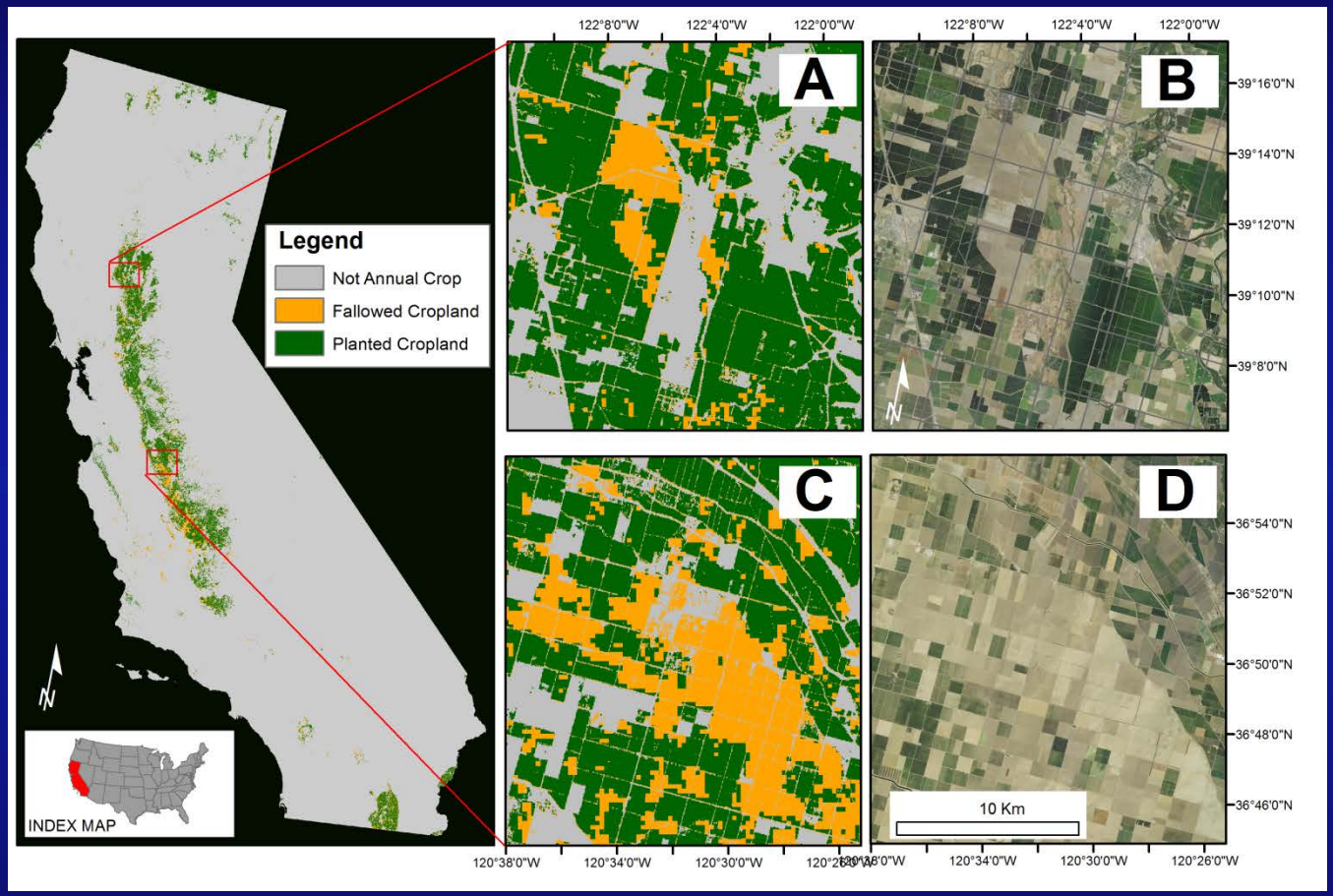
FANTA 2014: 2 of 4 questions = FALLOW is “TRUE”



FANTA 2014 FANTA Zoom NAIP July 2014

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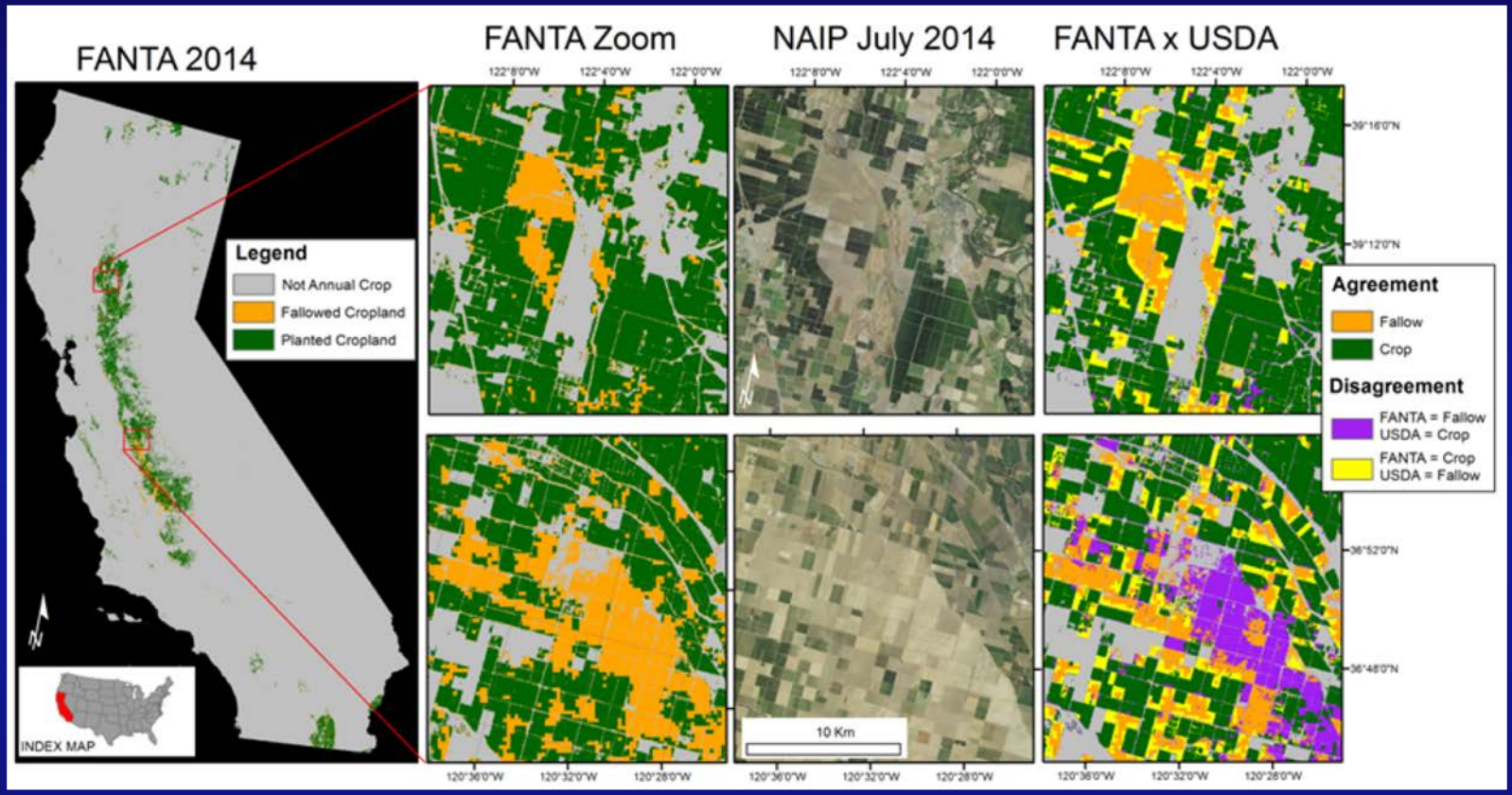
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

