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Field data collection for remote sensing of winter cover crops and crop residue cover

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with
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•U.S. Department of the Interior
•U.S. Geological Survey

Conservation Technology Information Center
Conservation Verification Network (CVN) kickoff meeting
August 25th, 2021, online

On-farm conservation performance is variable

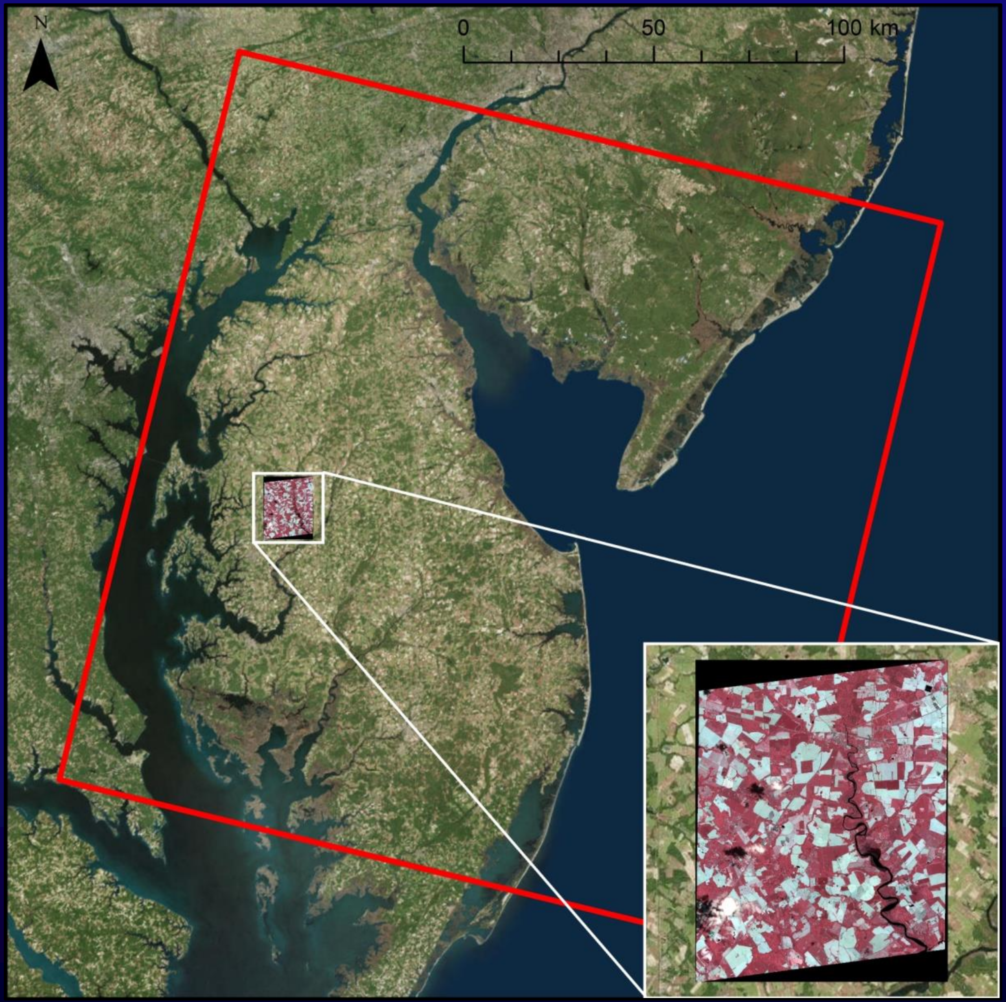
Green vegetation (cover crops)
crop residue (conservation tillage)
and bare soil (plow tillage)
each reflect light differently

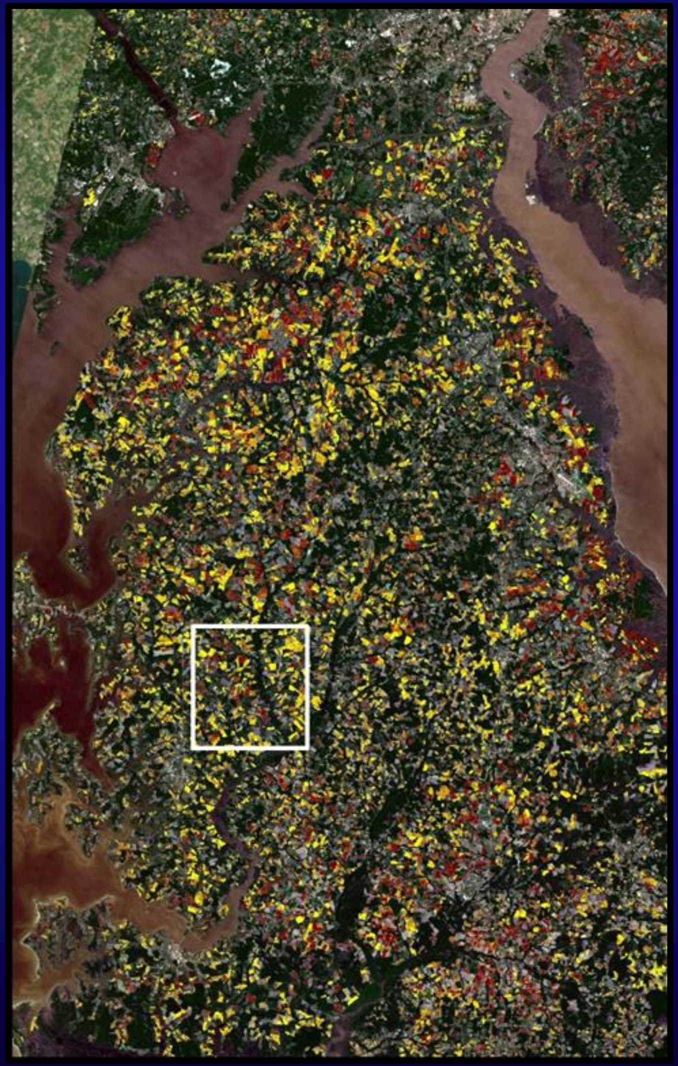
We can measure and map these practices using satellite imagery

