Comparing Methods for Modeling Fractional Cover using Simulated HyspIRI Spectra

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Craig Daughtry	USDA Agricultural Research Service
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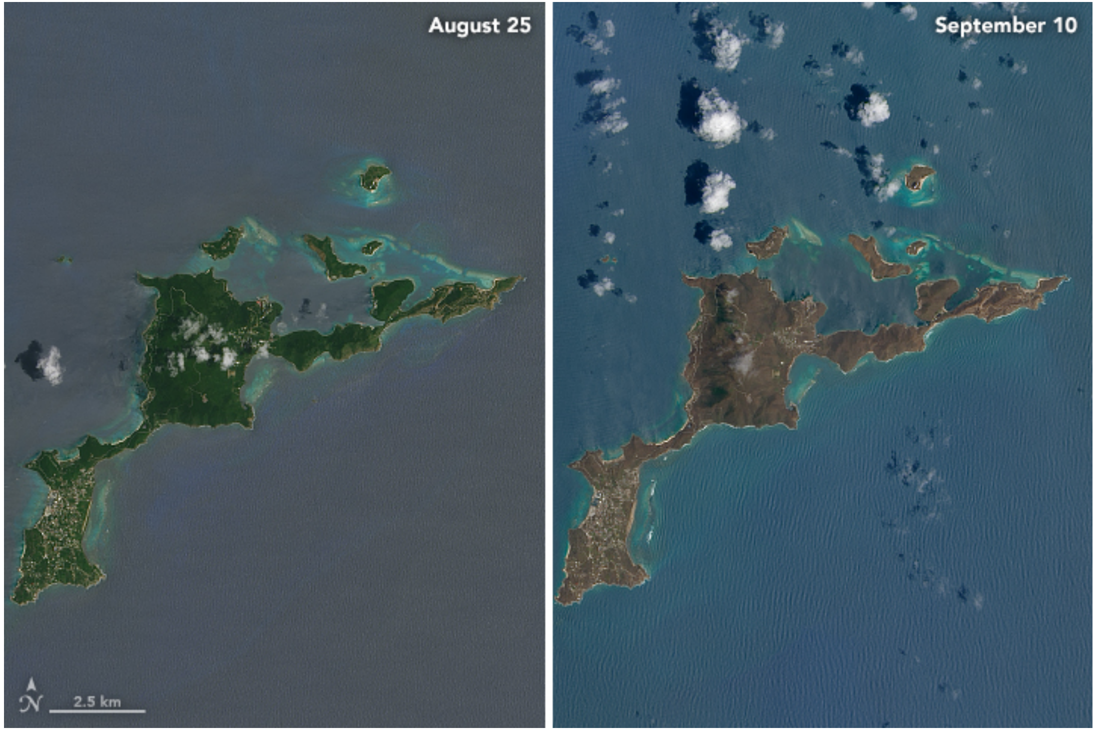
Erin Wetherley	UC Santa Barbara