FANTA 2014 with NAIP July 2014 and USDA 2014



FANTA versus 2014 Field Data

A 2014	Crop-Field	Fallow-Field	Total	User's
Crop-Model	123	16	139	0.88
Fallow-Model	12	49	61	0.80
Total	135	65	200	
Producer's	0.91	0.75		0.86

USDA versus 2014 Field Data

B 2014	Crop-Field	Fallow-Field	Total	User's
Crop-USDA	127	33	160	0.79
Fallow-USDA	8	32	40	0.80
Total	135	65	200	
Producer's	0.94	0.49		0.80

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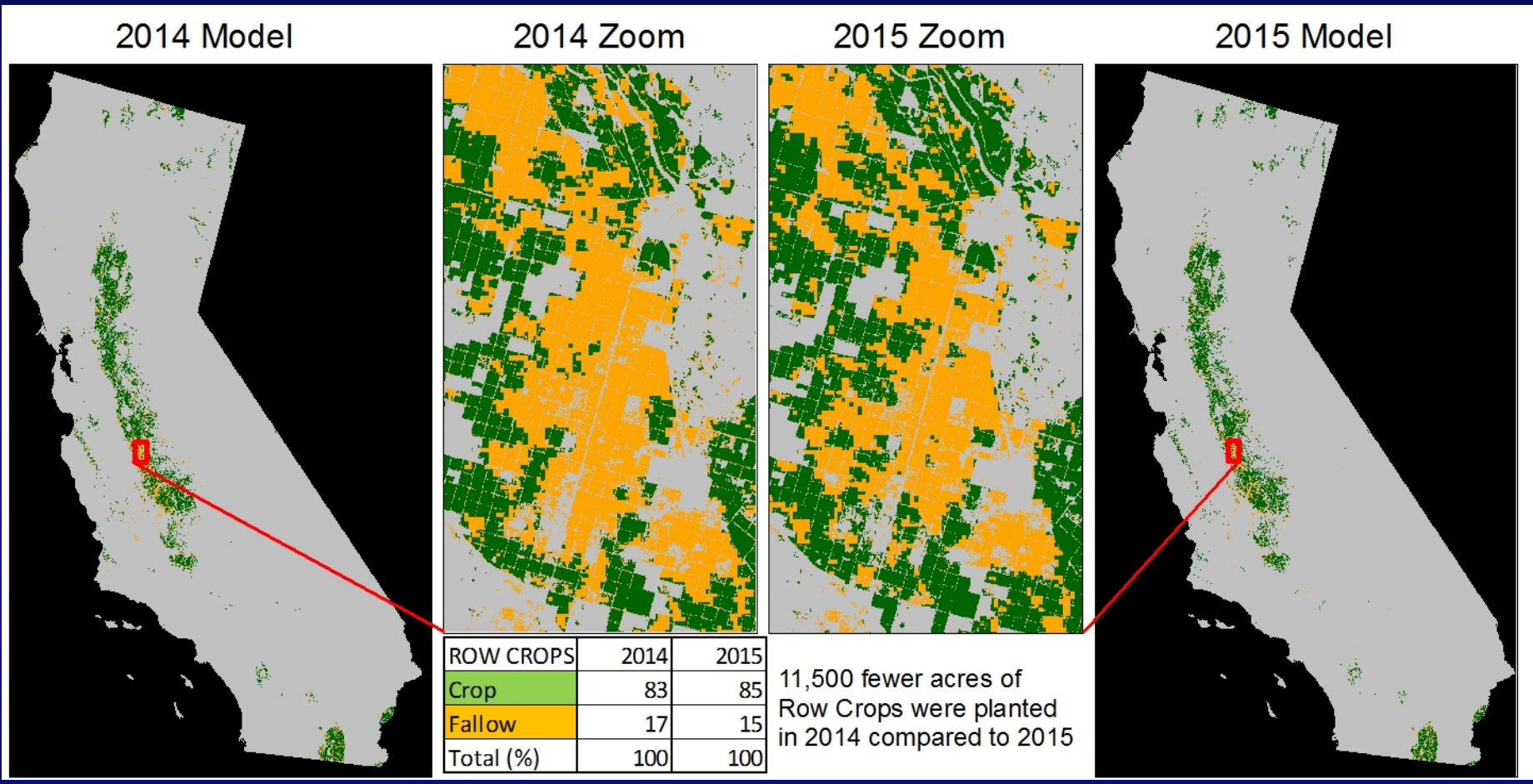
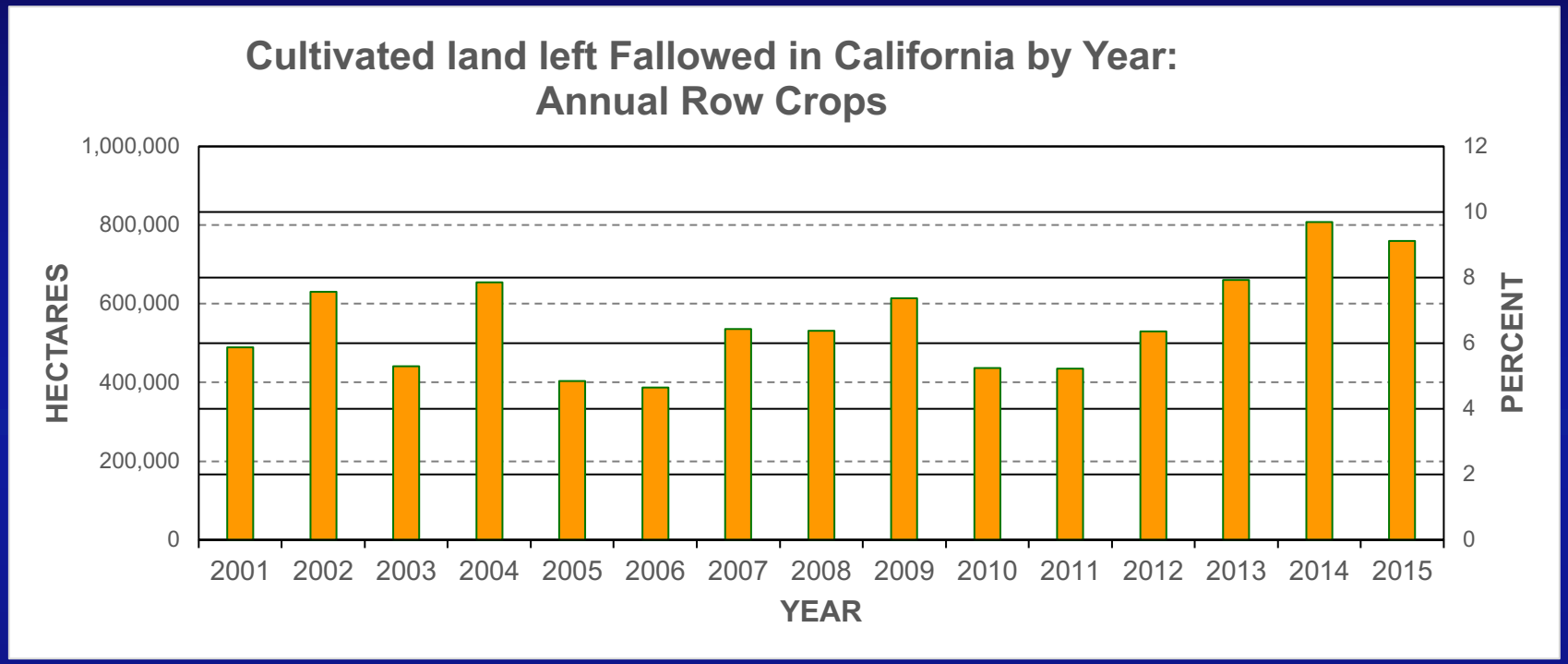
FANTA 2014 and 2015