Chesapeake Bay region

Focus on Maryland, Delaware

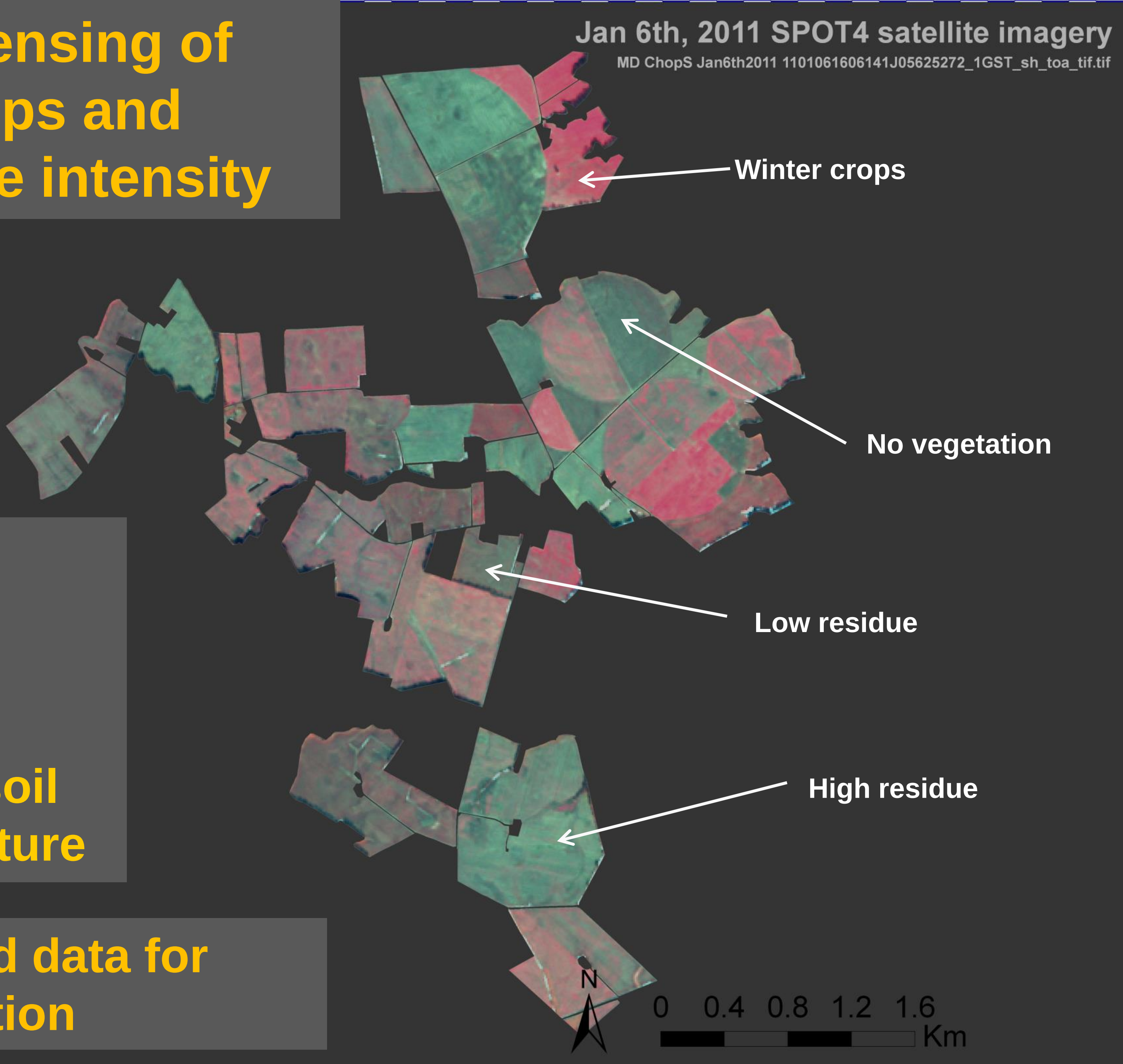
Delmarva Peninsula





Satellite remote sensing of winter cover crops and crop residue / tillage intensity

- Visible near-infrared indices for vegetation
- Shortwave infrared indices for crop residue
- In contrast with background soil
- Affected by background moisture



Requires field data for calibration

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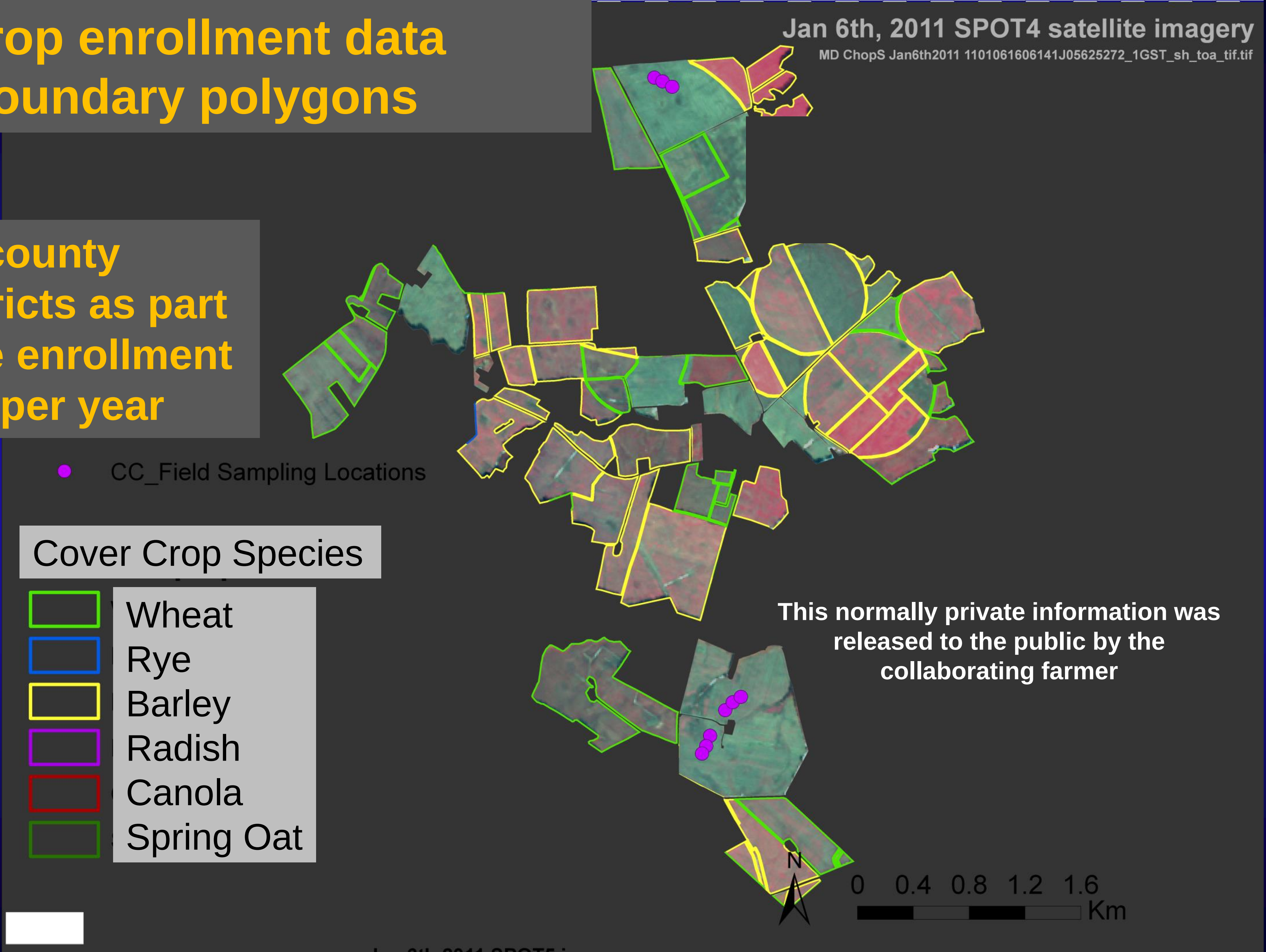
Cover crop enrollment data
Field boundary polygons

Digitized at county conservation districts as part of MDA cost-share enrollment
~ 25,000 fields per year

Long-term collaboration with Maryland Department of Agriculture supports access to farm cost-share enrollment data



This normally private information was released to the public by the collaborating farmer

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Cover crop enrollment data
Agronomic management data

- Cover crop species
- Planting date
- Planting method
- Planting rate
- Previous crop
- Termination date
- Termination method
- Watershed HUC12 ID
- County
- Field boundary