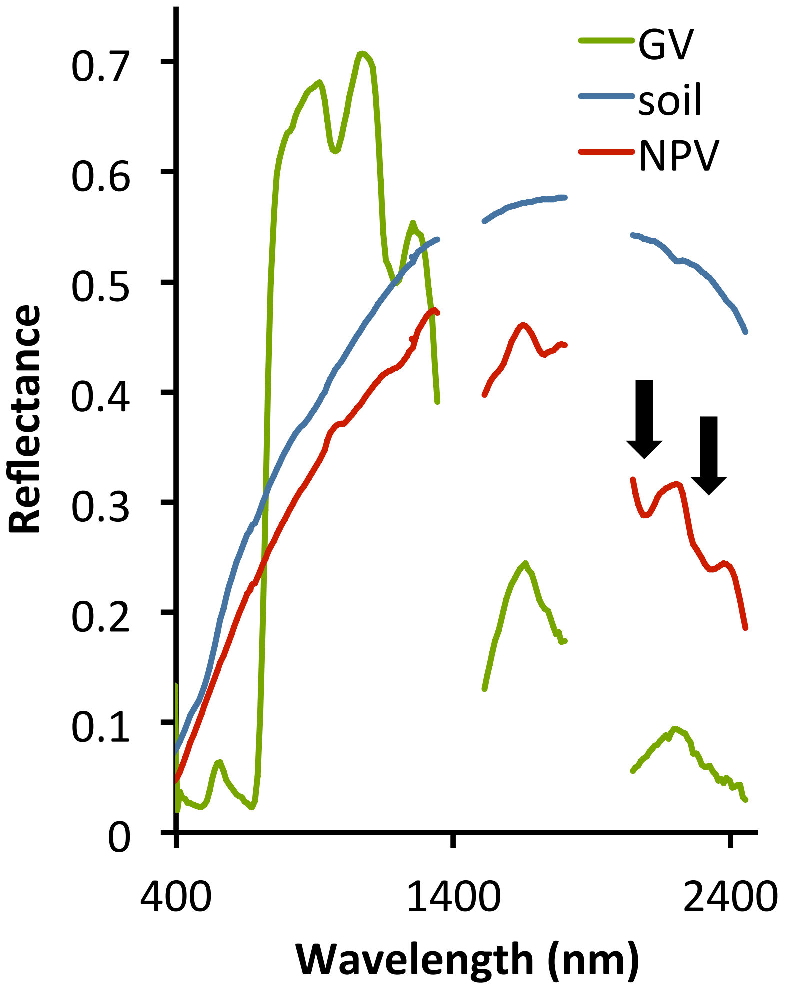
Fractional Cover

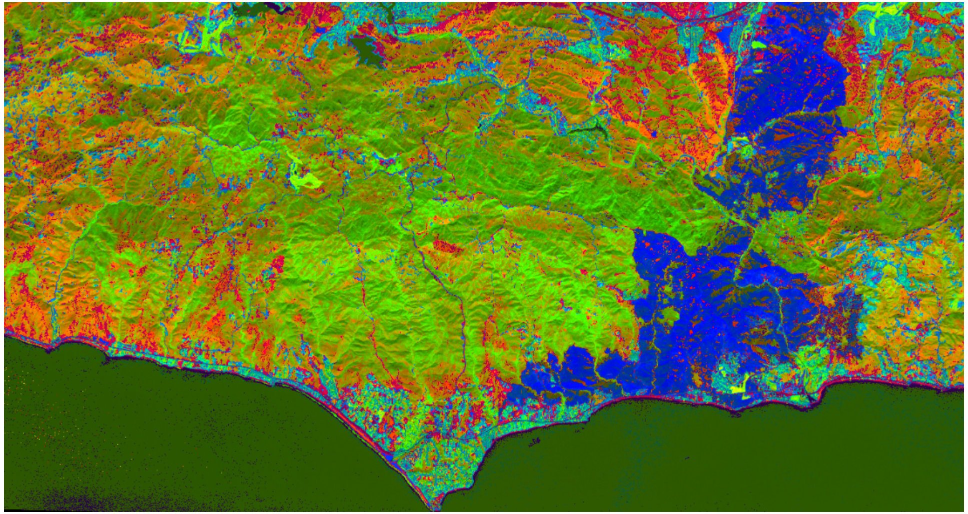
- Typically percent cover of green vegetation (GV), non-photosynthetic vegetation (NPV) and substrate within a pixel
- Importance:
  - GV: GPP, evapotranspiration, urban heat island
  - NPV: Senescence and mortality, wildfire danger
  - Soil: Erosion potential
  - All 3: Phenology, disturbance



OLI, Virgin Gorda (BVI) pre- and post-Irma (NASA Earth Observatory)

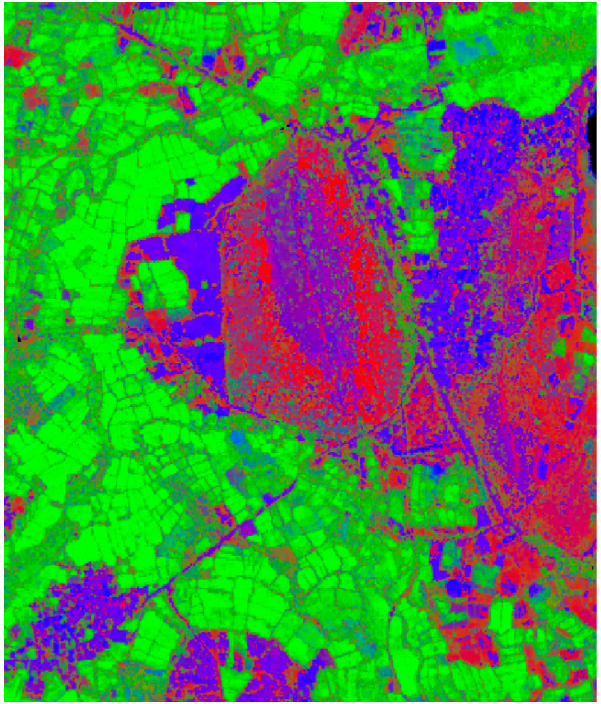
- GV is easily distinguishable from NPV and soil
- NPV is spectrally similar to soil, but is distinguishable using SWIR lignocellulose absorption





Fractional cover from 1996 AVIRIS data, Calabasas Fire (Dennison et al., 2000)

NPV GV Soil



Fractional cover from AVIRIS-NG India campaign (Ardilla et al., 2017)