ROW CROPS	2014	2015
Crop	83	85
Fallow	17	15
Total (%)	100	100

11,500 fewer acres of Row Crops were planted in 2014 compared to 2015

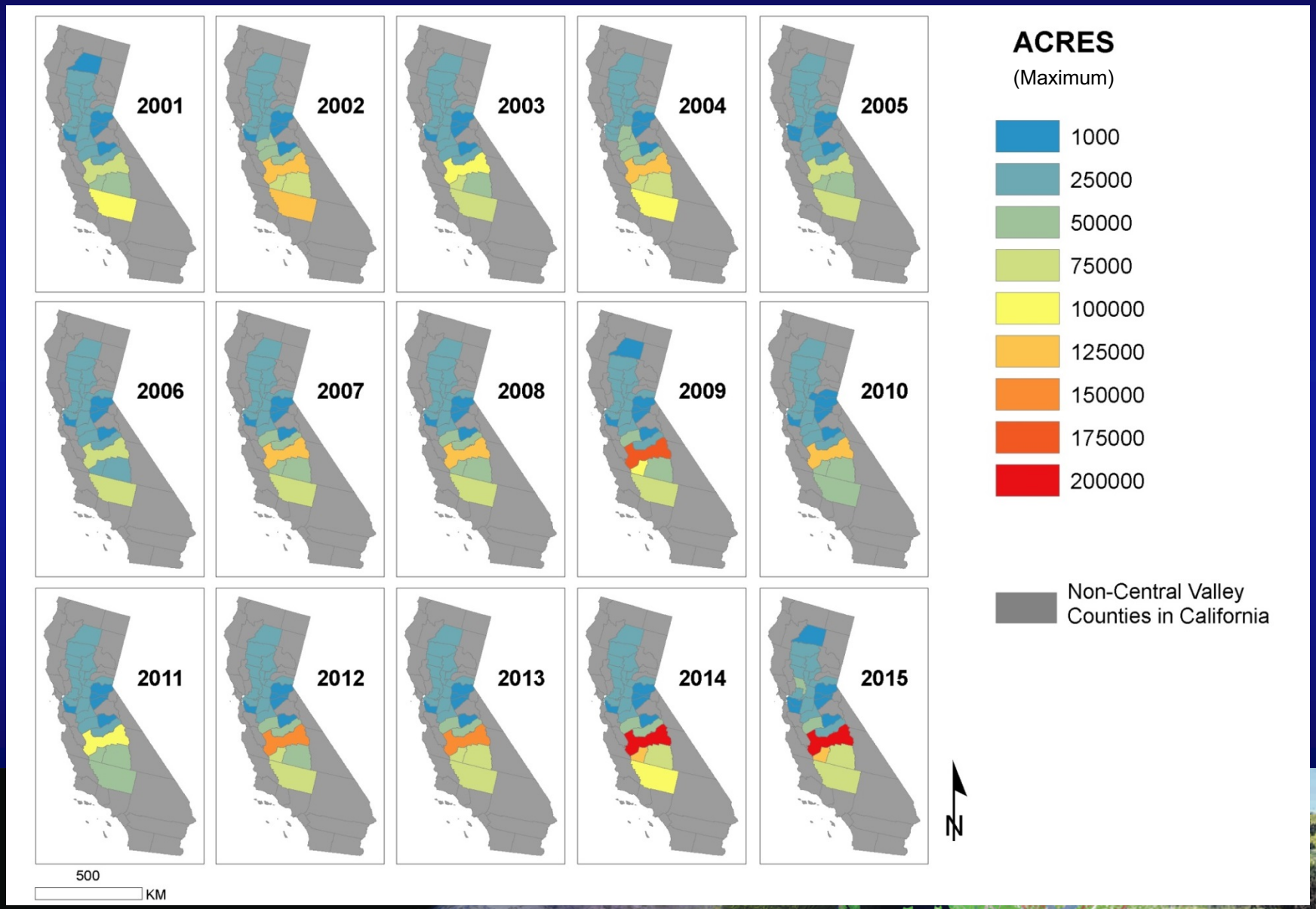
FANTA Total Fallowed Row Crops 2001 to 2014



