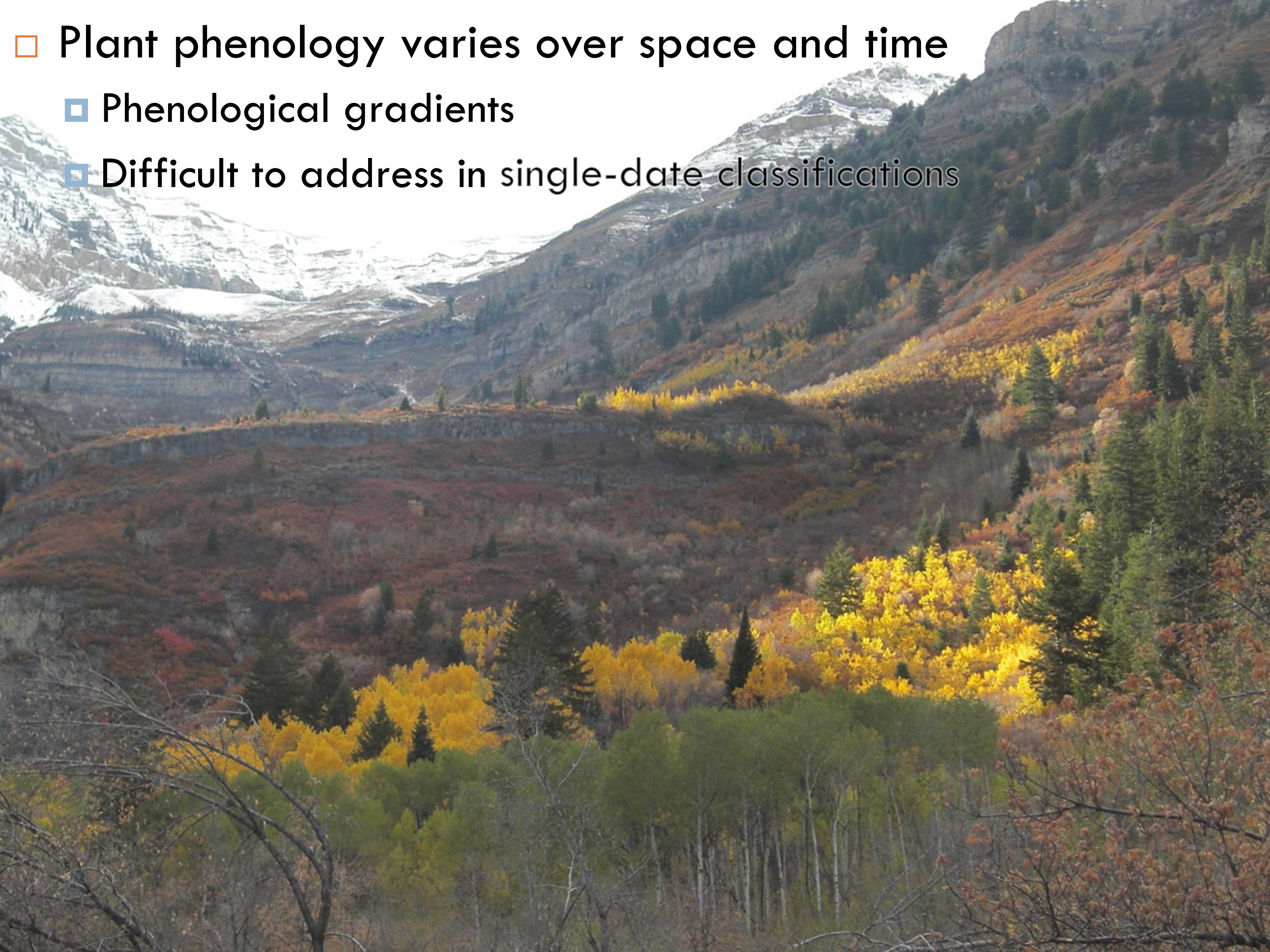
# SPECIES MAPPING USING A PHENOLOGICALLY INCLUSIVE MULTI-TEMPORAL SPECTRAL LIBRARY

Kenneth Dudley (Univ of Utah)
Philip Dennison (Univ of Utah)
Keely Roth (UC Davis)
Dar Roberts (UC Santa Barbara)

# Species Mapping and HyspIRI

- HyspIRI science goals include:
  - Mapping species and plant functional types (VQ1)
  - Seasonal cycles within functional types (VQ 2)
  - Interactions between functional types and energy/water/biogeochemical cycles (CQ4)
- Remote sensing of vegetation generally limited to single-date snapshots
- Species spectral response changes over time and space
- Single-date classifiers may not work in other regions or for other dates

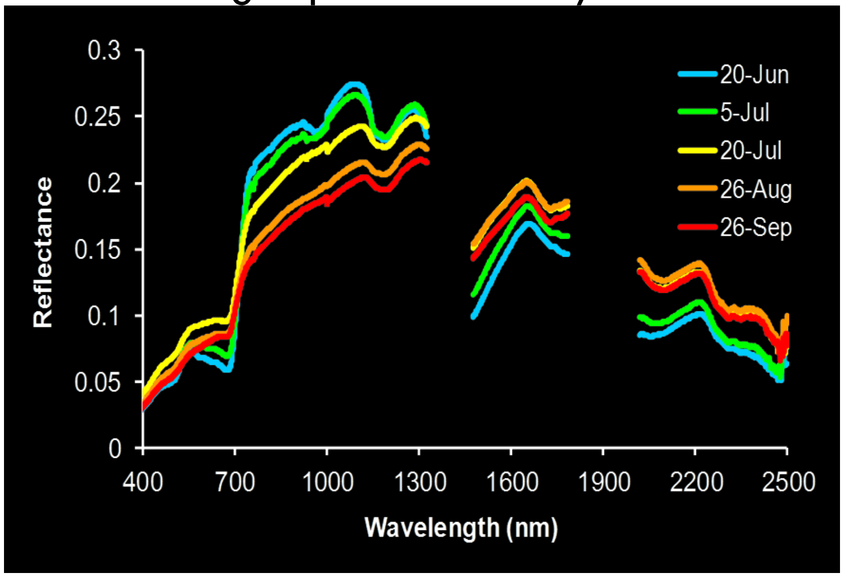
- Plant phenology varies over space and time
  - Phenological gradients
  - Difficult to address in single-date classifications