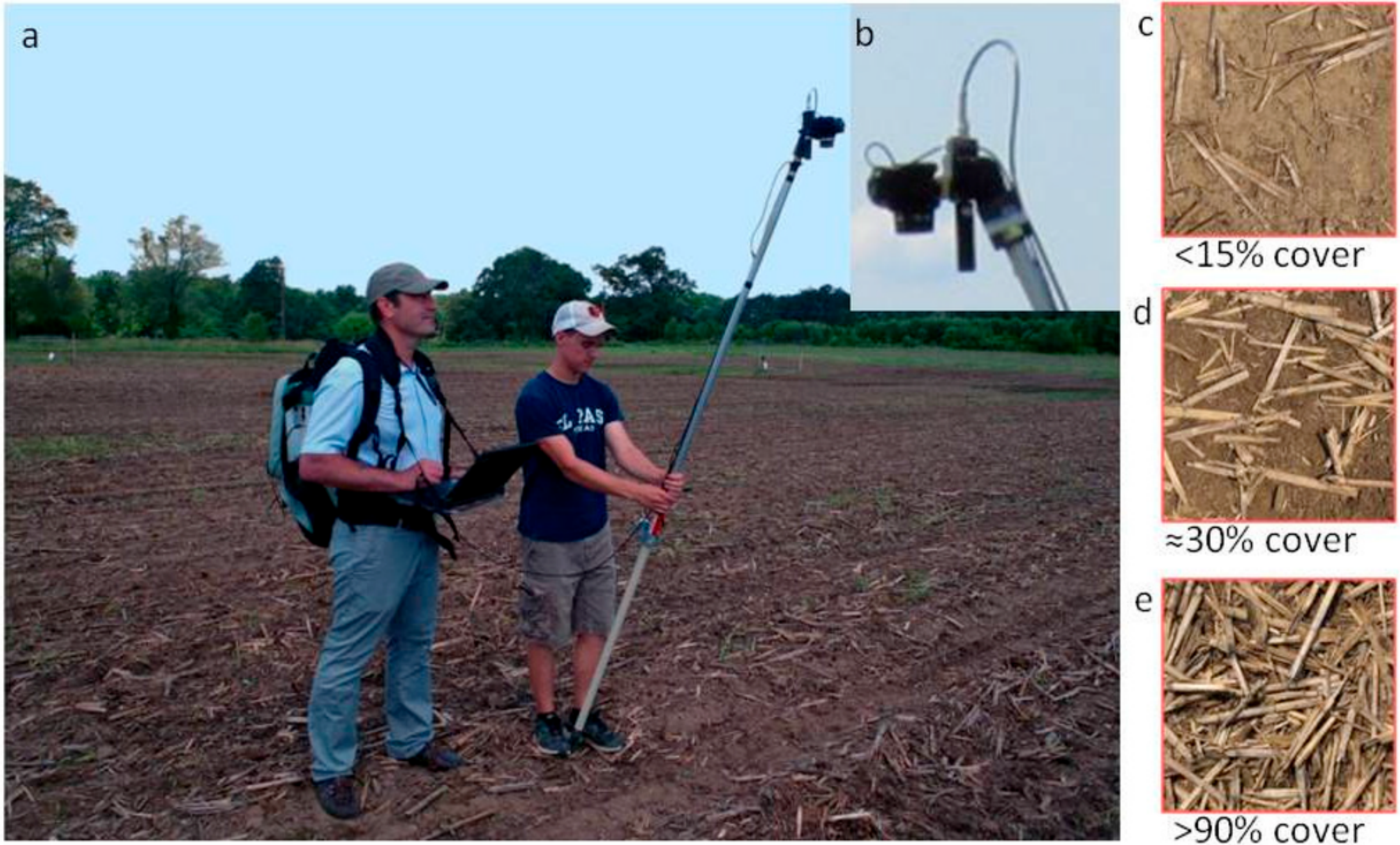
- Algorithms and applications have advanced, but validation is still very limited
- What is the uncertainty in fractional cover estimates?
- Which algorithms are most promising for estimating fractional cover as we move toward global satellite imaging spectroscopy?

Goals

1. Gather field spectra with associated fractional cover measurements from as many collaborators as possible
2. Create simulated HyspIRI spectra
3. Compare fractional cover mapping algorithms
4. Assess fractional cover accuracy for each algorithm

Datasets

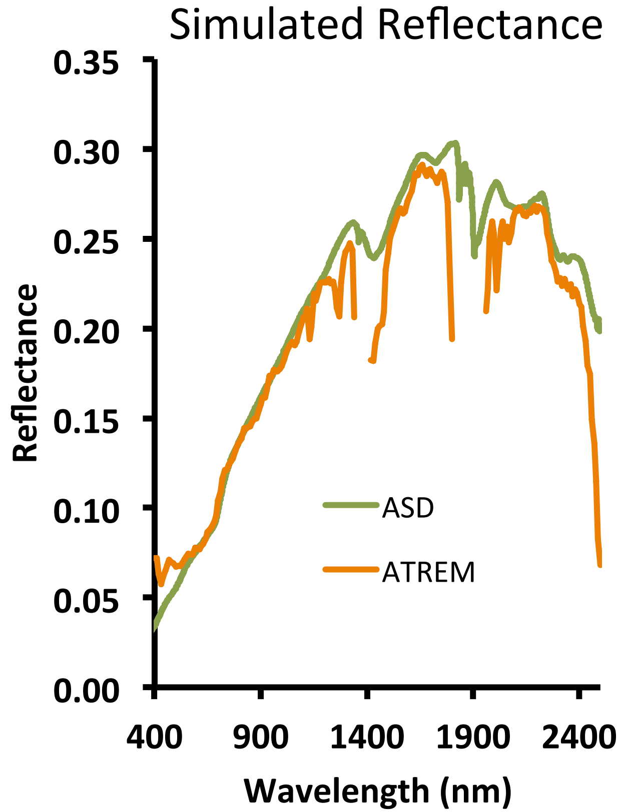
	NPV	GV	Soil
Daughtry & Hunt (2008) • 600 field spectra from 7 agricultural sites in Maryland • Fractional cover estimated using photo sampling	X	X	X
Kokaly • 19 field spectra from Wyoming rangeland plots • Shrub cover measured; grass, forb & soil cover visually estimated; aggregated to NPV/GV/Soil	X	X	X
Meerdink, Wetherley, Gader, & Roberts • 129 time series spectra from 12 grassland plots near Santa Barbara • Fractional cover estimated using photo classification	X	X	
Quemada & Daughtry (2016) • 410 field spectra from Maryland agricultural plots at single site • Experiments added moisture to mixtures of soil and crop residue • Fractional cover estimated using photo sampling	X		X



From Quemada & Daughtry (2016)