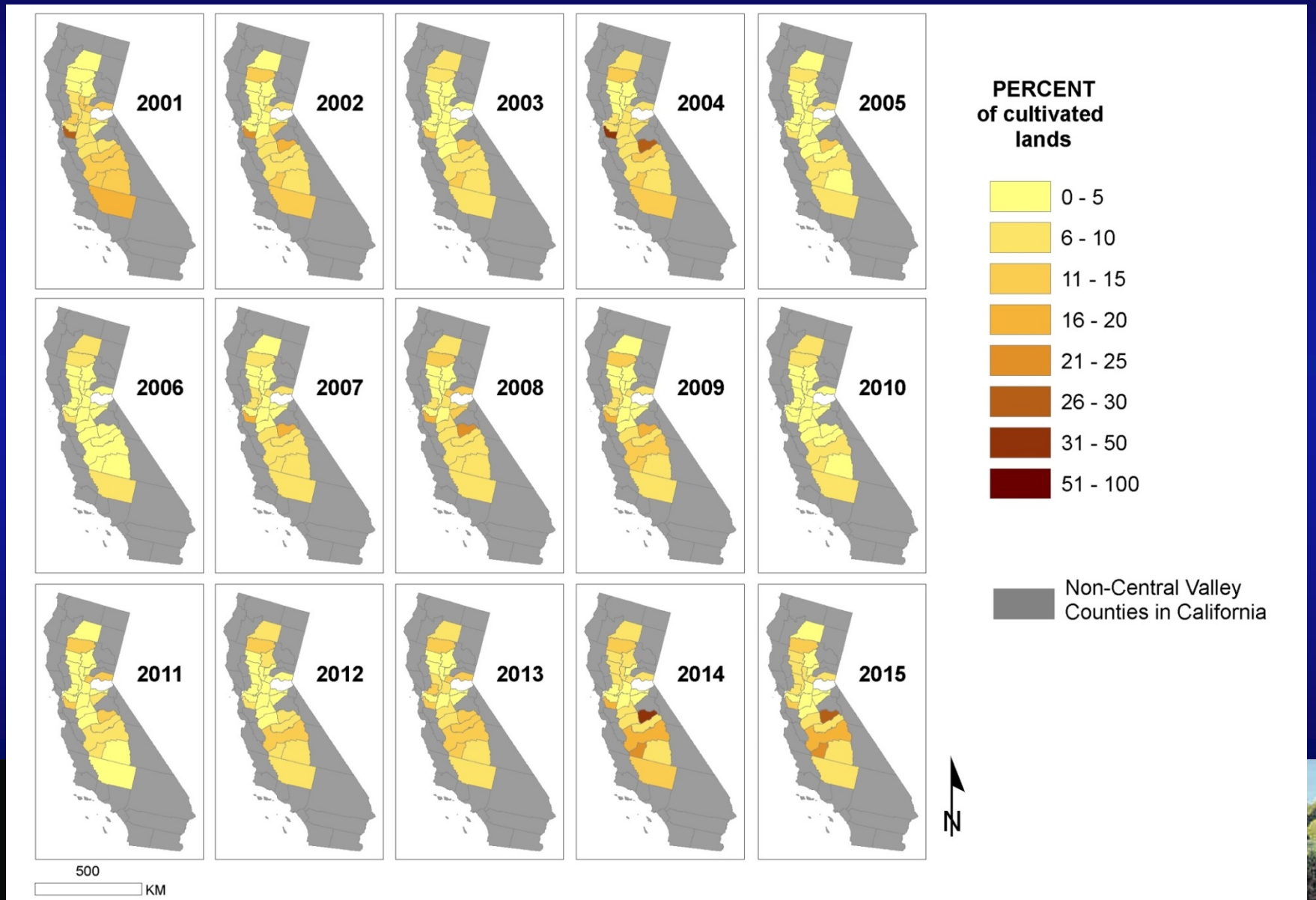
Percent of Cultivated land left Fallowed in California by Year. 1 percent ~ 80,000 hectares, based on the annual row crop mask derived from USDA CDL layers.

Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

FANTA Acres of Fallowed Cropland 2001-2015



FANTA Fallowed Cropland as Percent of Cultivated Land



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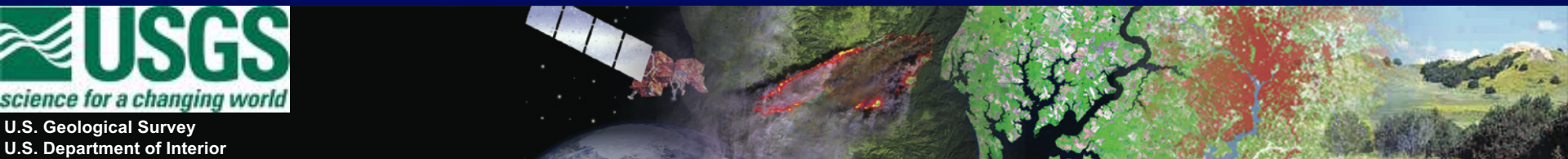

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U.S. Department of Interior

Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

Integrating Remote-Sensing and Ecological Forecasting into Decision-Support for Water and Wetland Management in the Central Valley of California: Optimizing Across Multiple Benefits

NASA ROSES: ECOLOGICAL FORECASTING

Collaborators include: Kristin Byrd (USGS), Austen Lorenz (USGS), Cynthia Wallace (USGS), Matt Reiter (Point Blue Conservation Science), Erin Conlisk (Point Blue Conservation Science)

Decision-makers: The Nature Conservancy, USFWS National Wildlife Refuges, Central Valley Partnership

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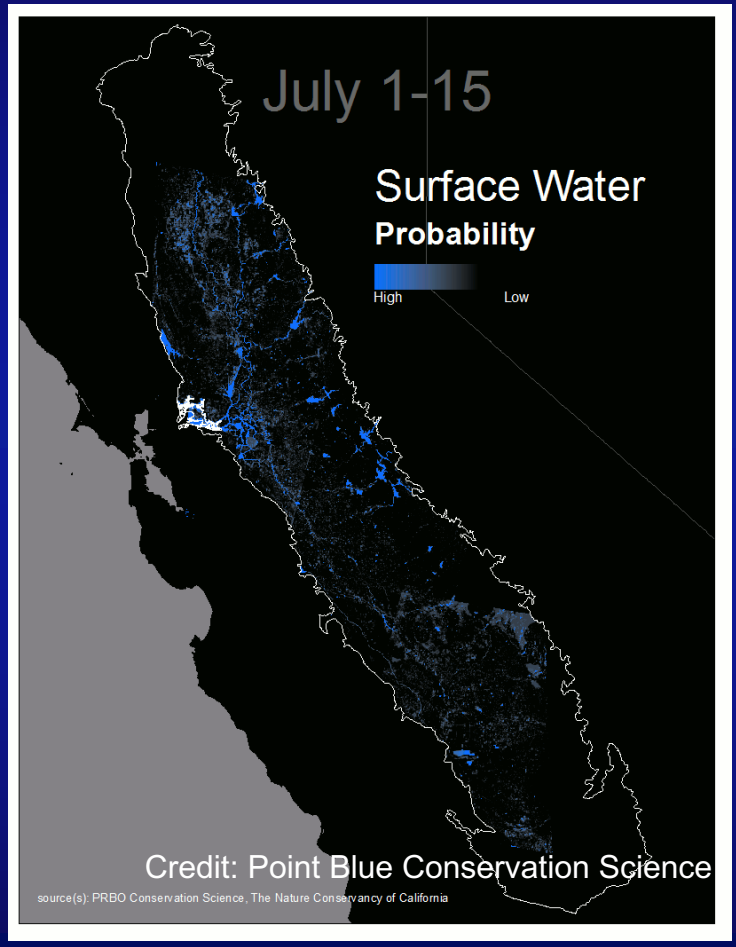
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