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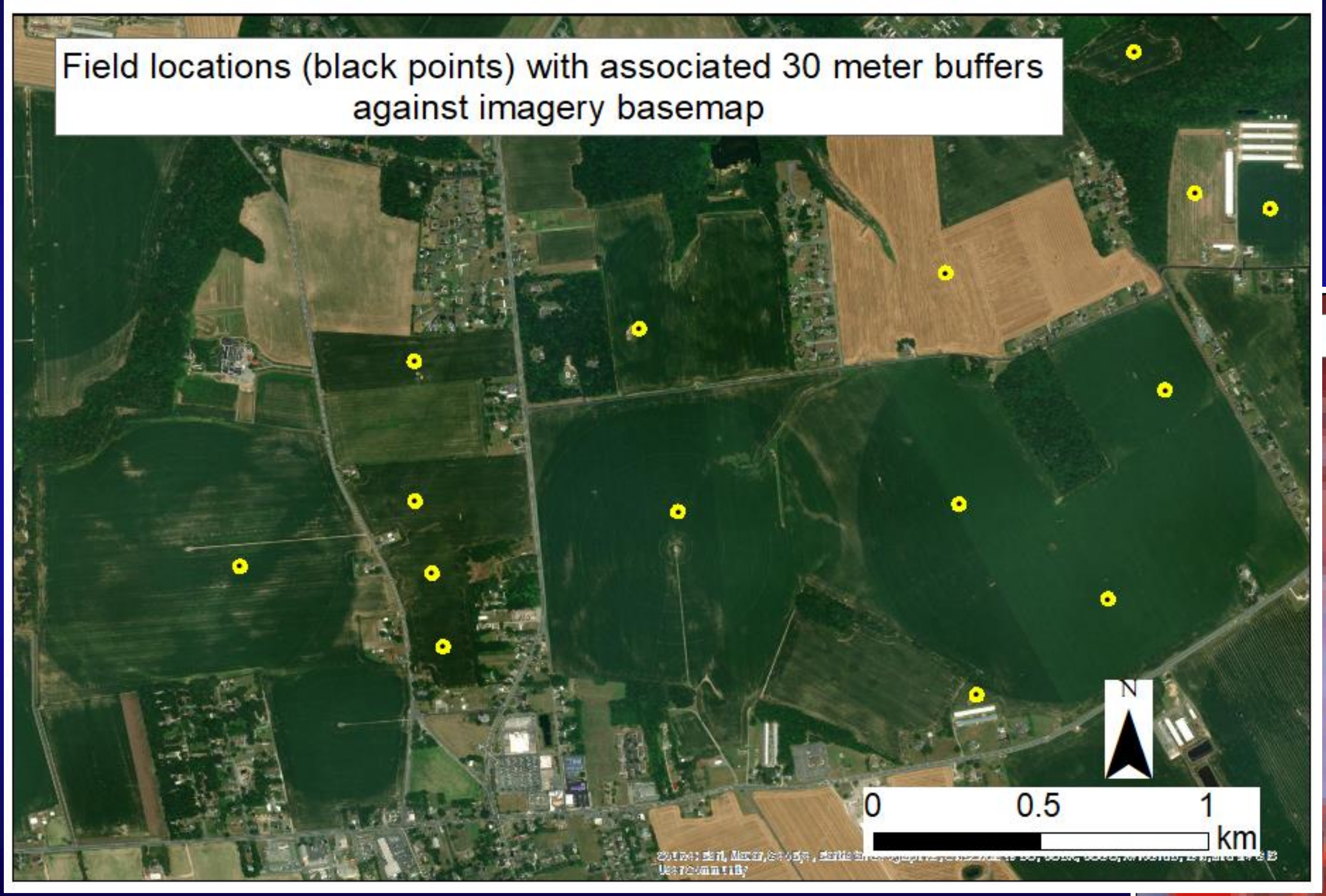
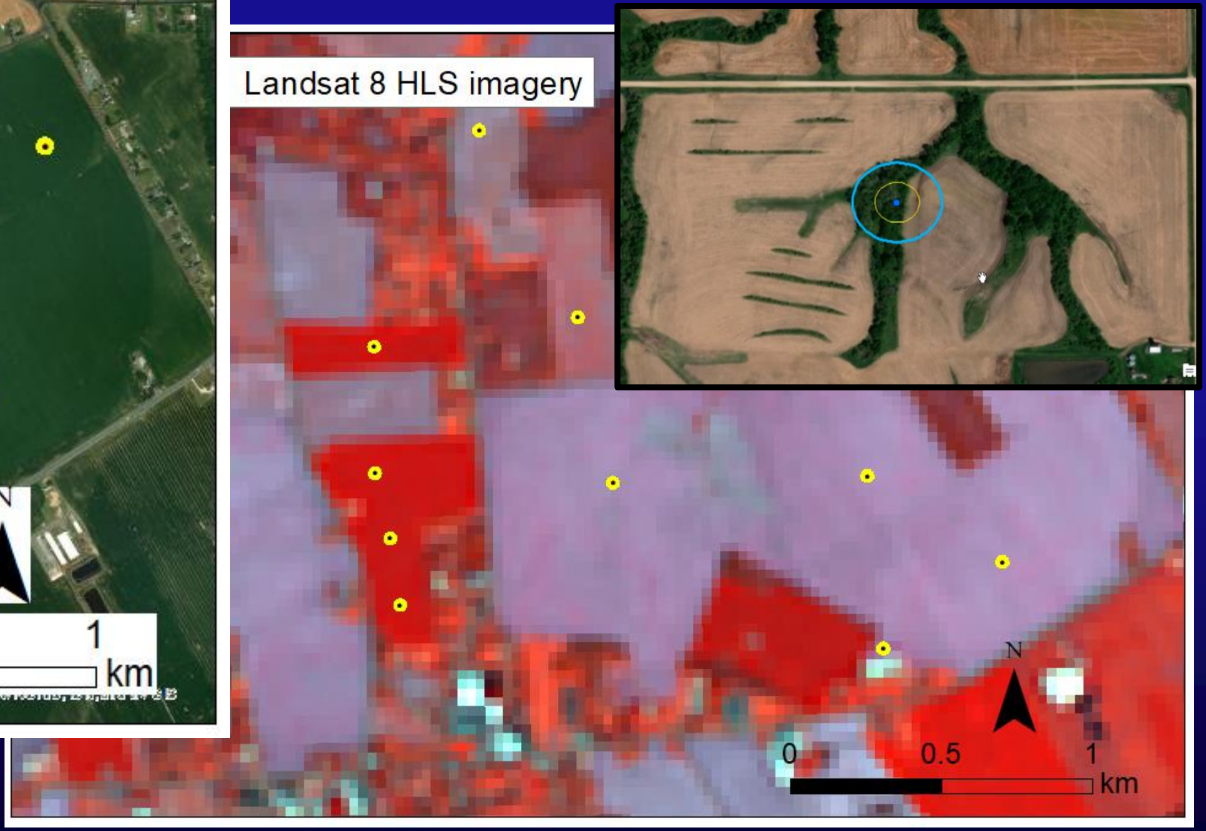
Cover crop enrollment data – points and centroids

Centroids for fields are useful, but not as useful as boundary polygons

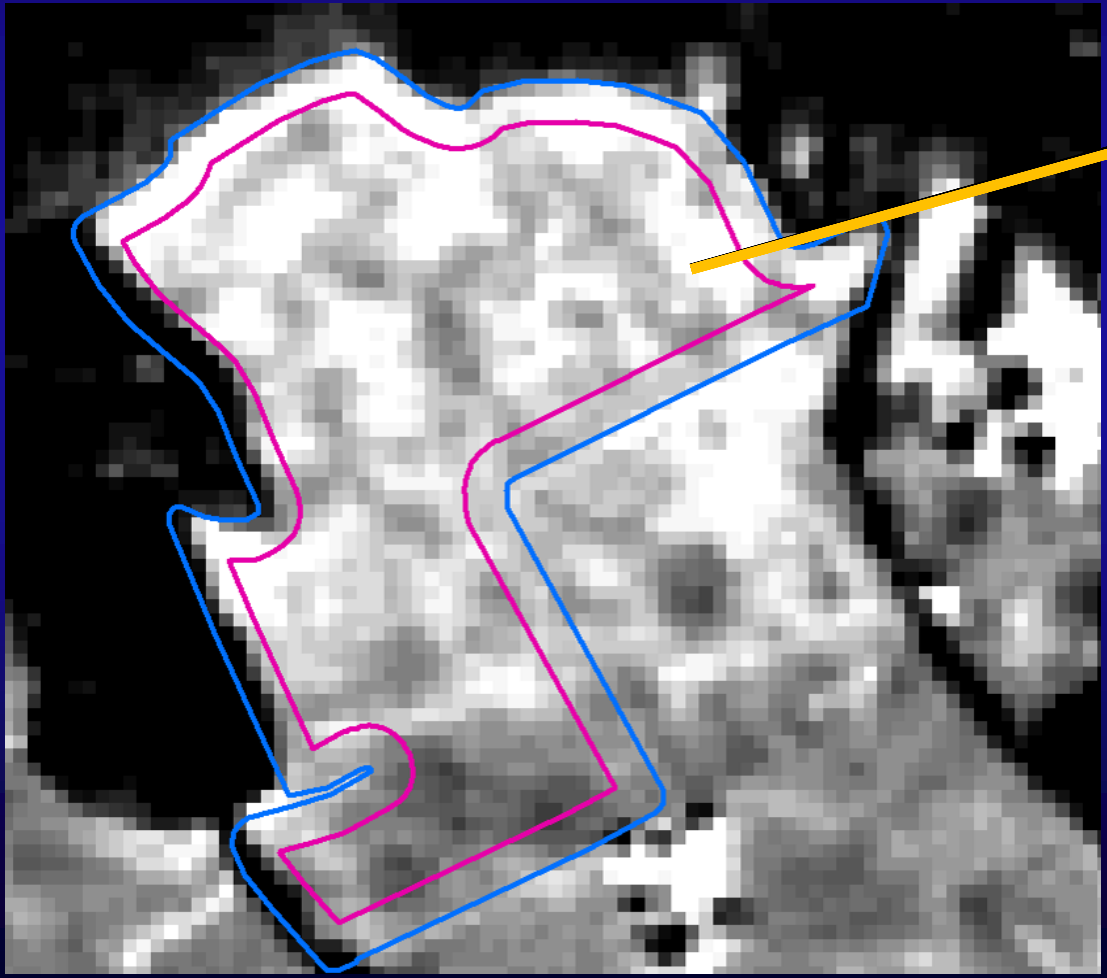
Sometimes issues with points falling on in-fields irregular features, grassed waterways, etc…





Calculate NDVI time series for each field

- Harmonized Landsat and Sentinel (HLS) satellite imagery
- Up to 4-day repeat frequency depending on clouds