# Goals

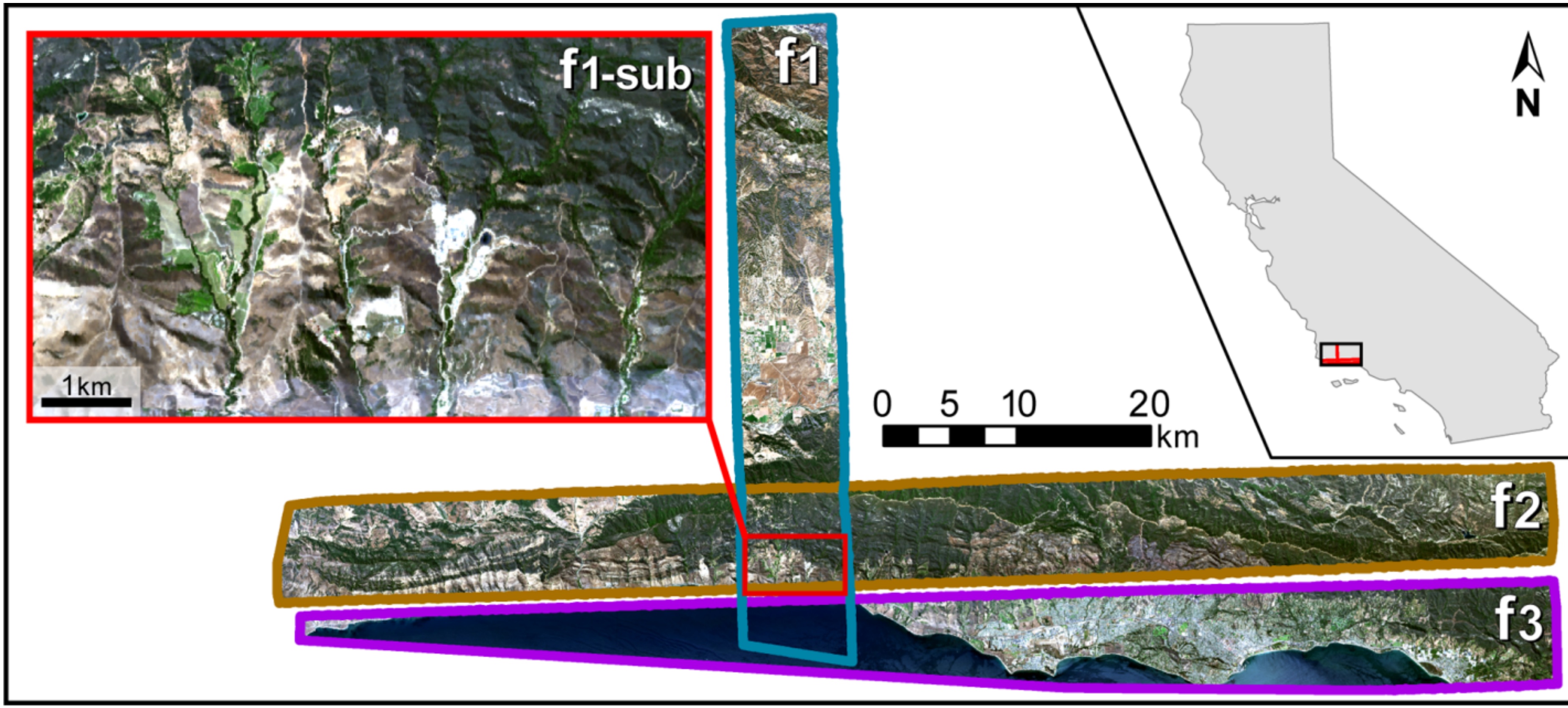
- Include phenological information in classification
- Expand capabilities for vegetation mapping at species level
- Create robust classifier which allows for spectral variability over space and time
- **Q**: Can a multi-temporal species classifier accurately classify single-date images while capturing phenological variability?

Sage spectra in one year




(Qi, Dennison, Spencer, & Riaño, 2012)

# Study Area



# AVIRIS Classic

- 5 dates from 2009
  - 10 Mar, 30 Mar, 8 May, 17 Jun, 26 Aug
- Training & Validation data from Roth, Dennison, and Roberts (2012)
  - 299 polygons with 21 classes
  - 75% or greater single-species composition
    Meentemeyer and Moody (2000)

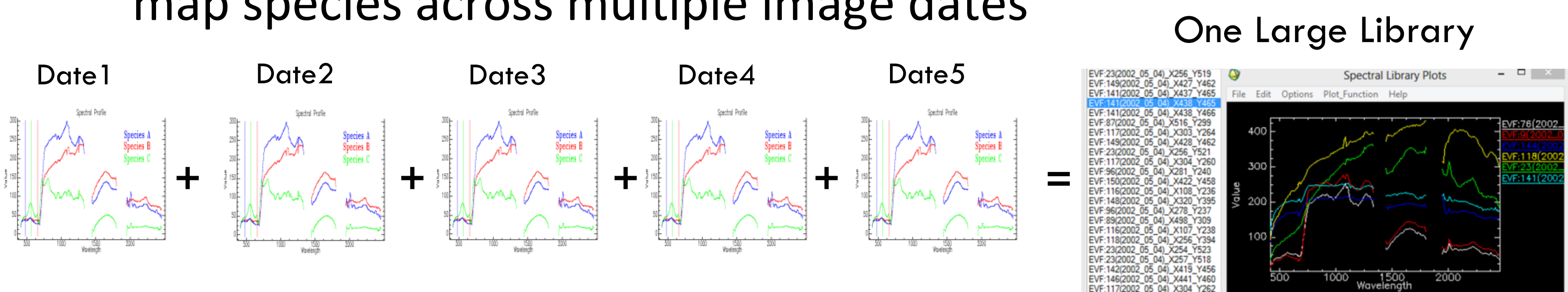
| Image Date | Swath | Pixel Size(m) | Solar Zenith(°) | Solar Azimuth(°) |
|---|---|---|---|---|
| 10 Mar | f1 | 16.0 | 43.2 | 210.9 |
| 10 Mar | f2 | 15.7 | 45.3 | 216.8 |
| 10 Mar | f3 | 16.4 | 47.3 | 221.5 |
| 30 Mar | f1 | 16.0 | 31.0 | 172.4 |
| 30 Mar | f2 | 15.8 | 31.4 | 194.2 |
| 30 Mar | f3 | 16.4 | 30.6 | 181.9 |
| 8 May | f1 | 11.1 | 17.6 | 183.4 |
| 8 May | f2 | 10.9 | 17.8 | 166.7 |
| 8 May | f3 | 11.5 | 18.4 | 201.6 |
| 17 Jun | f1 | 11.2 | 14.2 | 220.4 |
| 17 Jun | f2 | 11.1 | 12.2 | 205.2 |
| 17 Jun | f3 | 11.5 | 17.9 | 236.1 |
| 26 Aug | f1 | 11.3 | 27.7 | 212.0 |
| 26 Aug | f2 | 11.2 | 30.2 | 221.6 |
| 26 Aug | f3 | 11.7 | 32.8 | 228.5 |