OBJECTIVE

Prioritize and strategically create an integrated network of wetland habitat on the landscape as part of large-scale coordinated conservation



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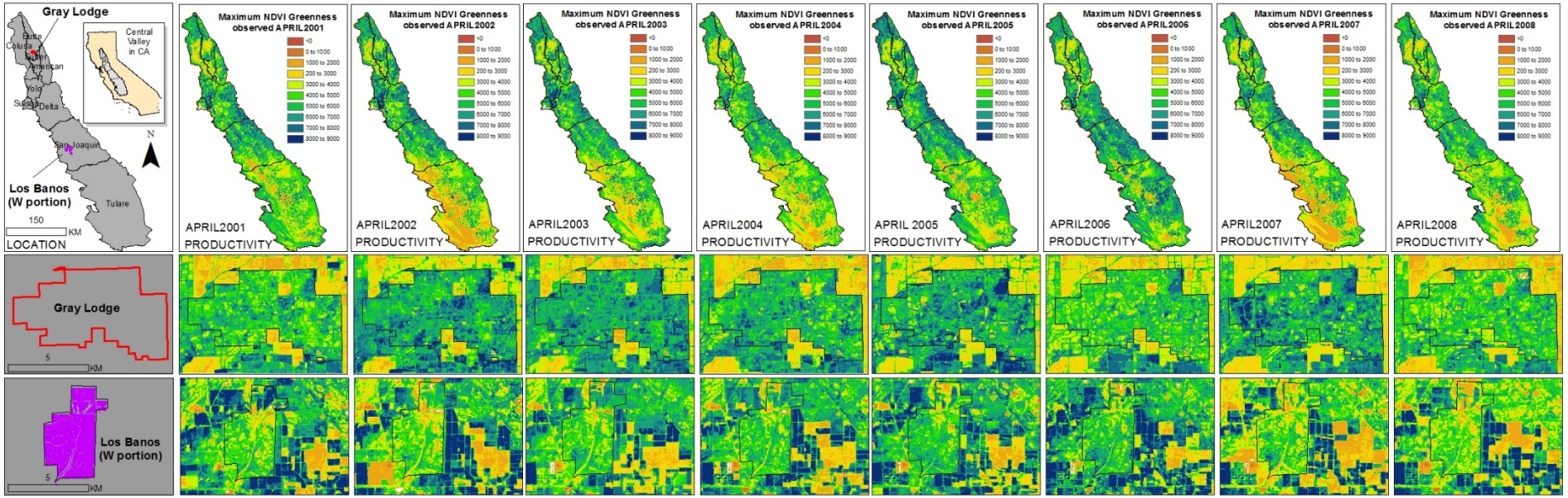
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

OBJECTIVE

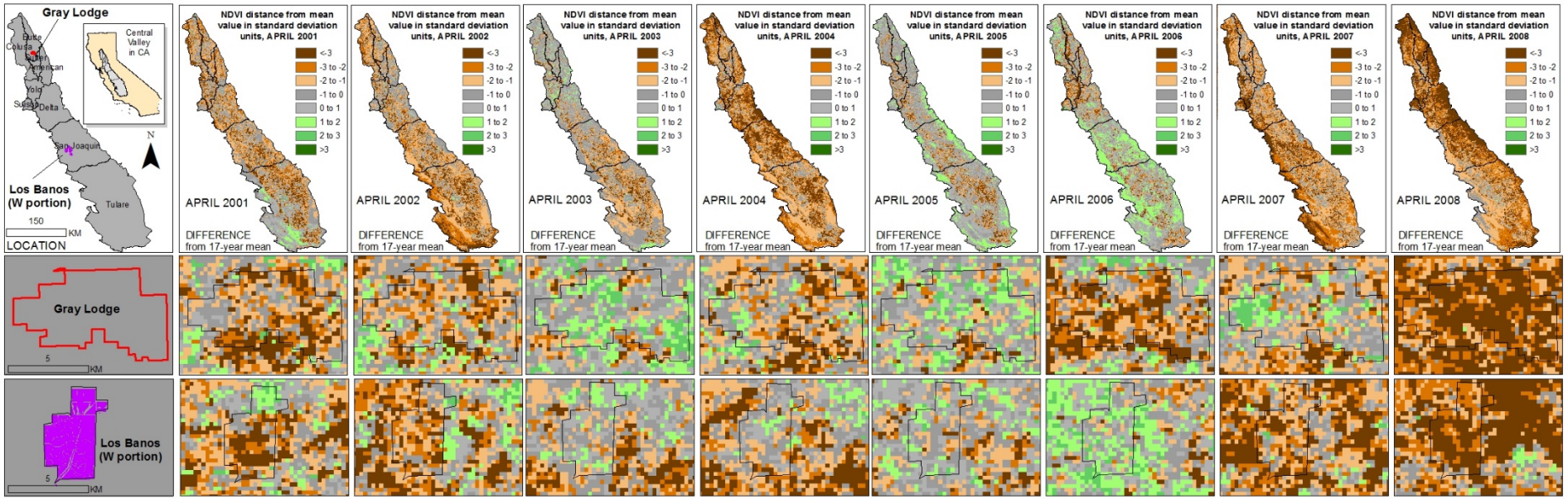
Optimize focal wetland-dependent species and habitats, biodiversity, spatio-temporal habitat connectivity, and groundwater recharge in the Central Valley

Credit: Point Blue Conservation Science

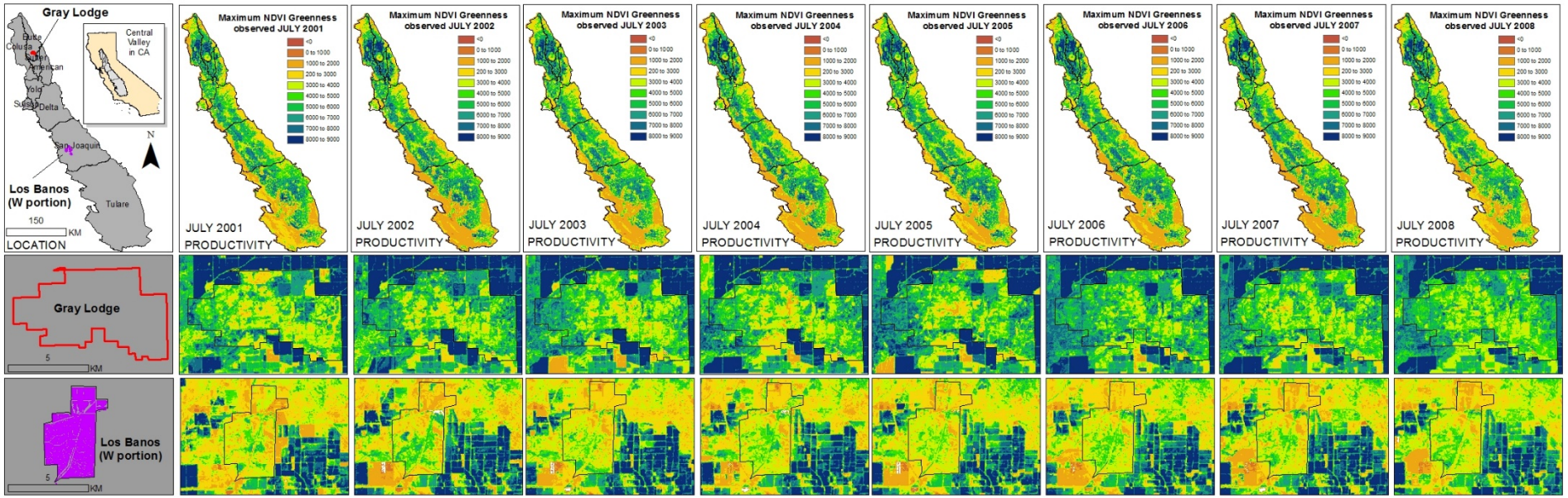
Maximum Greenness observed in April 2001 to 2008