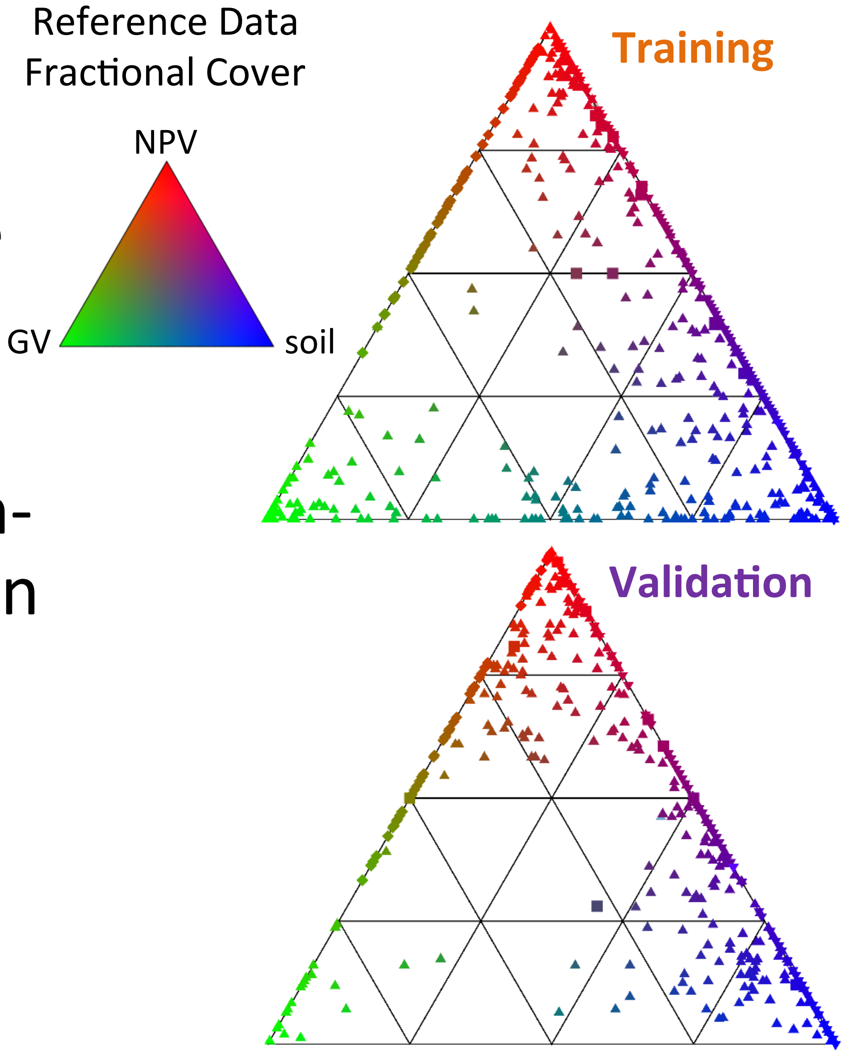
Simulating HyspIRI VSWIR Spectra

1. Reflectance field spectra were convolved to 10 nm band spacing and FWHM
2. Reflectance spectra were converted to simulated radiance using a MODTRAN-generated lookup table
3. Noise was added using a radiance-dependent HyspIRI VSWIR noise function
4. David Thompson retrieved reflectance from the radiance spectra using ATREM



Training and Validation Spectral Libraries

- ▲ *Daughtry spectra*: split by site (345/255)
- ■ *Kokaly spectra*: (9/10)
- ◆ *Meerdink et al. spectra*: green-up period → training, dry-down period → validation (72/57)
- ▼ *Quemada spectra*: split by experiment, soil moisture > 60% excluded (214/102)



Fractional Cover Modeling

GV	
NDVI	Normalized difference vegetation index
SAVI	Soil-adjusted vegetation index
EVI	Enhanced vegetation index
NDII	Normalized difference infrared index (SWIR2)
MESMA	Multiple endmember spectral mixture analysis
SFA	Spectral feature analysis (Kokaly & Skidmore)
PLS	Partial least squares regression

NPV	
CAI	Cellulose absorption index (Daughtry 2001)
CAI2	Cellulose absorption index (Serbin et al 2009)
hSINDRI	Hyperspectral SWIR normalized residue index
LCA	ASTER ligno-cellulose absorption index
MESMA	
SFA	
PLS	

Soil
$1-(GV_{NDVI} + NPV_{CAI2})$
$1-(GV_{SFA} + NPV_{SFA})$
MESMA
PLS

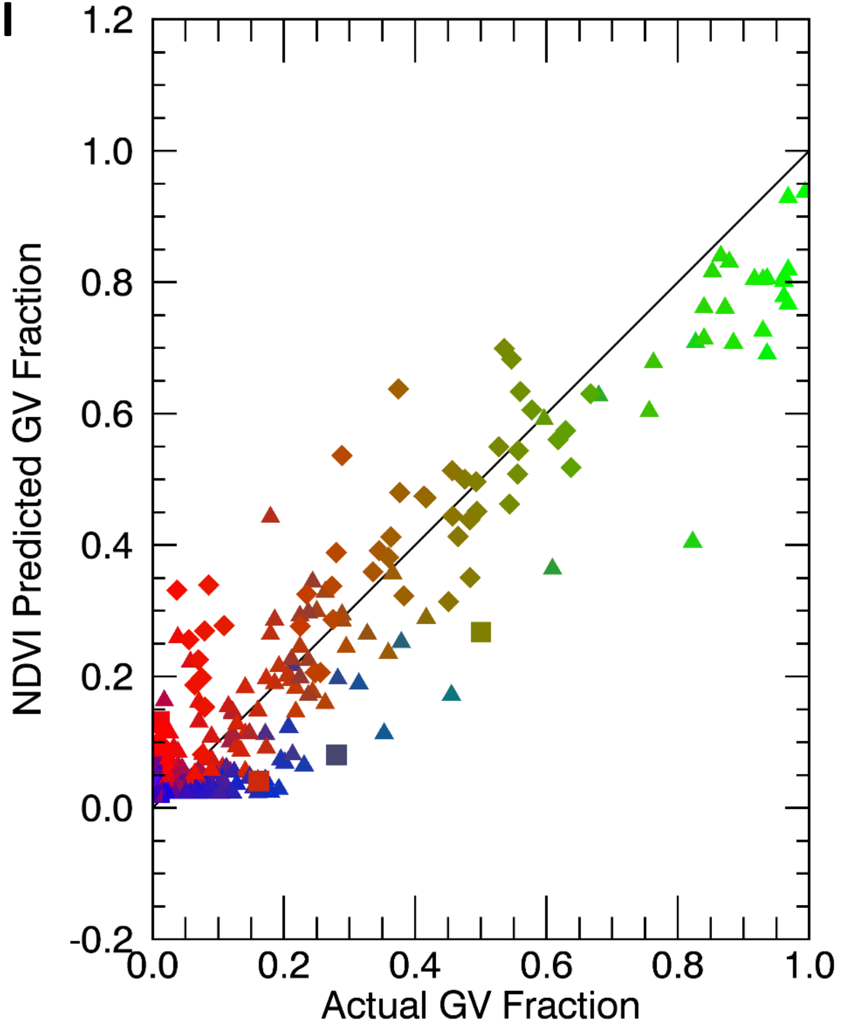
Green = broadband indices
Violet = narrowband indices
Blue = contiguous spectrum