# Data – Species/Classes

| Common Name | Class Name | Abbrev. | NP | km$^2$ |
|---|---|---|---|---|
| *Chamise* | *Adenostoma fasciculatum* | ADFA | 28 | 0.34 |
| *CA Sagebrush-Purple Sage* | *Artemisia californica-Salvia leucophylla* | ARCA-SALE | 14 | 0.28 |
| *Bigberry Manzanita* | *Arctostaphylos glauca/glandulosa* | ARGL | 15 | 0.27 |
| *Coyote Brush* | *Baccharis pilularis* | BAPI | 13 | 0.06 |
| *Black Mustard* | *Brassica nigra* | BRNI | 13 | 0.38 |
| *Buckbrush* | *Ceanothus cuneatus* | CECU | 13 | 0.11 |
| *Bigpod Ceanothus* | *Ceanothus megacarpus* | CEME | 20 | 0.31 |
| *Greenbark Ceanothus* | *Ceanothus spinosus* | CESP | 13 | 0.16 |
| *Orange/Lime/…* | *Citrus* spp. | CISP | 15 | 0.11 |
| *CA Buckwheat* | *Eriogonum fasciculatum* | ERFA | 13 | 0.28 |
| *Eucalyptus* | *Eucalyptus* spp. | EUSP | 15 | 0.27 |
| -- | Irrigated Grass (mixed species) | IRGR | 14 | 0.14 |
| "Grasslands" | Mediterranean annual grasses and forbs | MAGF | 12 | 0.6 |
| *Avocado* | *Persea Americana* | PEAM | 18 | 0.15 |
| *Gray Pine* | *Pinus sabiniana* | PISA | 15 | 0.21 |
| *CA Sycamore* | *Platanus racemosa* | PLRA | 14 | 0.3 |
| *Coast Live Oak* | *Quercus agrifolia* | QUAG | 5 | 0.06 |
| *Blue Oak* | *Quercus douglasii* | QUDO | 17 | 0.31 |
| -- | Rock | ROCK | 12 | 0.06 |
| -- | Soil | SOIL | 11 | 0.13 |
| *CA Bay Laurel* | *Umbellularia californica* | UMCA | 9 | 0.1 |
| | Total Polygons/Area | | 299 | 4.61 |

# Methods Overview

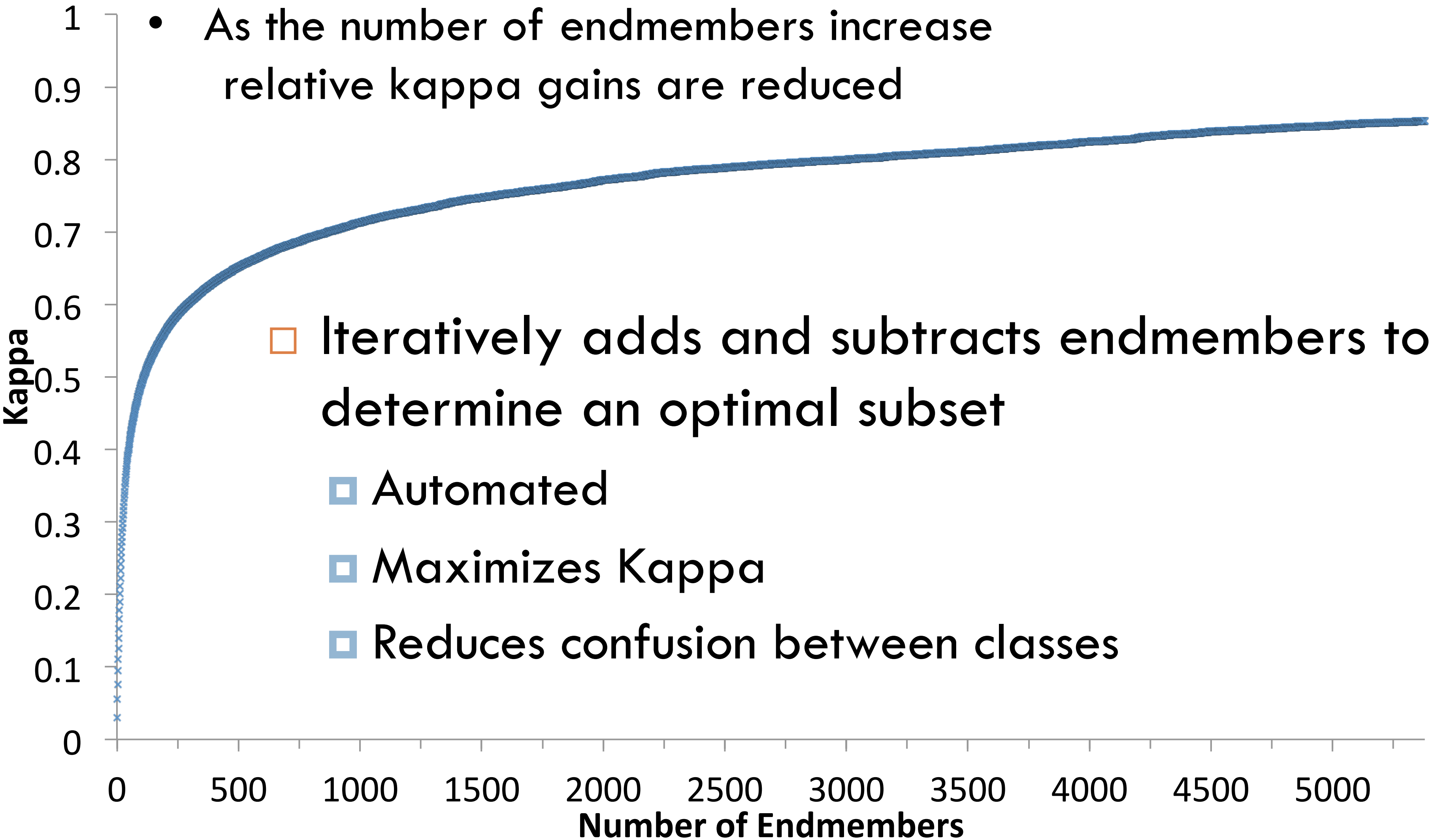
- Assess capabilities of a multi-temporal spectral library:
  - Extract spectral libraries from 5 AVIRIS dates
  - Select random spectra to separate into training/validation
  - Combine training spectra from all dates into a single library
  - Simplify library - Iterative Endmember Selection (IES)
  - Classify with Multiple Endmember Spectral Mixture Analysis (MESMA)
  - Compare classification of single-date and multi-date classifications
  - Examine how endmember dates from multi-temporal library map species across multiple image dates