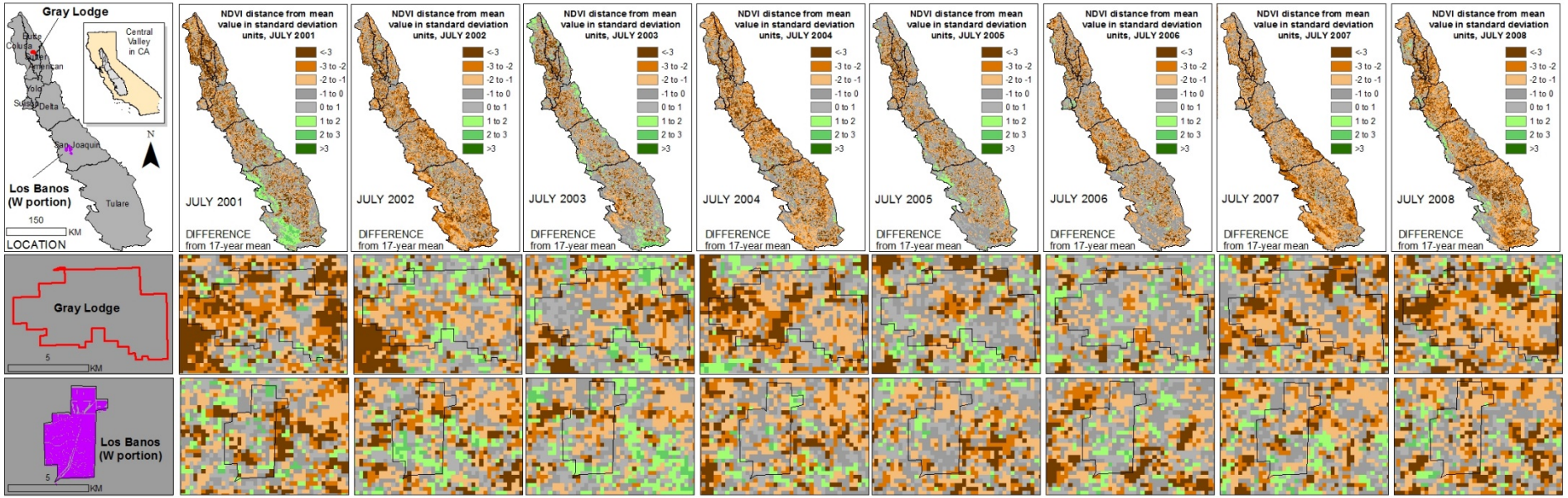
April Greenness Anomaly (SD distance from 17-year mean)



Maximum Greenness observed in July 2001 to 2008

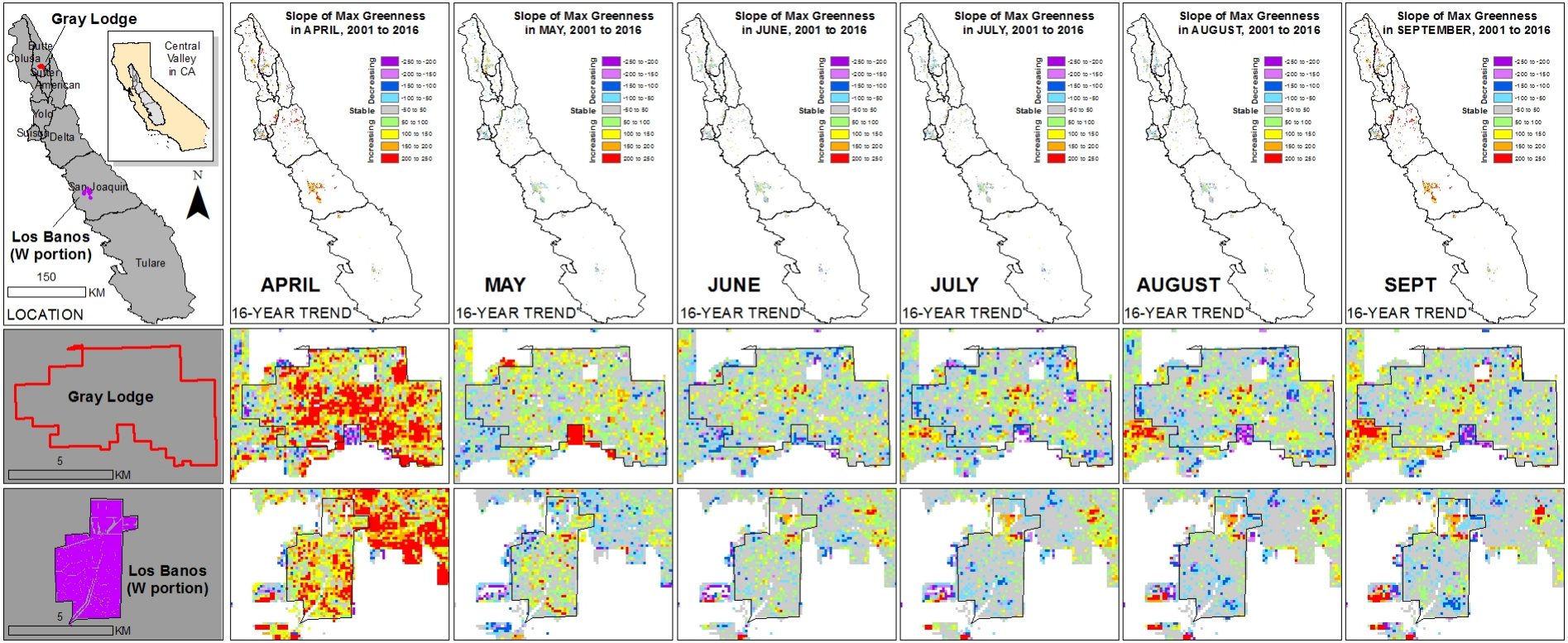


July Greenness Anomaly (SD distance from 17-year mean)



Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

Monthly Greenness Trends in Wetlands observed 2001 to 2016
Red = Increasing, Gray = Stable, Blue = Decreasing



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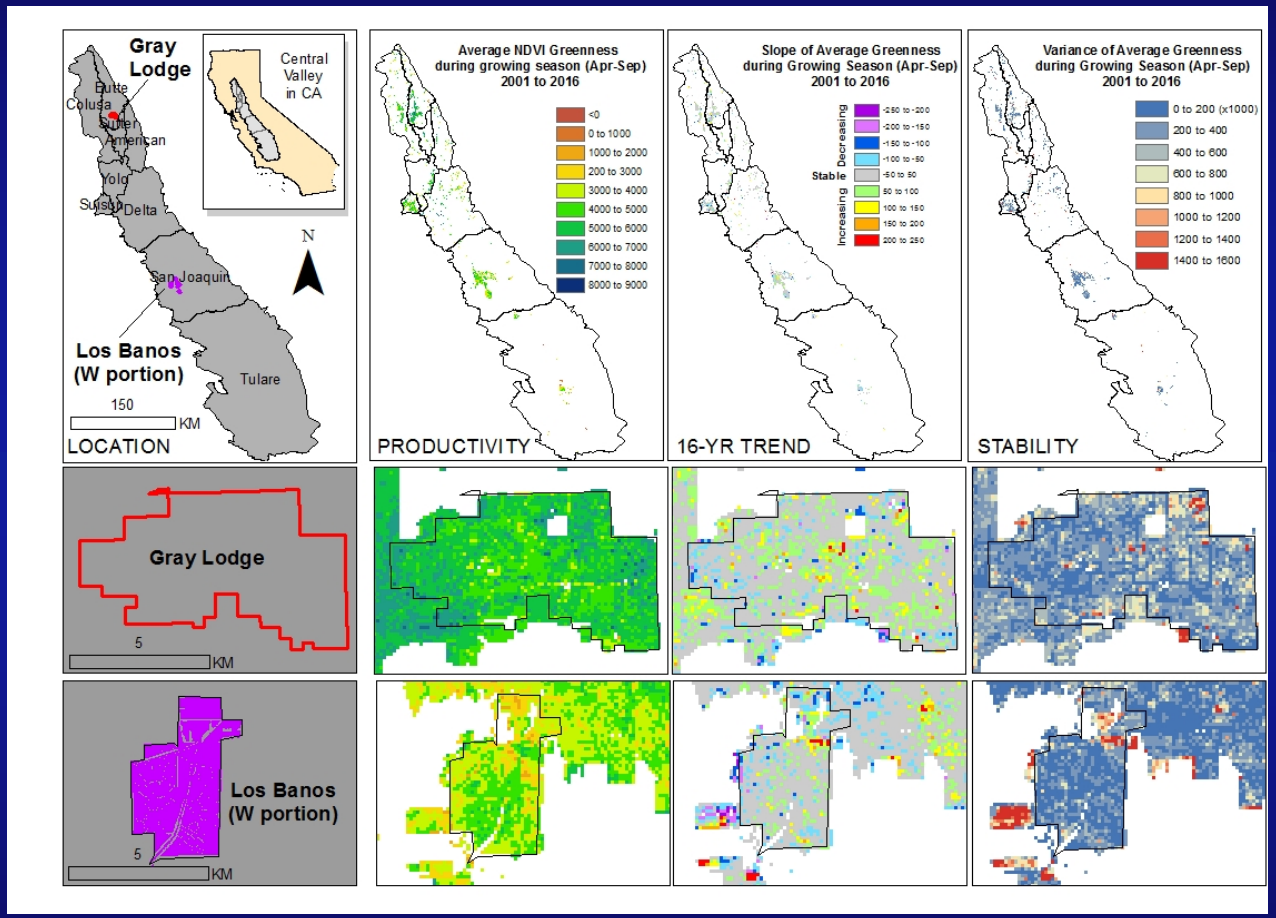
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

Greenness in Wetlands over the Growing Season (April through September)
16-year (2001 to 2016) Statistics



Location Mean Trend (Slope) Variance

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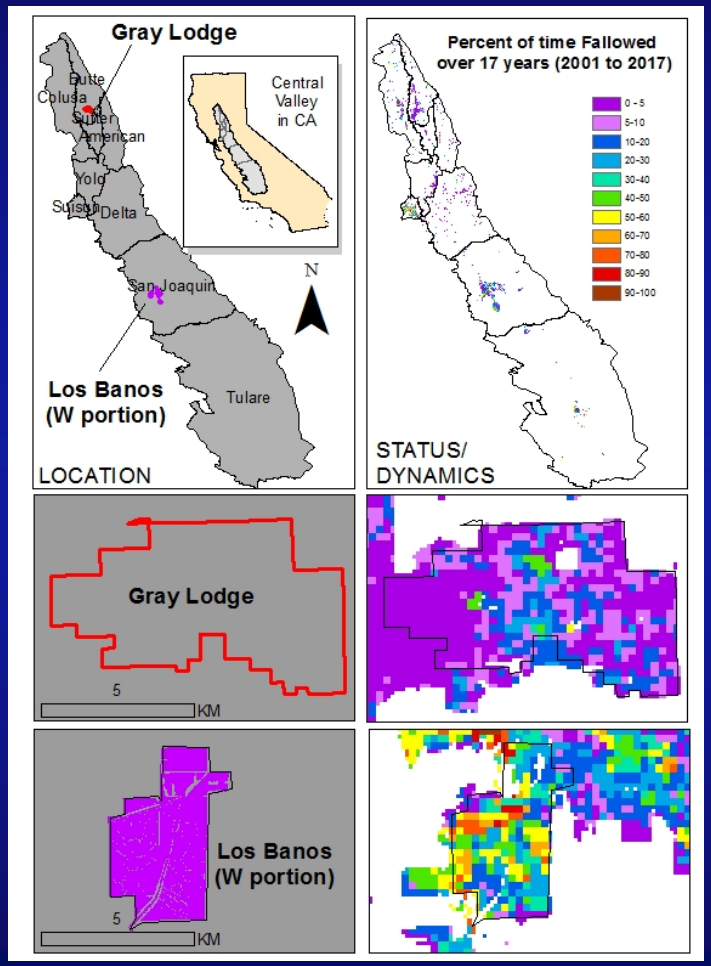
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

Wetlands behave like Irrigated Agriculture →
Evaluating Wetlands for % Fallowed 2001 to 2017