Fractional Cover Modeling

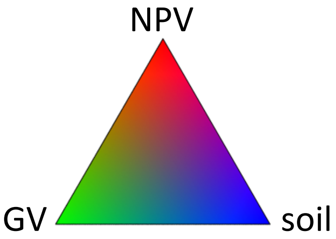
- For indices and SFA, best fit relationships from training library were applied to validation library and error was assessed
  - Second degree polynomial function was used for GV broadband indices, otherwise a linear function was used
- MESMA endmembers were selected from a universal library guided by Daughtry and Kokaly training spectra
  - 3 & 4 endmember models merged based on best fit model RMSE

GV

NDVI



Reference Data Fractional Cover



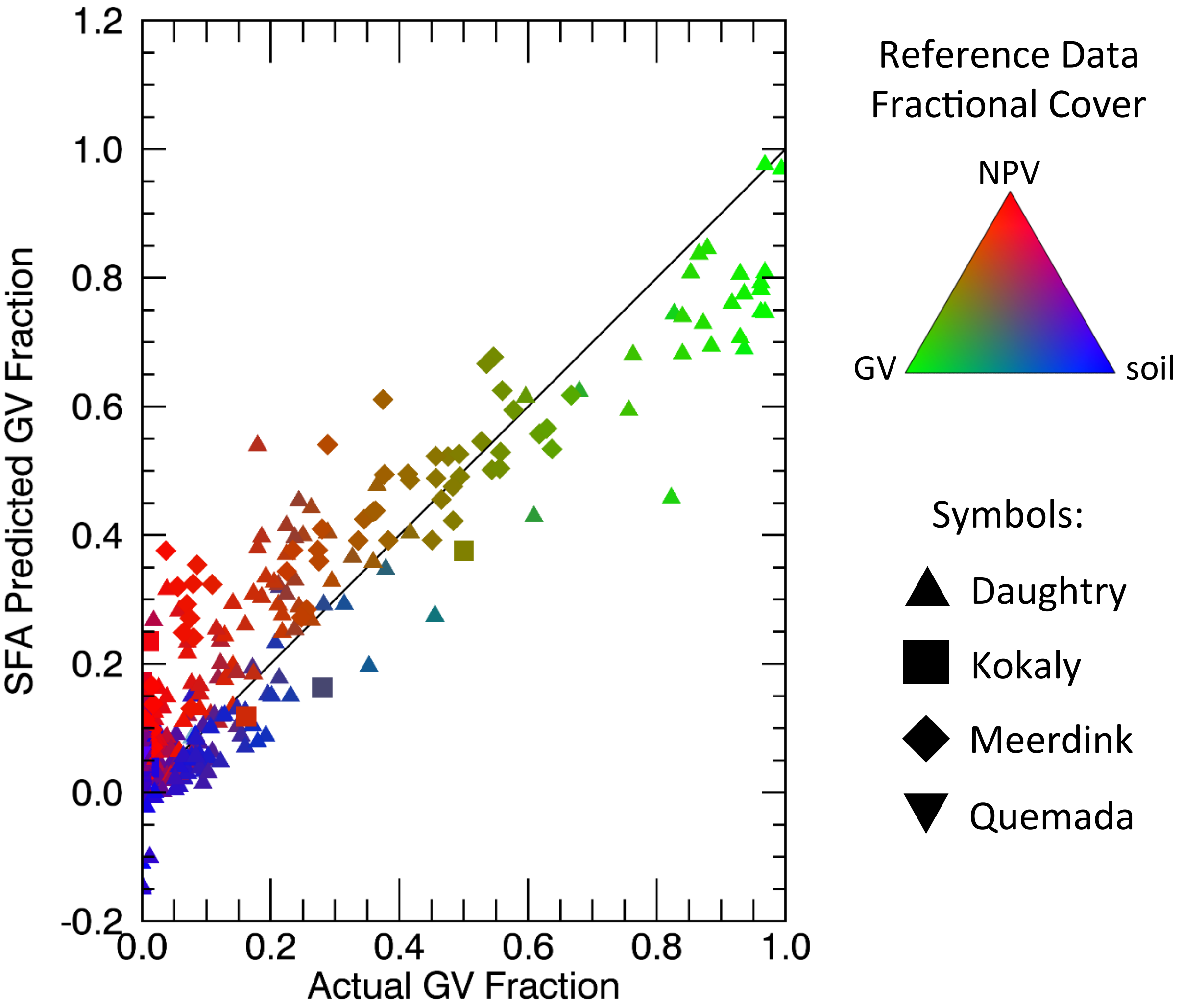
Symbols:

- ▲ Daughtry
- ■ Kokaly
- ◆ Meerdink
- ▼ Quemada

GV metric	RMSE
NDVI	0.077
SFA	0.085
EVI	0.091
SAVI	0.096
NDII	0.106
PLS	0.107
MESMA	0.118

SFA

GV



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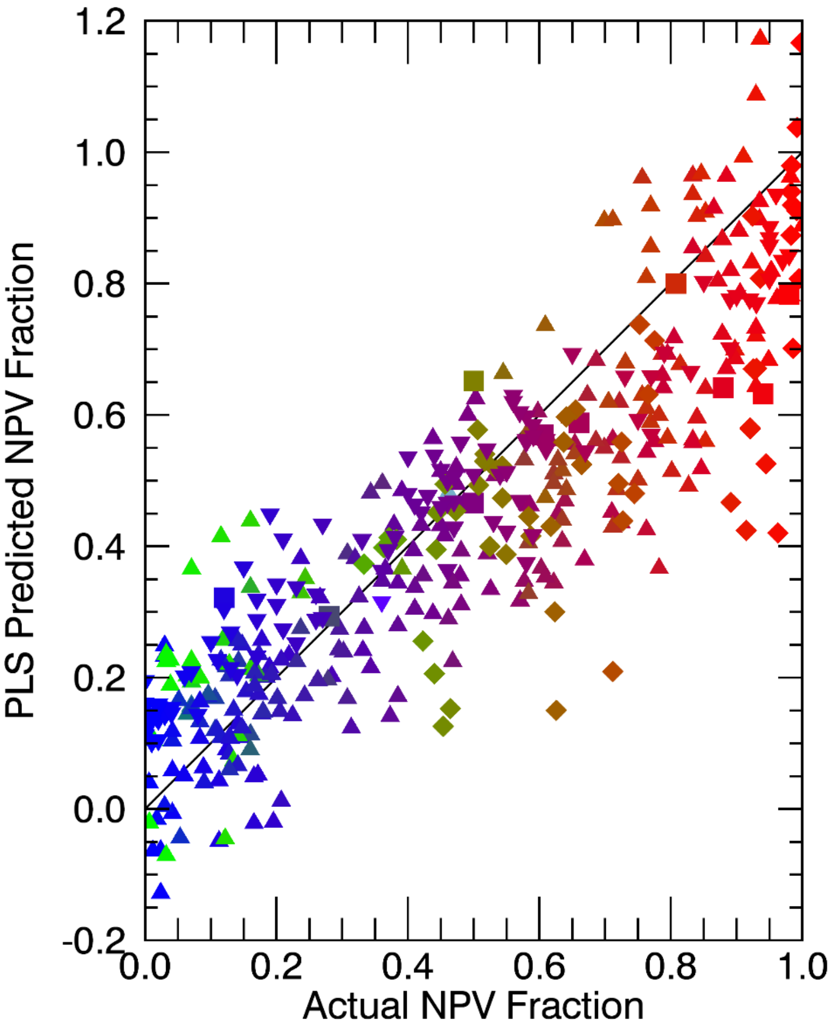
NPV



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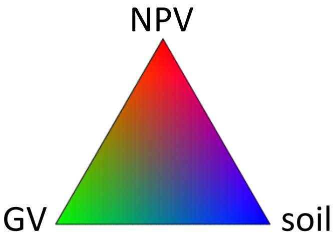