# Iterative Endmember Selection (IES)

- As the number of endmembers increase relative kappa gains are reduced

- Iteratively adds and subtracts endmembers to determine an optimal subset
  - Automated
  - Maximizes Kappa
  - Reduces confusion between classes



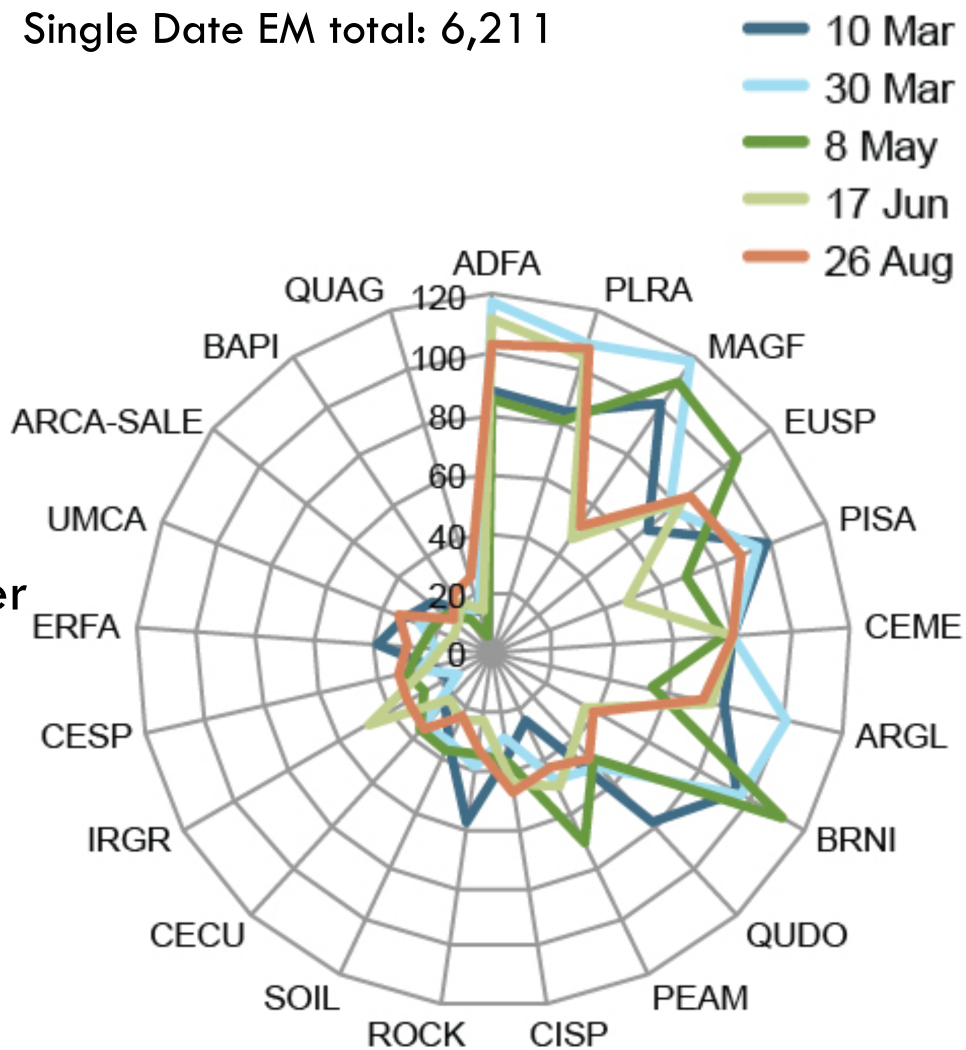
# Multiple Endmember Spectral Mixture Analysis (MESMA)

- MESMA (Roberts et al., 1998)
- Extends Spectral Mixture Analysis (SMA)
  - Can require pixels modeled to meet minimum spectral fit, fraction, and residual constraints.
- Allows for variability within a given class
- Allows for differences in brightness of spectra and provides a measure for fractional abundance

# Results – Multi-temporal Spectral Library

| Image Date | Training Spectra | IES EM | IES Kappa |
|---|---|---|---|
| 10-Mar | 9,868 | 1,365 | 0.826 |
| 30-Mar | 9,928 | 1,282 | 0.854 |
| 8-May | 9,878 | 1,311 | 0.835 |
| 17-Jun | 9,874 | 1,030 | 0.875 |
| 26-Aug | 9,879 | 1,223 | 0.847 |
| Multi-Temp | 49,427 | 5,379 | 0.855 |