Average NDVI per field, per image date

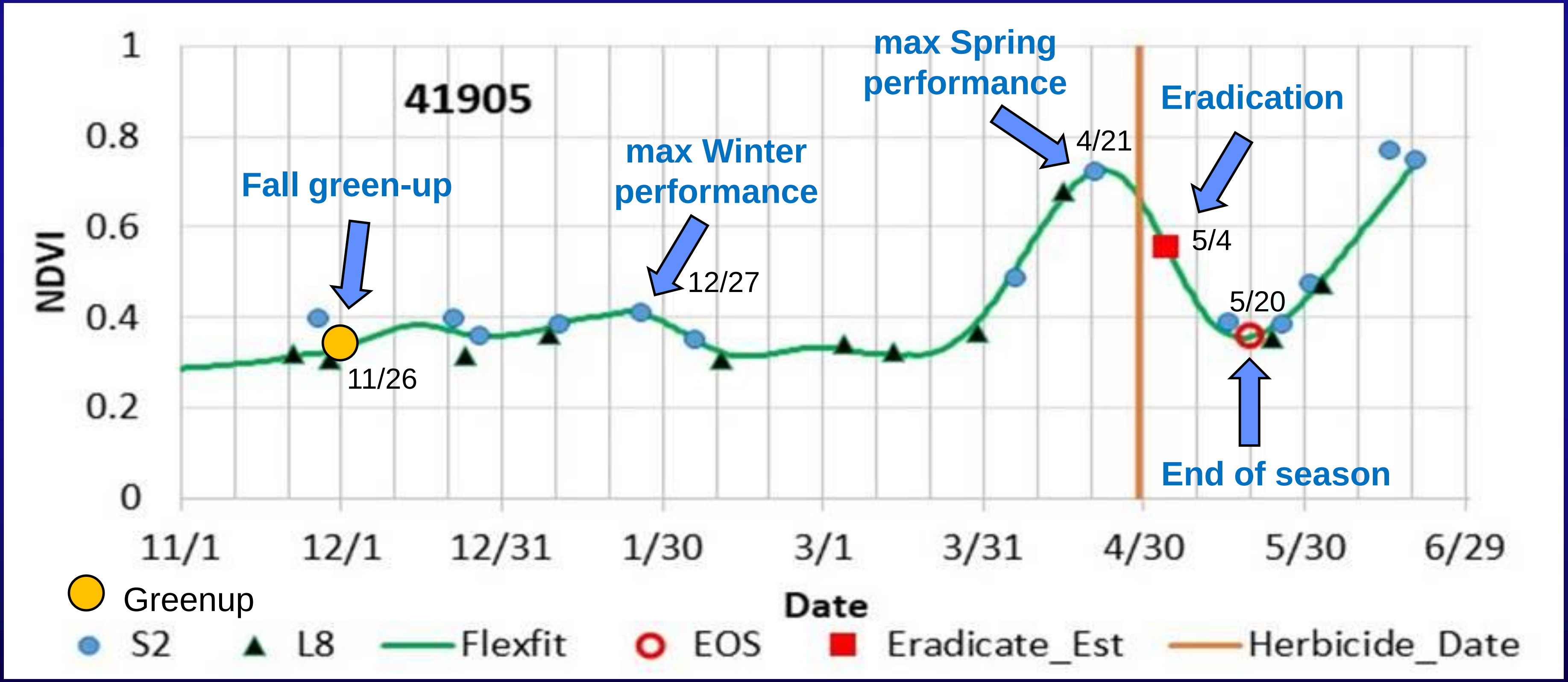
Normalized difference vegetation index

Curve fitting approach to phenology identifies:

- Green-up date
- Green-up momentum
- Maximum wintertime and springtime NDVI and associated performance
- Termination date

Cover crop phenology from HLS imagery

- Greenup and termination dates identified by vegetation index inflection points using Harmonized Landsat Sentinel (HLS) satellite imagery
- Maximum performance in wintertime and springtime derived from index correlation with field sampling data (aboveground biomass, fractional green vegetative cover)



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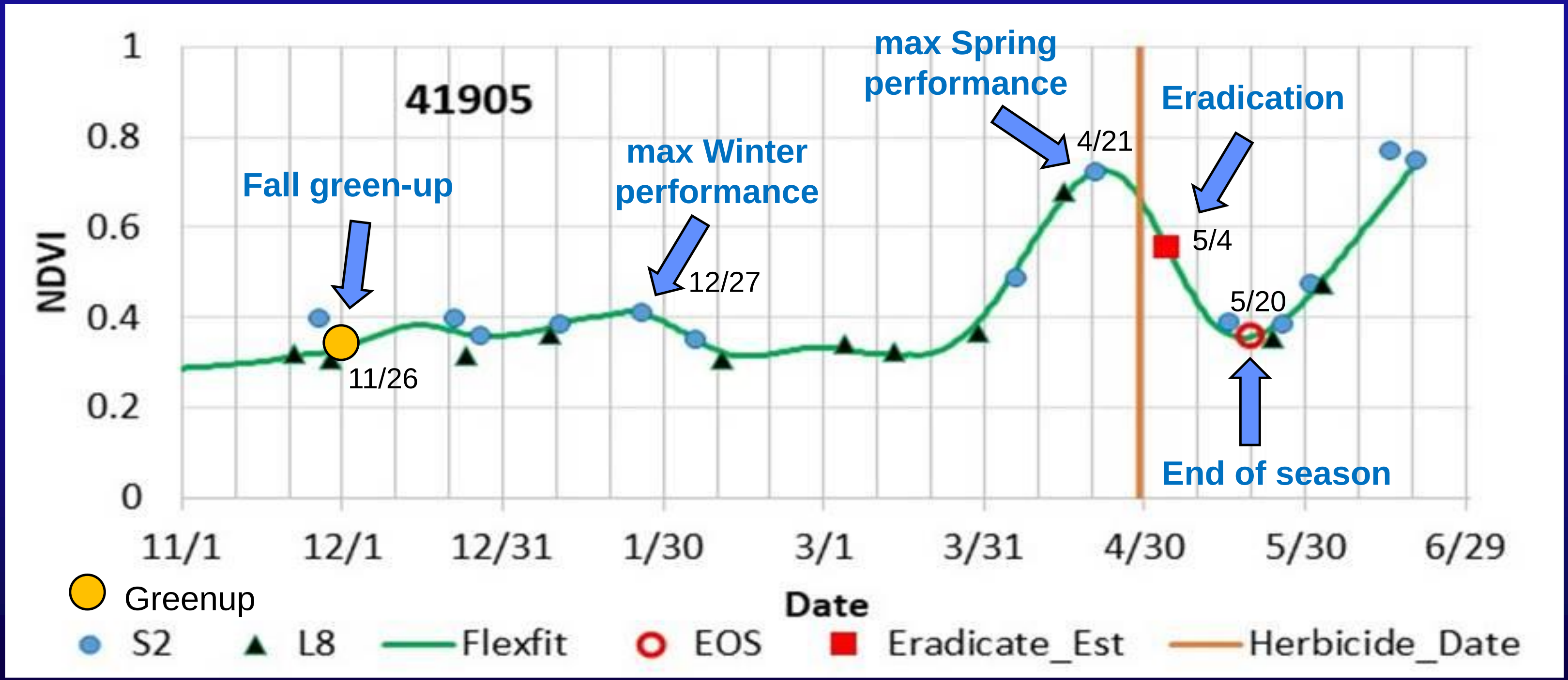
These data are preliminary and are subject to revision.