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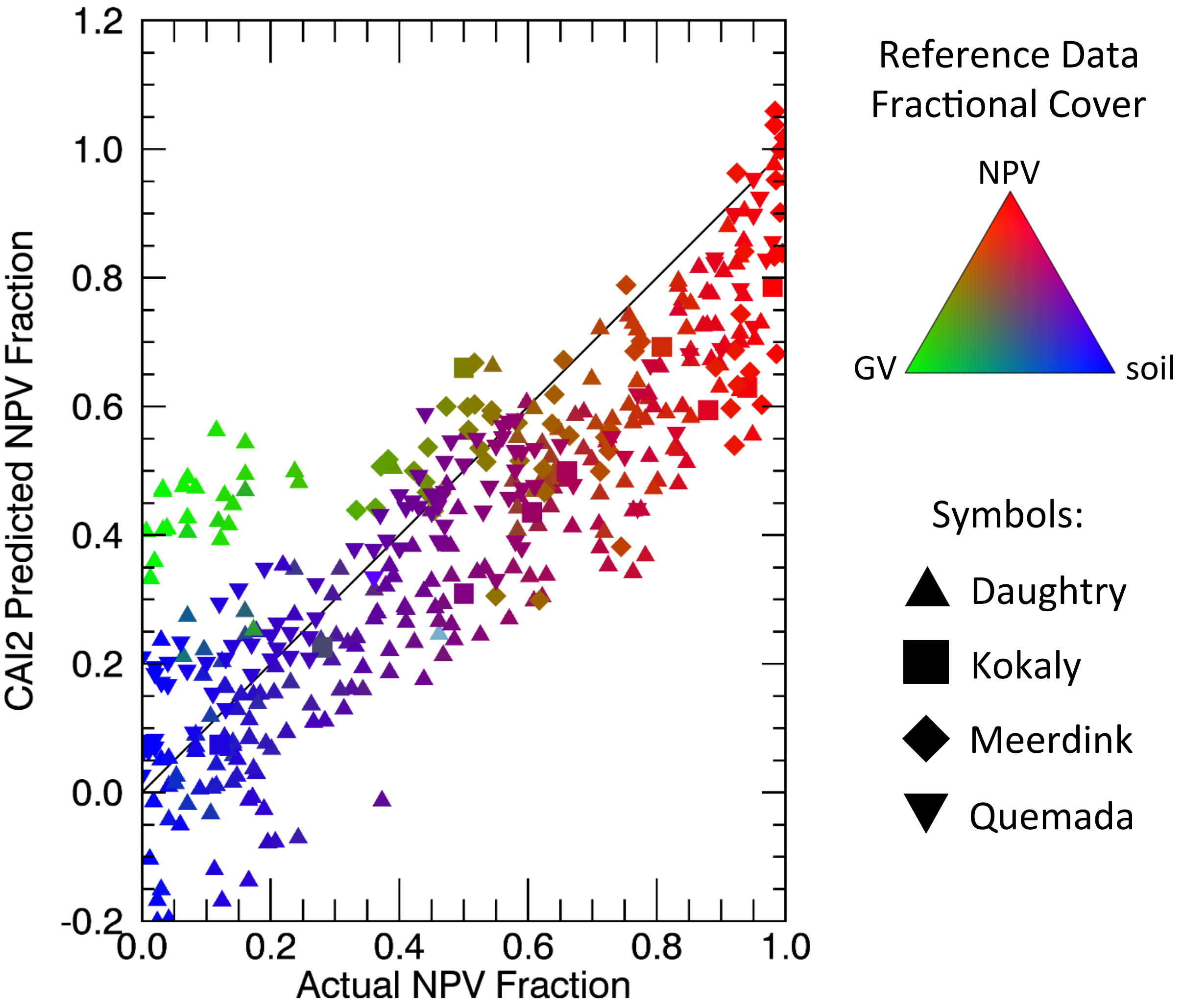
NPV metric	RMSE
PLS	0.148
SFA	0.158
CAI2	0.177
MESMA	0.187
CAI	0.187
LCA	0.198
hSINDRI	0.230