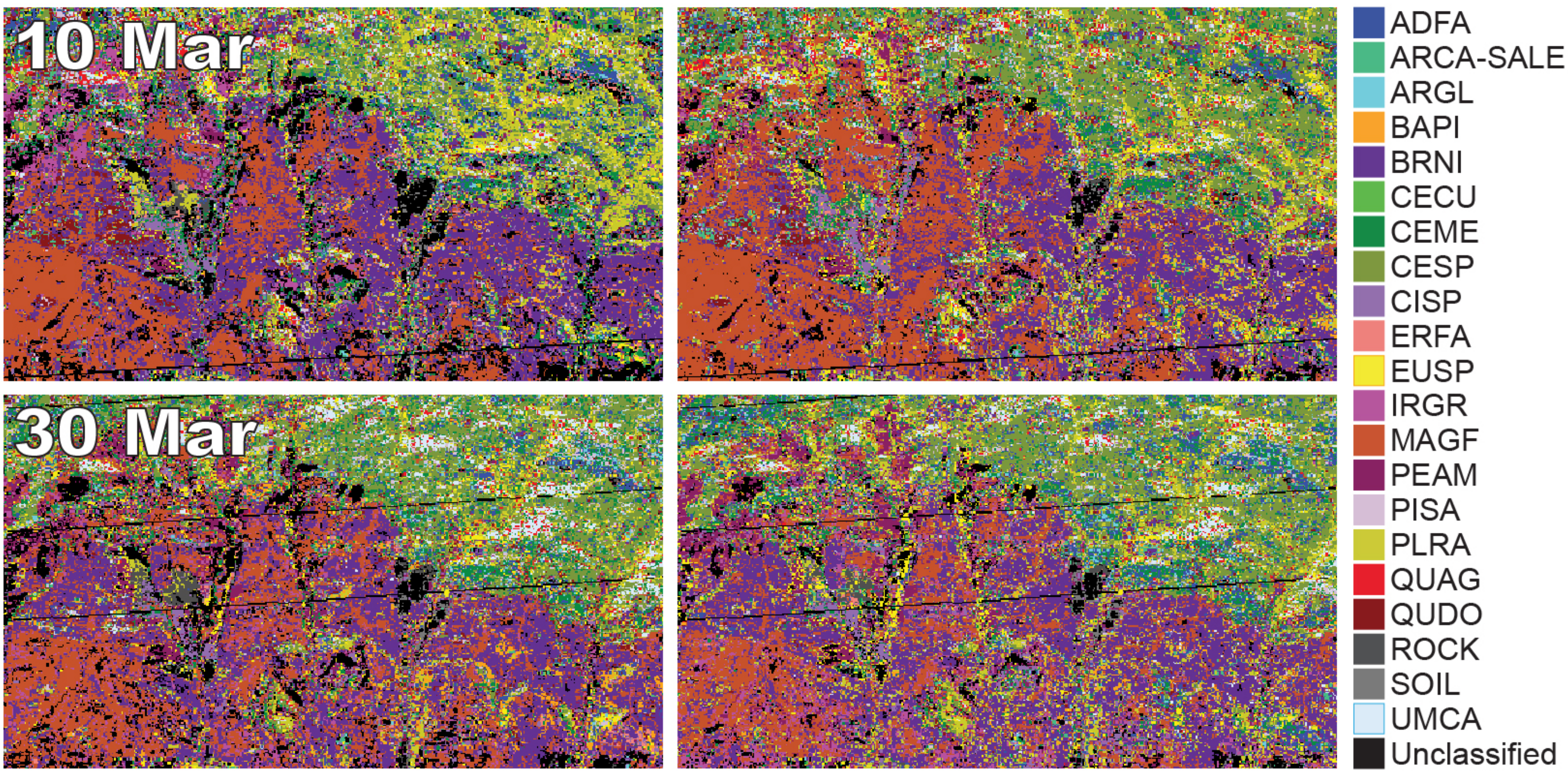
Single Date EM total: 6,211




- Multi-temporal library selects fewer endmembers
- ADFA required more late season endmembers
- MAGF, BRNI required more early season endmembers
- CEME nearly the same in all dates