Cover crop phenology analysis

- Farmer-reported planting date, species, planting method, seeding rate, previous crop allows evaluation of green-up and establishment
- Farmer-reported termination date and termination method (herbicide, plow, green chop) allows evaluation of end of season dynamics

June 22nd roadside survey to confirm identity of grain crops grown for harvest



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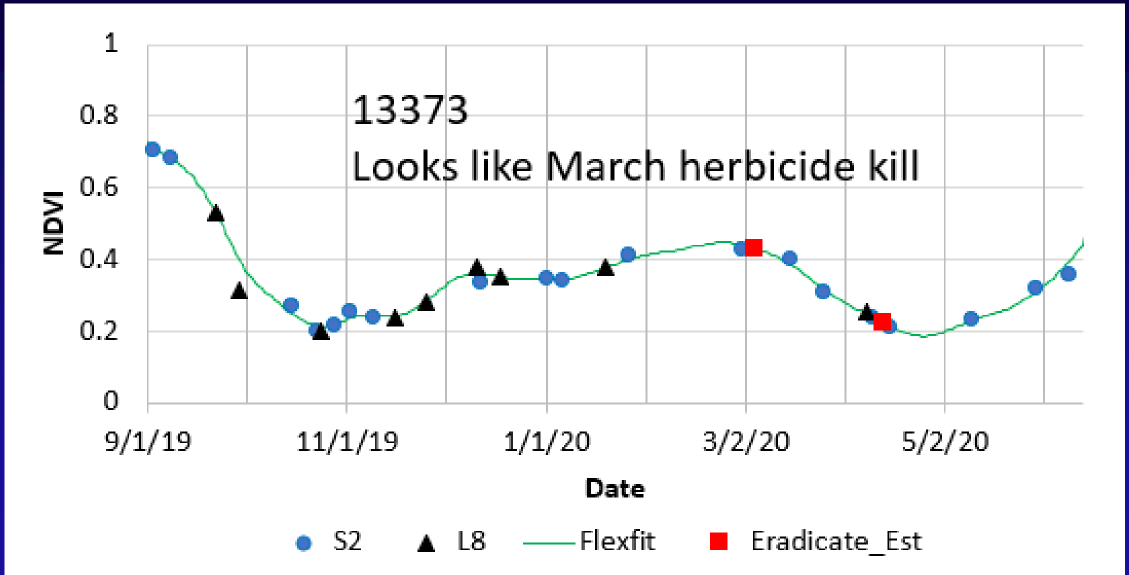
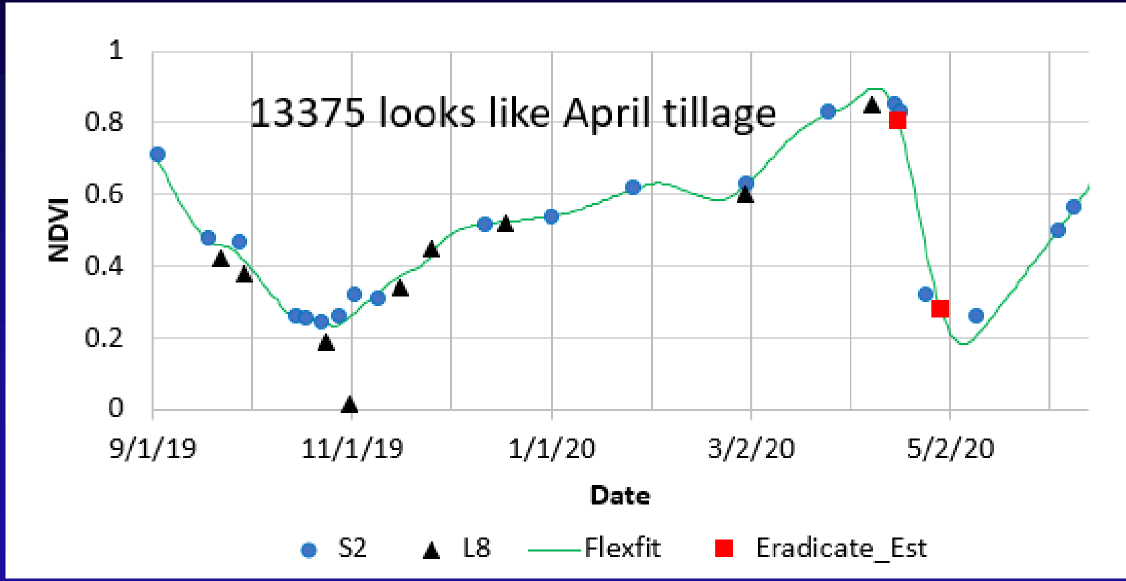
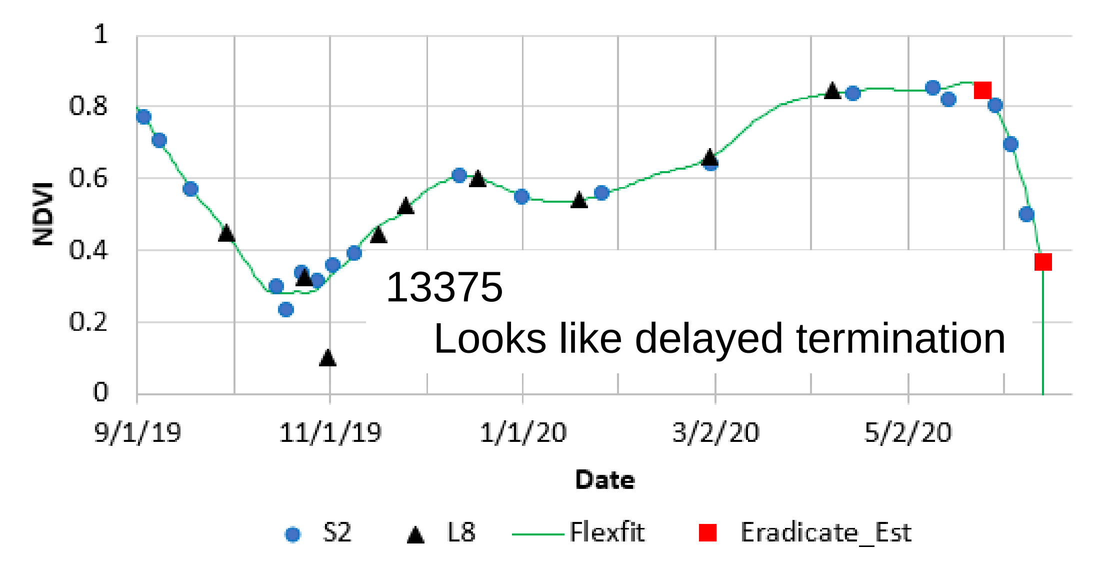
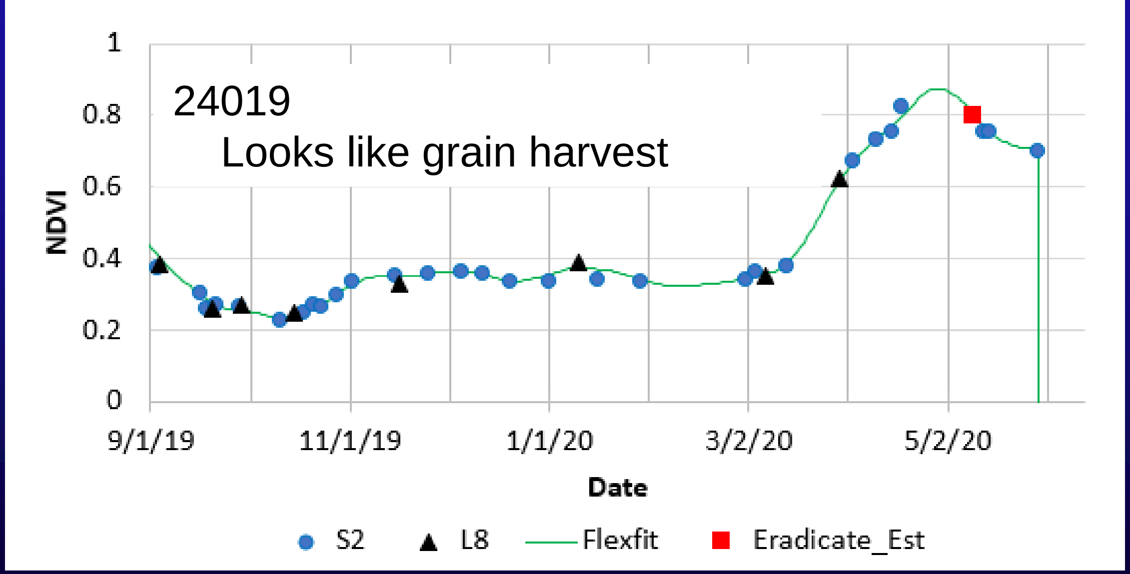
Spring termination analysis









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Measuring cover crops in the field

Physical sampling of plants

- Biomass (weight per 0.5 m^2 quadrat)
- Ground cover (by photo analysis)
- Plant nitrogen content, C:N ratio
- Plant growth stage, height, tillering, etc…

- 3 quadrats per field, > 10 photos
- 60 m apart to fall in different pixels
- Avoiding edges and irregular areas
- > 2000 on-farm samples over 10 yr