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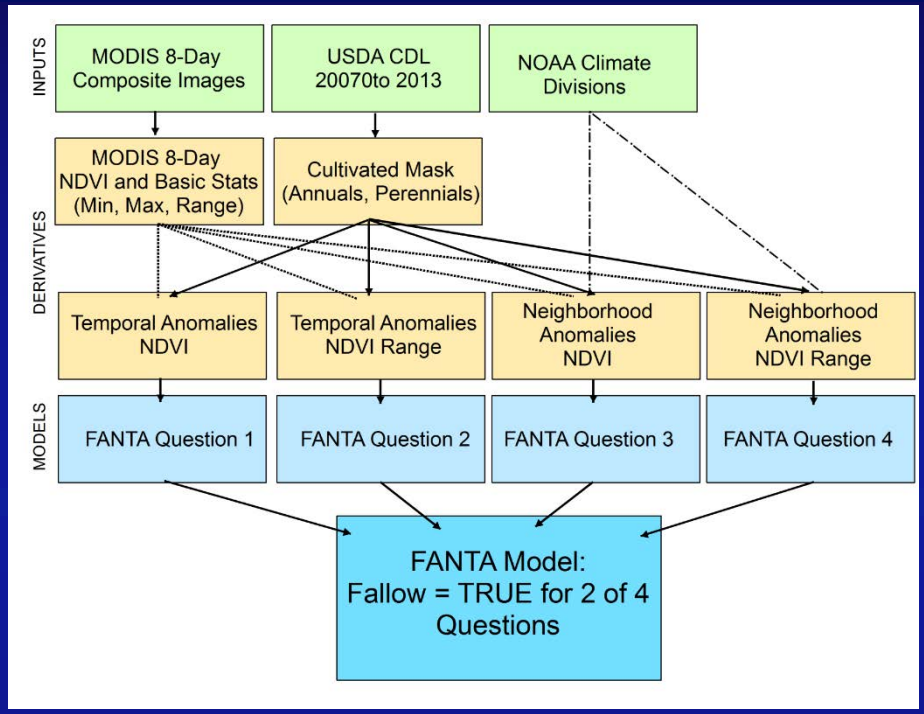
Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA)

FANTA Transferrable to any region, any VI; inputs easy to obtain

INPUTS:

1. Vegetation Index
2. Cultivated Mask Layer
3. Neighborhood Shapefile.



TRANSFERRABILITY:

Because FANTA compares current greenness to historical greenness and to neighbors, it automatically calibrates to the location:

1. “Does it LOOK like a crop based on its history?”
2. “Does it ACT like a crop based on its history?”
3. “Does it LOOK like a crop based on its neighbors?”
4. “Does it ACT like a crop based on its neighbors?”

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Thank you!

Publication:

Fallow-land Algorithm based on Neighborhood and Temporal Anomalies (FANTA) to map planted versus fallowed croplands using MODIS data to assist in drought studies leading to water and food security assessments.

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USGS Point Blue

2. FANTA model: 2 Temporal Questions

1. "Does it LOOK like a crop based on its history?"

   FALLOW = TRUE IF [TA_NDVI (May)< -3 and TA_NDVI (June)< -3 and TA_NDVI (July)< -3]

   RATIONALE: During the main growing season, the NDVI of a fallowed pixel will be consistently low compared to a "pure crop" signal for every month, based on its history.

2. "Does it ACT like a crop based on its history?"

   FALLOW = TRUE IF [TA_NDVIrange (May) < -3 and TA_NDVIrange (June) < -3 and TA_NDVIrange (July) < -3]

   RATIONALE: During the main growing season, the dynamic range of the NDVI in a fallowed pixel will be consistently low compared to the dynamics of a "pure crop" signal for every month, based on its history.

2. FANTA model: 2 Temporal Questions

1. "Does it LOOK like a crop based on its history?"

   FALLOW = TRUE IF [TA_NDVI (May)< -3 and TA_NDVI (June)< -3 and TA_NDVI (July)< -3] OR [TA_NDVI (April) < -3 and TA_NDVI (May) < -3 and TA_NDVI (June) < -3]}

   RATIONALE: During the main growing season, the NDVI of a fallowed pixel will be consistently low compared to a "pure crop" signal for every month, based on its history. Likewise, the NDVI of a fallowed pixel during each month of an early growing season will be consistently low.

2. "Does it ACT like a crop based on its history?"

   FALLOW = TRUE IF [TA_NDVIrange (May) < -3 and TA_NDVIrange (June) < -3 and TA_NDVIrange (July) < -3]

   RATIONALE: During the main growing season, the dynamic range of the NDVI in a fallowed pixel will be consistently low compared to the dynamics of a "pure crop" signal for every month, based on its history.

2. FANTA model: 2 Temporal Questions

1. "Does it LOOK like a crop based on its history?"

   FALLOW = TRUE IF [TA_NDVI (May)< -3 and TA_NDVI (June)< -3 and TA_NDVI (July)< -3] OR [TA_NDVI (April) < -3 and TA_NDVI (May) < -3 and TA_NDVI (June) < -3]}

   RATIONALE: During the main growing season, the NDVI of a fallowed pixel will be consistently low compared to a "pure crop" signal for every month, based on its history. Likewise, the NDVI of a fallowed pixel during each month of an early growing season will be consistently low.

2. "Does it ACT like a crop based on its history?"

   FALLOW = TRUE IF [TA_NDVIrange (May) < -3 and TA_NDVIrange (June) < -3 and TA_NDVIrange (July) < -3] OR [TA_NDVIrange (April) <-3 and TA_NDVIrange (May) <-3 and TA_NDVIrange (June)<-3]}

   RATIONALE: During the main growing season, the dynamic range of the NDVI in a fallowed pixel will be consistently low compared to the dynamics of a "pure crop" signal for every month, based on its history. Likewise, the dynamic range of the NDVI of a fallowed pixel during each month of an early growing season will be consistently low.

2. FANTA model: 2 Spatial Questions

3. "Does it LOOK like a crop compared to its neighbors?"

   FALLOW = TRUE IF {MAX [NDVI(April), NDVI(May), NDVI(June), NDVI(July)] < 0.8*MAX [MedianCD (April), MedianCD (May), MedianCD (June), MedianCD (July)]}

   RATIONALE: During the main growing season, the absolute NDVI value of a fallowed pixel will be consistently lower than the NDVI of planted ("pure crop") pixels within its climate division (CD) neighborhood for every month.

4. "Does it ACT like a crop compared to its neighbors?"

   FALLOW = TRUE IF {MAX [NDVIrange (April), NDVIrange (May), NDVIrange (June), NDVIrange (July)] <
   0.8 * MAX [MedianCD (April), MedianCD (May), MedianCD (June), MedianCD (July)]}

   RATIONALE: During the main growing season, the dynamic range of NDVI values during a month for a fallowed pixel will be consistently lower than the dynamic range of planted ("pure crop") pixels within its its climate division (CD) neighborhood for every month.