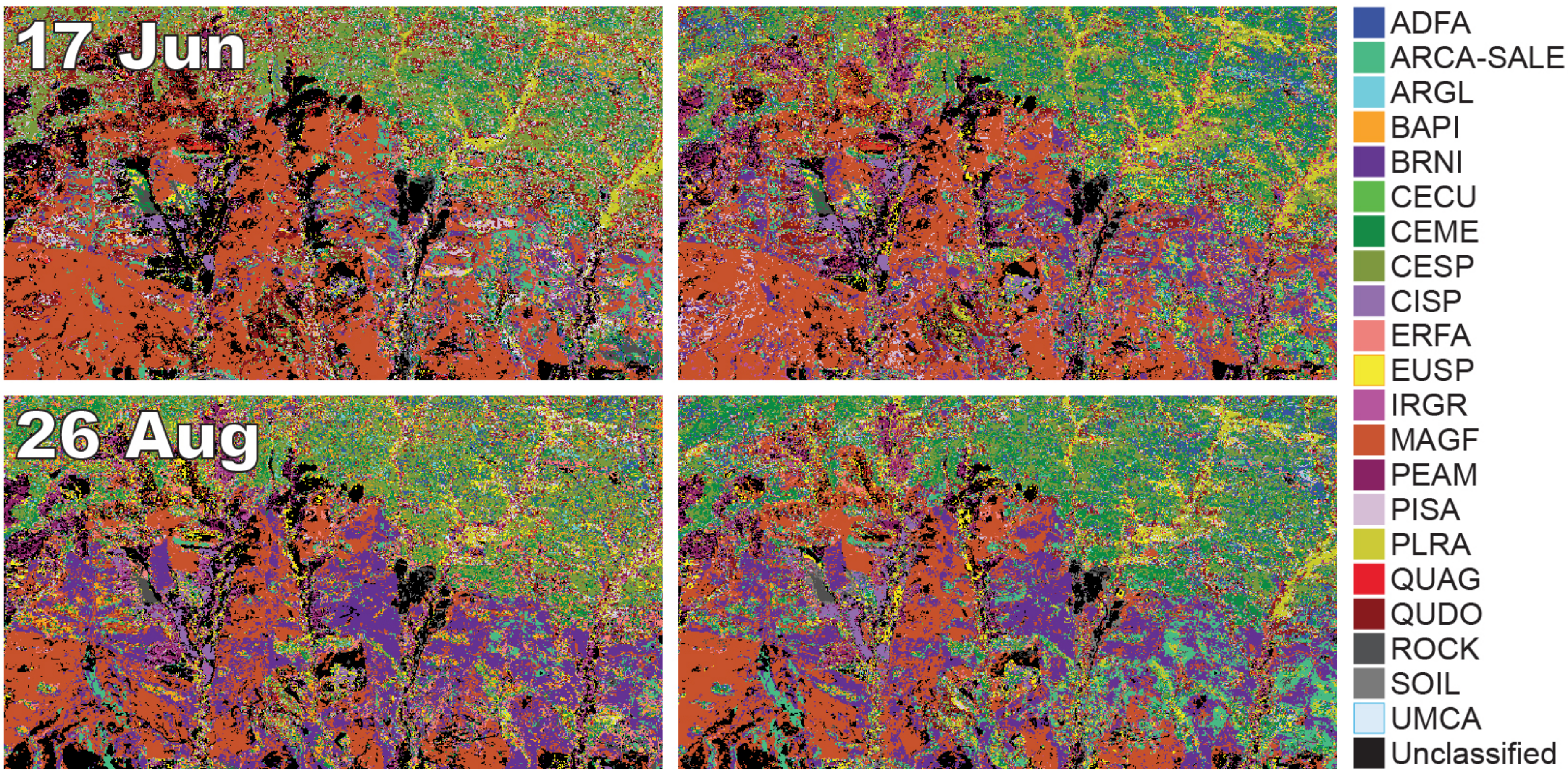
# Results – MESMA 10, 30 Mar

Same-date classification | Multi-temporal classification



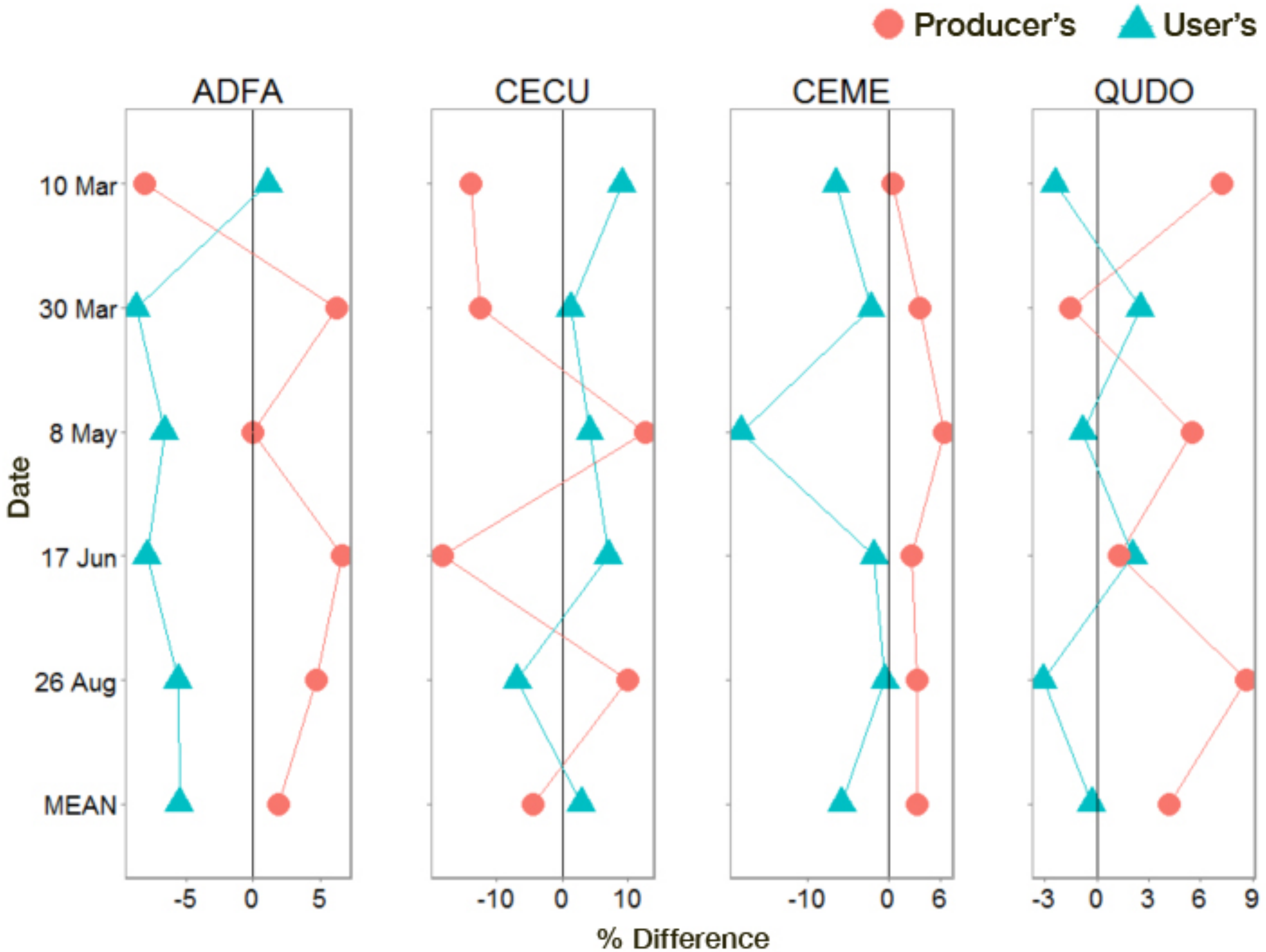
# Results – MESMA Jun/Aug

Same-date classification Multi-temporal classification



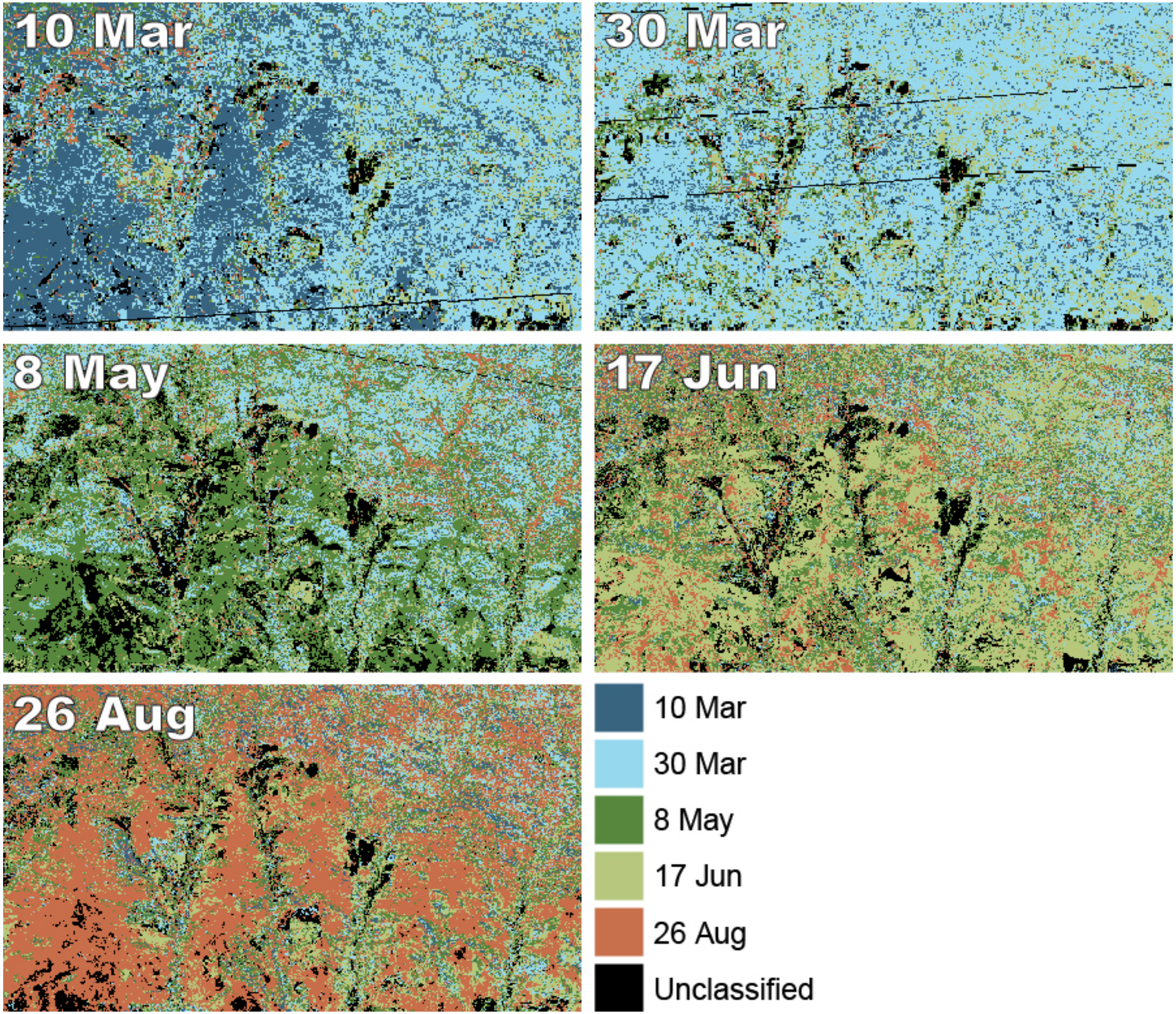
# Results – Overall Accuracy %

| | Same-Date | Multi-Temp | Difference |
|---|---|---|---|
| 10-Mar | 67.88 | 66.58 | -1.3 |
| 30-Mar | 70.49 | 70.54 | 0.05 |
| 8-May | 69.88 | 68.82 | -1.06 |
| 17-Jun | 76.44 | 75.46 | -0.98 |
| 26-Aug | 70.82 | 71.66 | 0.84 |