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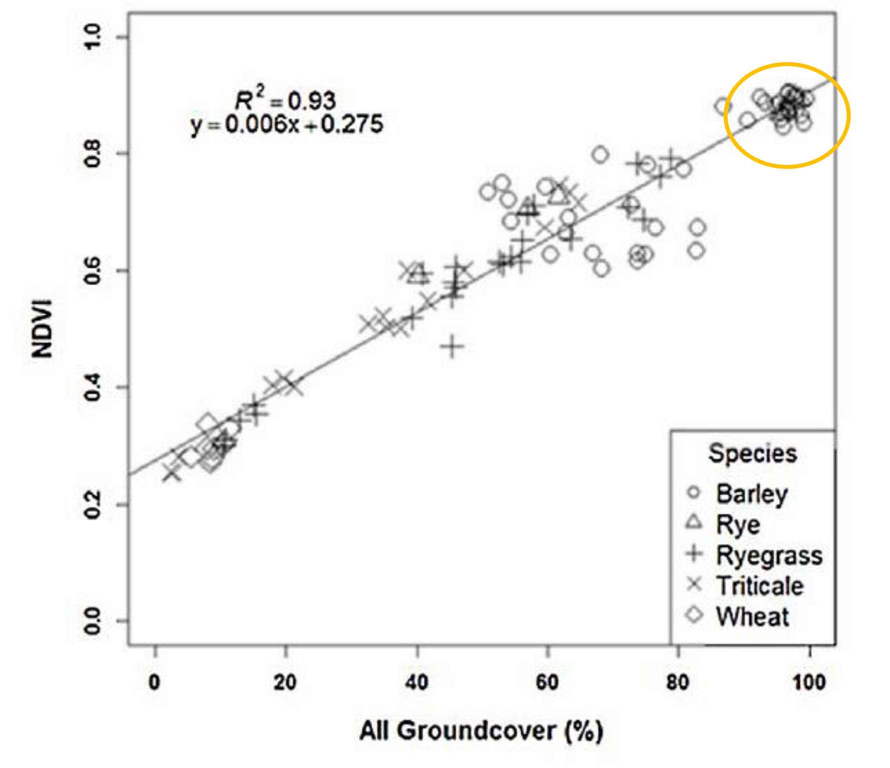
Cover crop performance

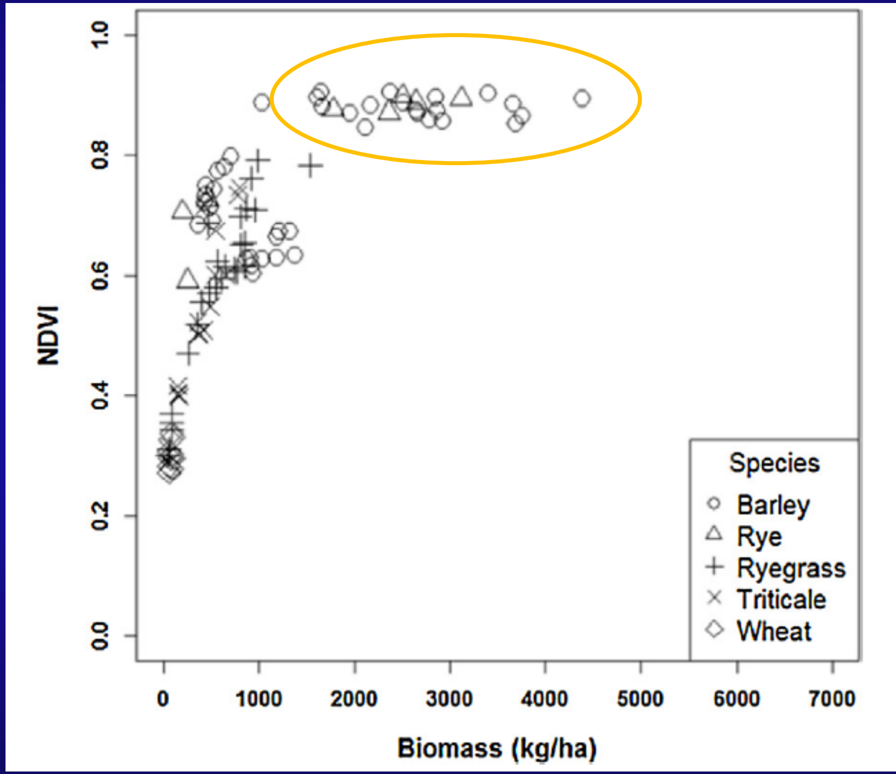
Seasonal maxNDVI translated to performance using field calibration dataset

Percent green ground cover



Accurate below NDVI = 0.8 (~80% cover)

Aboveground biomass



Saturates above NDVI = 0.8 (~1000 to 1500 kg/ha)

Various indices available

	r^2
NDVI	0.970
GNDVI	0.960
SR	0.880
SAVI (L=1)	0.970
G-R	0.900
EVI	0.960
TVI	0.950
NGRD	0.920
VARI	0.920
NDREI	0.940

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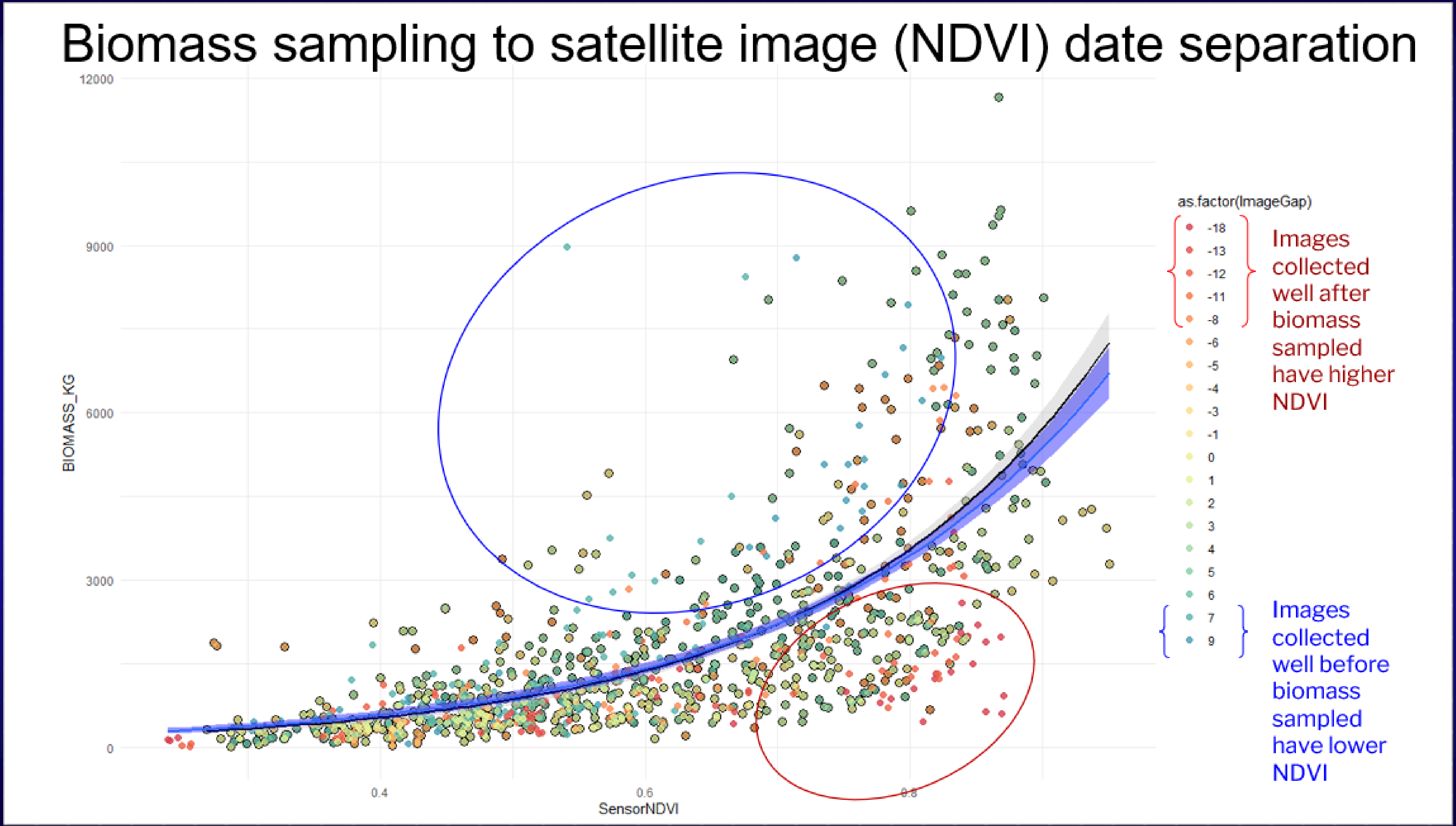
Prabhakara et al., 2015.