CAI2

NPV



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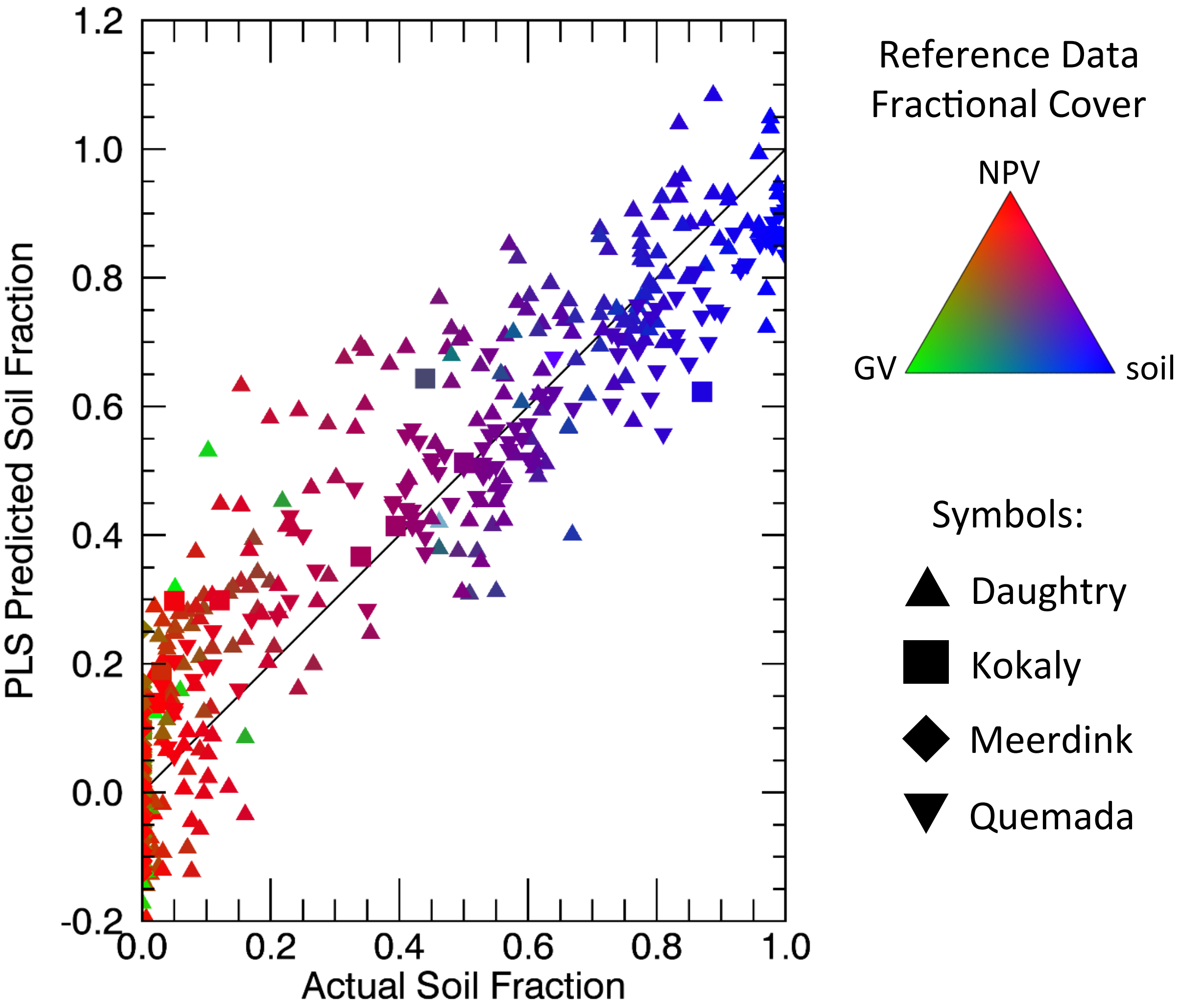
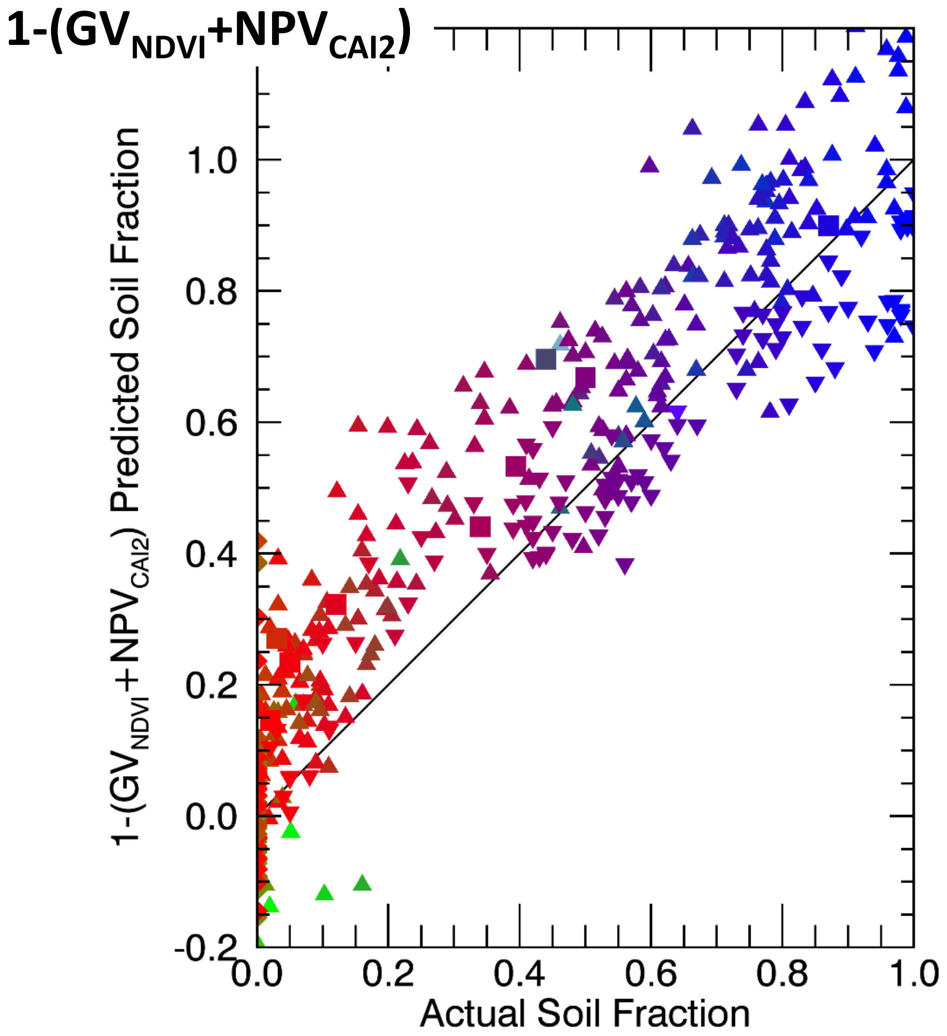
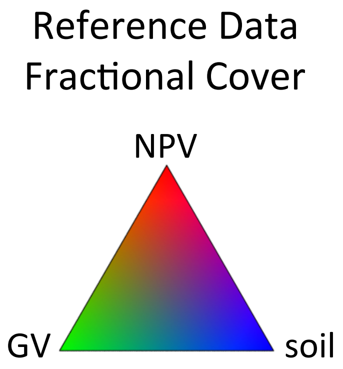
soil

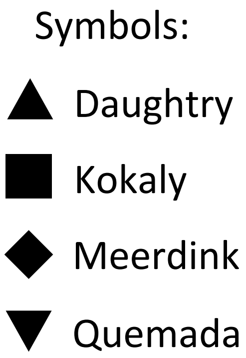


soil metric	RMSE
PLS	0.133
$1-(GV_{SFA}+NPV_{SFA})$	0.144
$1-(GV_{NDVI}+NPV_{CAI2})$	0.159
MESMA	0.167

soil







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Library Limitations

- Training and validation data include error in field-assessed cover (5-10%?)
- Library is biased toward agricultural plots
- Library is heavy on soil-NPV mixtures, light on GV mixtures
  - Average fractional cover: 43.5% soil, 41.5% NPV, 15.0% GV
- GV cover in library is low LAI
- Modeled atmosphere and solar geometry were not varied

Conclusions

- GV fraction is easy to estimate (RMSE < 10%) even using broadband multispectral data
- Accurate estimation of NPV and soil fraction requires narrow bands, contiguous spectra
  - Achievable RMSE for NPV and soil fractional cover is closer to 15%
- Spectral feature analysis and partial least squares regression produced the highest accuracies
- MESMA produced a wide range of accuracies, depending on endmember selection
  - However, MESMA's constraints and multiple levels of endmember complexity may still be advantageous for implementation
- More work is needed to demonstrate true portability of methods and validate AVIRIS and future HyspIRI fractional cover products

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