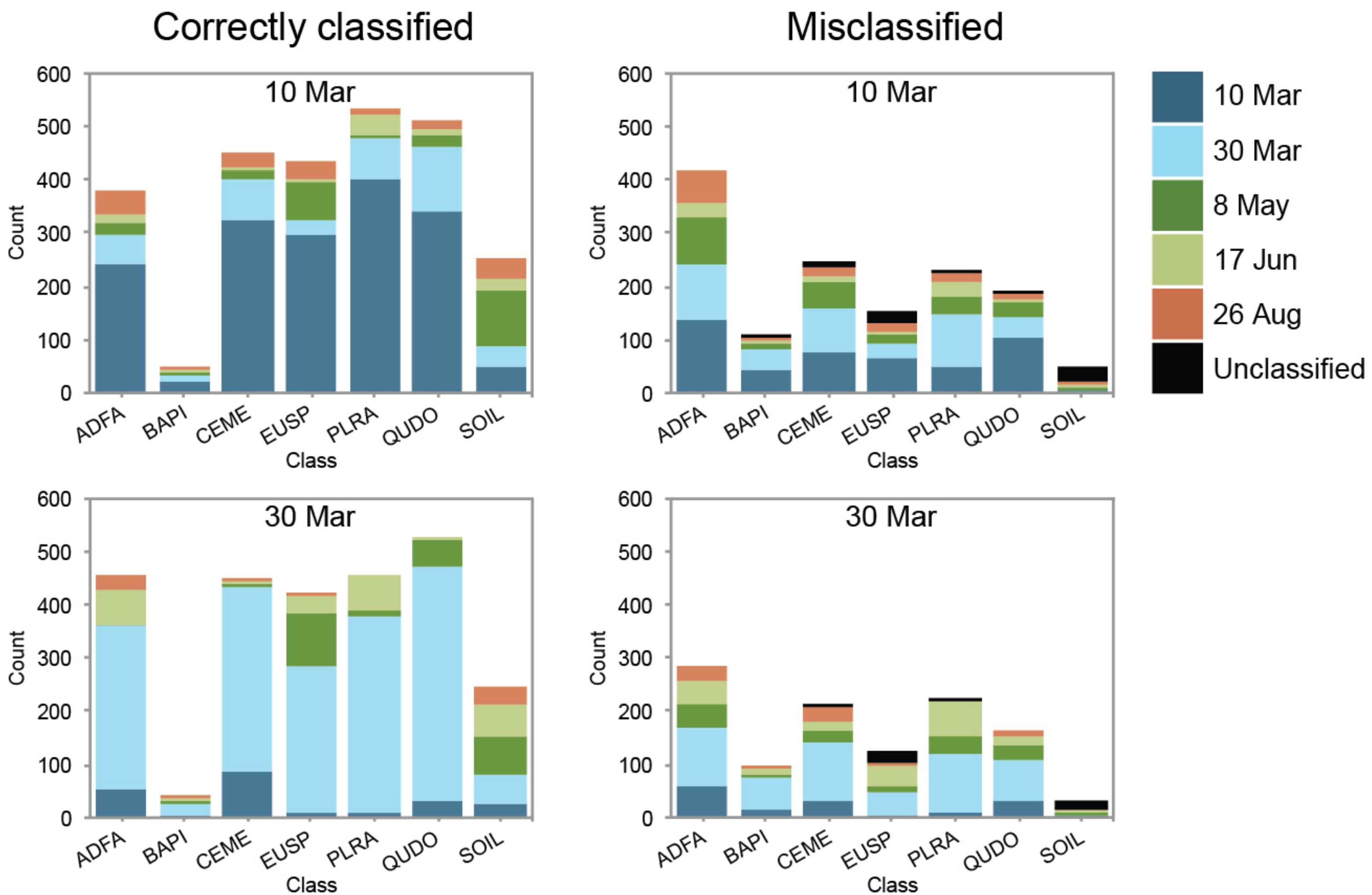


Producer's
User's
ADFA
CECU
CEME
QUDO
10 Mar
30 Mar
8 May
17 Jun
26 Aug
MEAN
Date
-5
0
5
-10
0
10
-10
0
6
-3
0
3
6
9
% Difference

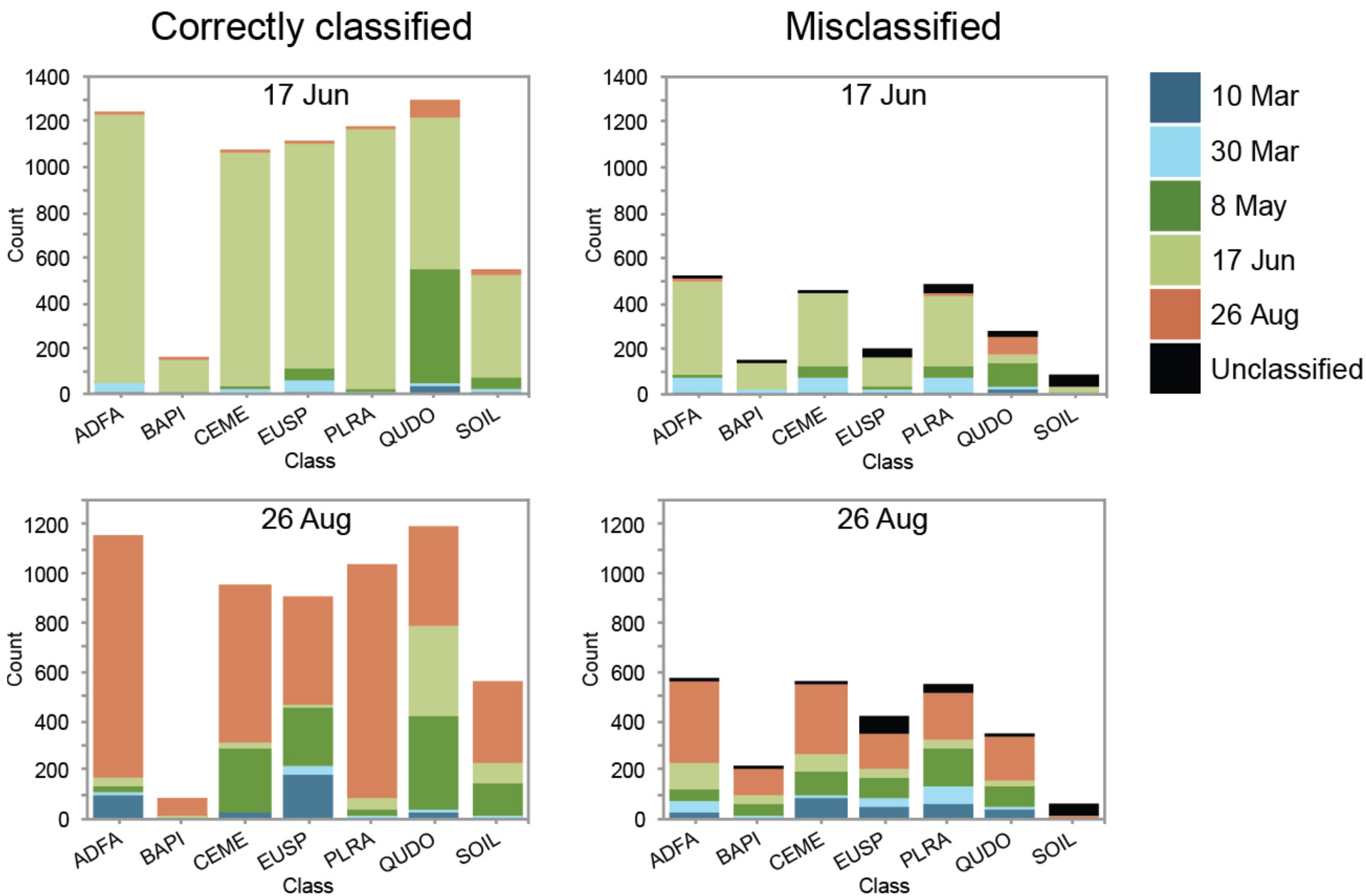
# Results – Multi-Temporal Analysis



# Results – Multi-Temporal Date Accuracy



# Results – Multi-Temporal Date Accuracy



# Summary

- A multi-temporal spectral library has similar overall performance compared with single-date libraries
- Accuracy within 1.3% of single-date libraries
  - ADFA, CEME, ERFA, MAGF, PEAM, QUDO generally increased in Producer's accuracy
  - BAPI, CECU, CESP, CISP, PISA, QUAG, UMCA generally decreased in Producer's accuracy
- Previous research found drought stress degraded species classification accuracy (Dennison & Roberts 2003a)
  - IES may be a good endmember selection technique for drought-stressed vegetation

# Discussion

- Phenology Applications
  - Phenological gradients (elevation, precipitation…)
  - Dominant image/species phenology
  - ID dates with greatest separability for target species
  - Identify short- & long-term variability in species phenology

# Future Directions

- Determine how this works between years
  - Use image dates not included in multi-temporal library
  - Classification accuracy inside and outside of date range
- Determine temporal density of endmembers needed for capturing phenological variability
- Test on different species and regions
- Further testing across larger elevation and precipitation gradients
- Use multi-temporal spectra to improve species classification

# Acknowledgements

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