Calibration: Biomass ~ NDVI



Mismatch between sampling date and imagery date causes error

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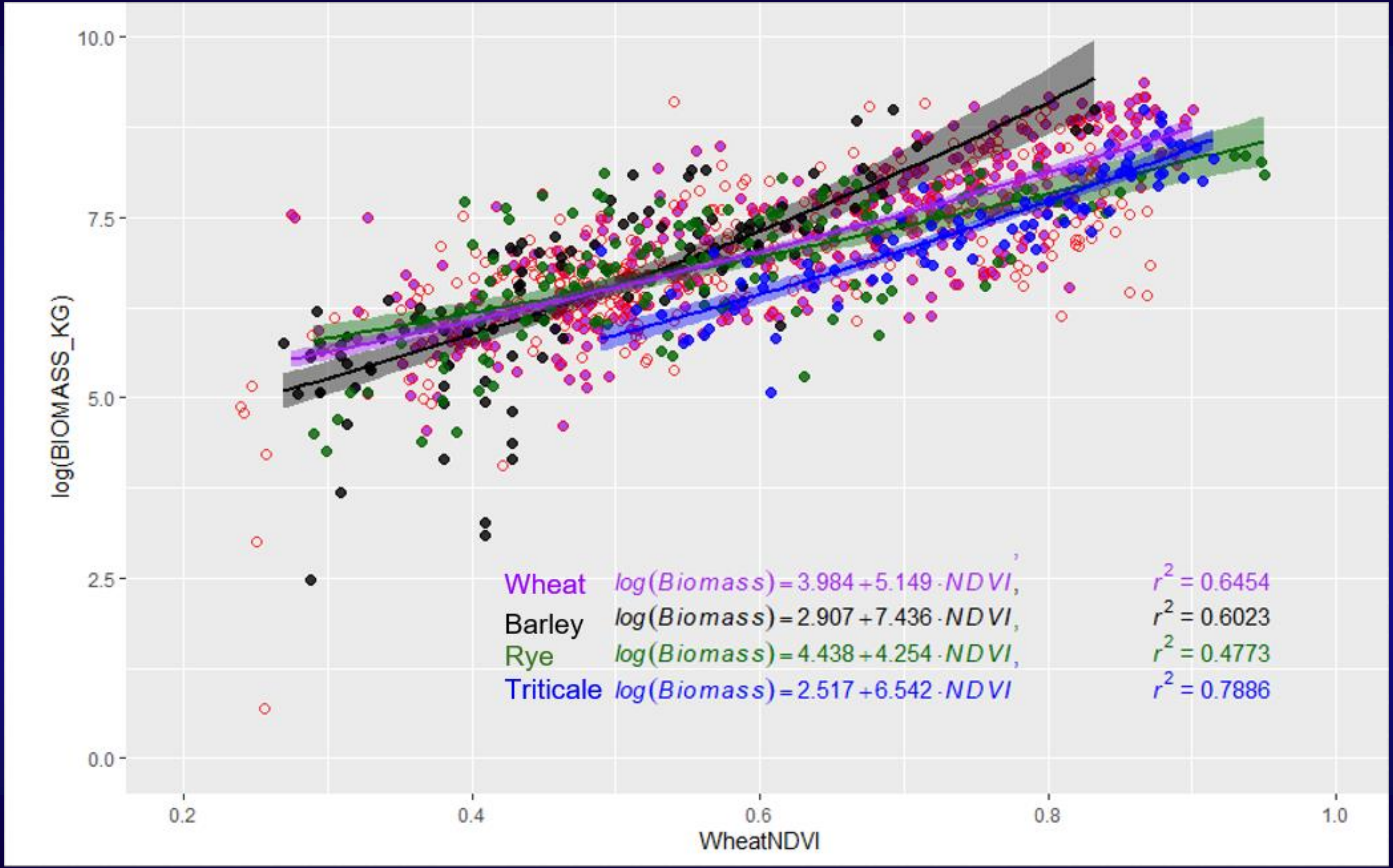
Calibration: Biomass ~ NDVI

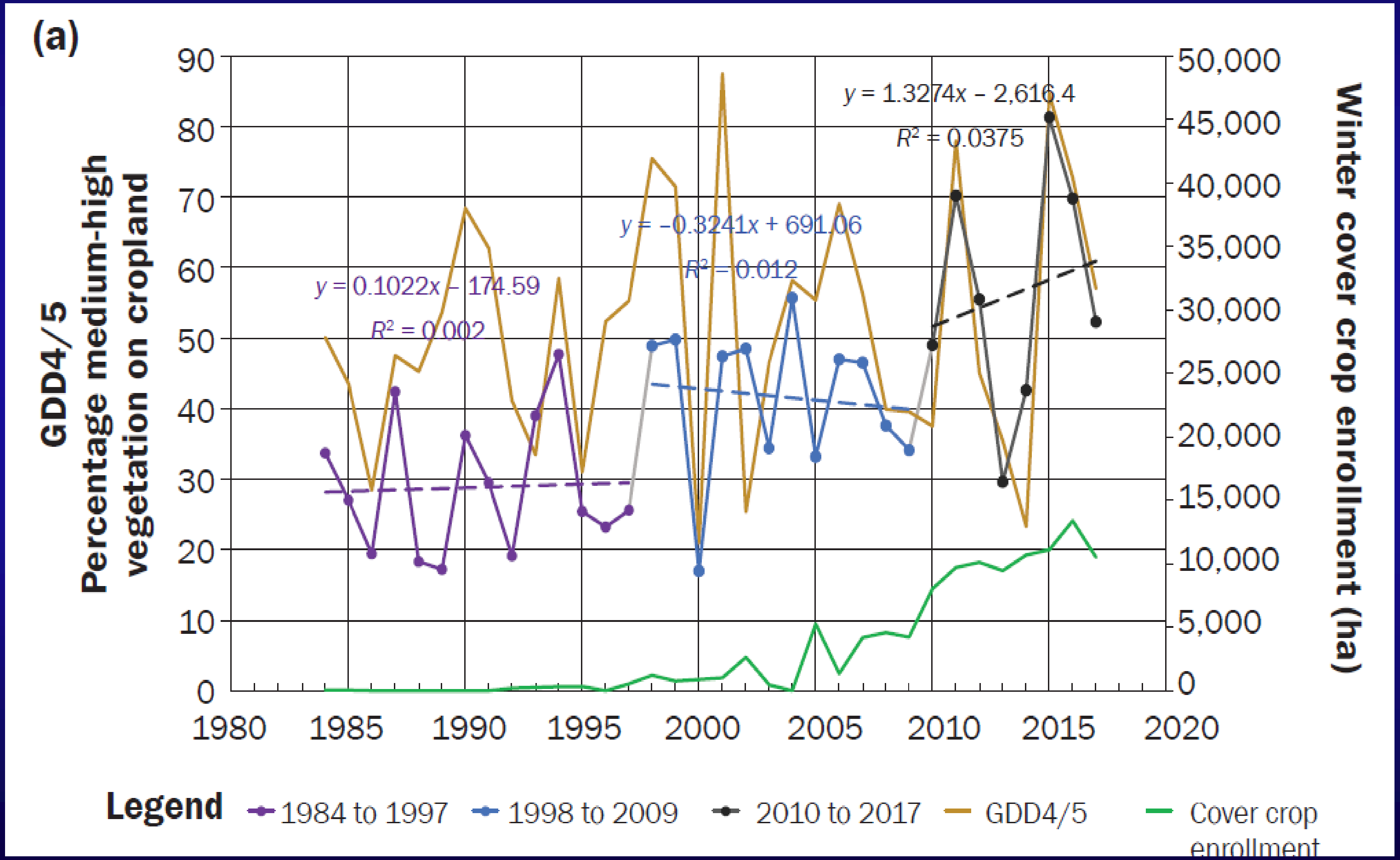


Species relationship with NDVI can vary due to leaf angle distribution

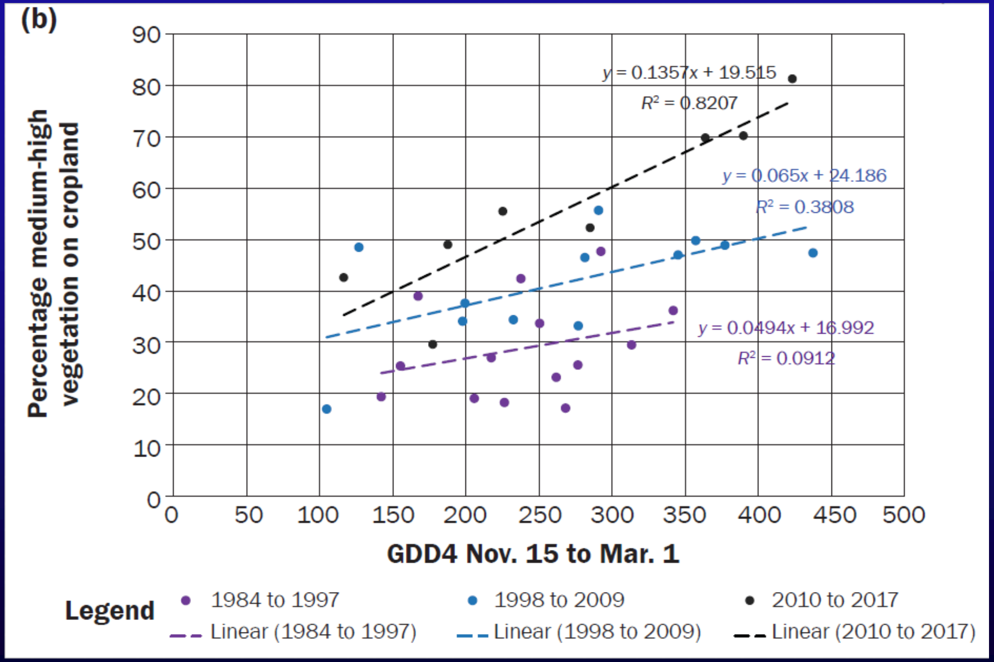
Climate data are also important

GDD 4^{0}C base temperature

Frost GDD to measure onset of dormancy and chlorosis



- Increased cover crop associated with increased winter ground cover
- Long-term time series was needed to account for effect of wintertime climate variation



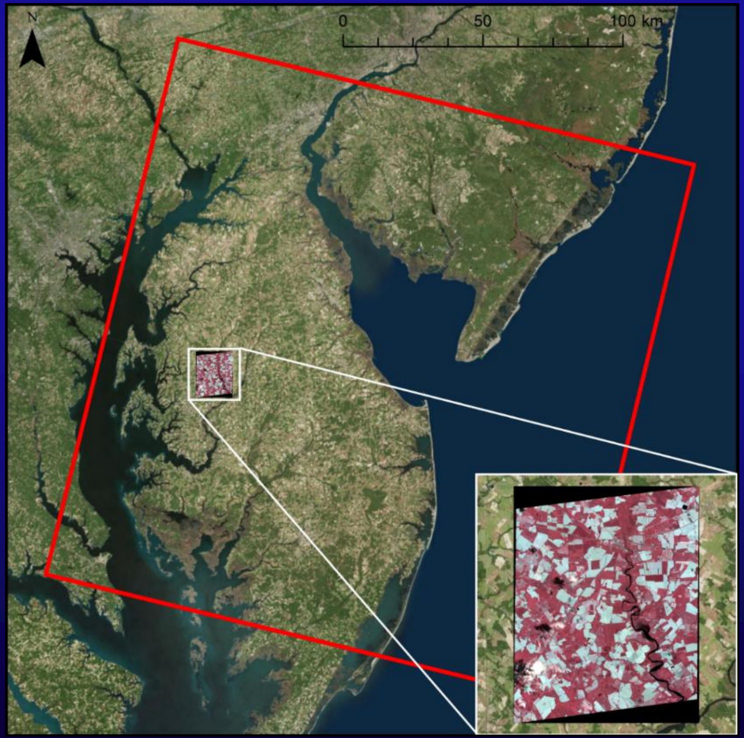
USGS *Hively et al., 2020. doi:10.2489/jswc.75.3.362*

Summary – cover crop field data

- In-field nadir photos from camera at 4m height is our best tool for green vegetative ground cover calibration data
  - > 10 photos per field, several per satellite pixel
  - In-field spatial variability is significant
  - Avoid field edge areas – walk a long distance in each field
- Photos processed using "Green Fraction" code in python, makes batch processing easy
  - Will publish method and code in 2021
- Biomass Nitrogen, Carbon content of samples also used to calibrate satellite analyses
- Field boundaries and agronomic management data from Maryland cost-share program are extremely useful for calibration and for determining cover crop outcomes
- Farmers have been very supportive in allowing access to fields
- I would also like to have information about yield goals and actual yields, to evaluate residual soil N – there are a lot of N limited cover crops, and it affects performance – currently those data are not available

Remote sensing of crop residue / tillage intensity

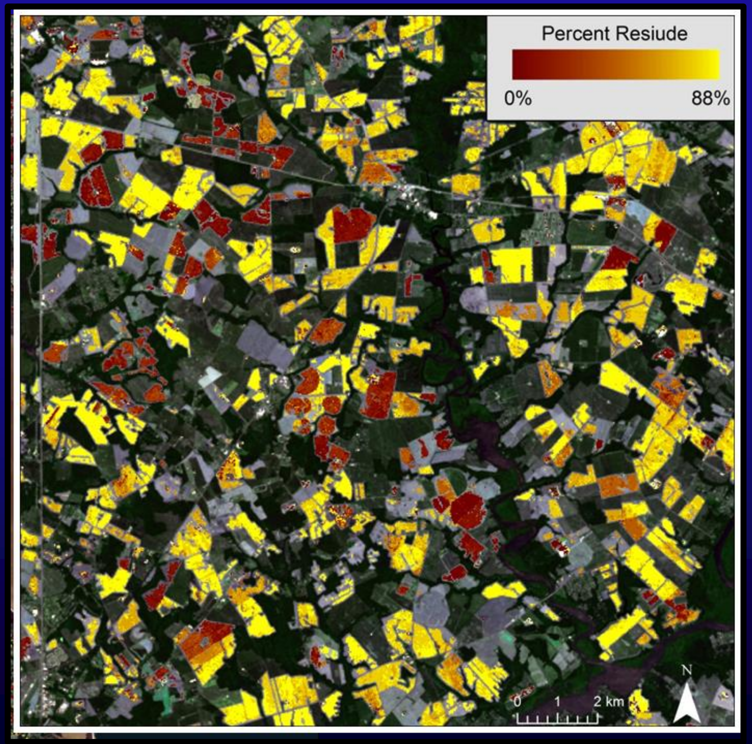
- **Best achieved by measuring cellulose / lignin absorption feature near 2100 nm**
  - **Requires spectral resolution near 2100 nm (WorldView3, ASTER, PRISMA)**
- **Also achievable from Landsat and Sentinel using the Normalized Difference Tillage Index (1600 nm - 2100 nm) / (1600 nm + 2100 nm) and/or machine learning**
- **Interference from green vegetation and background soil moisture**



Mapping conservation performance

Plow tillage
0-30% cover

High residue
60-100% cover



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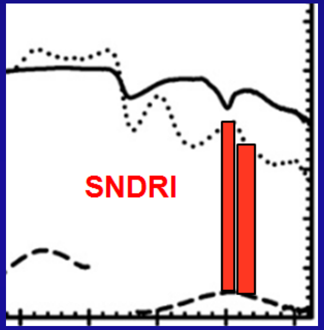
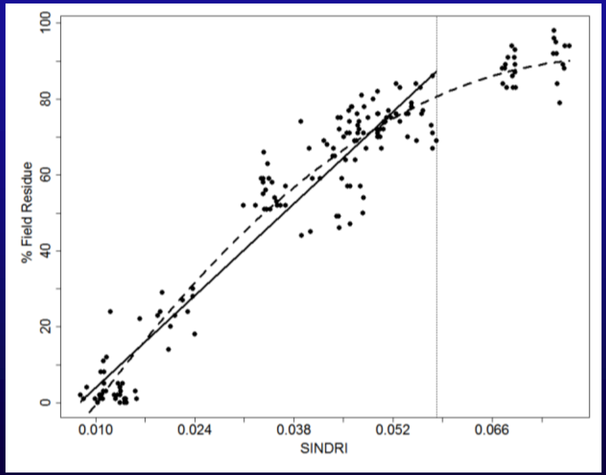
Hively et al., 2018. https://doi.org/10.3390/rs10101657

Mapping crop residue using Worldview 3 SWIR imagery

Achieved high accuracy (R^2 = 0.94) in mapping crop residue on fields with minimal vegetation (NDVI <0.3)





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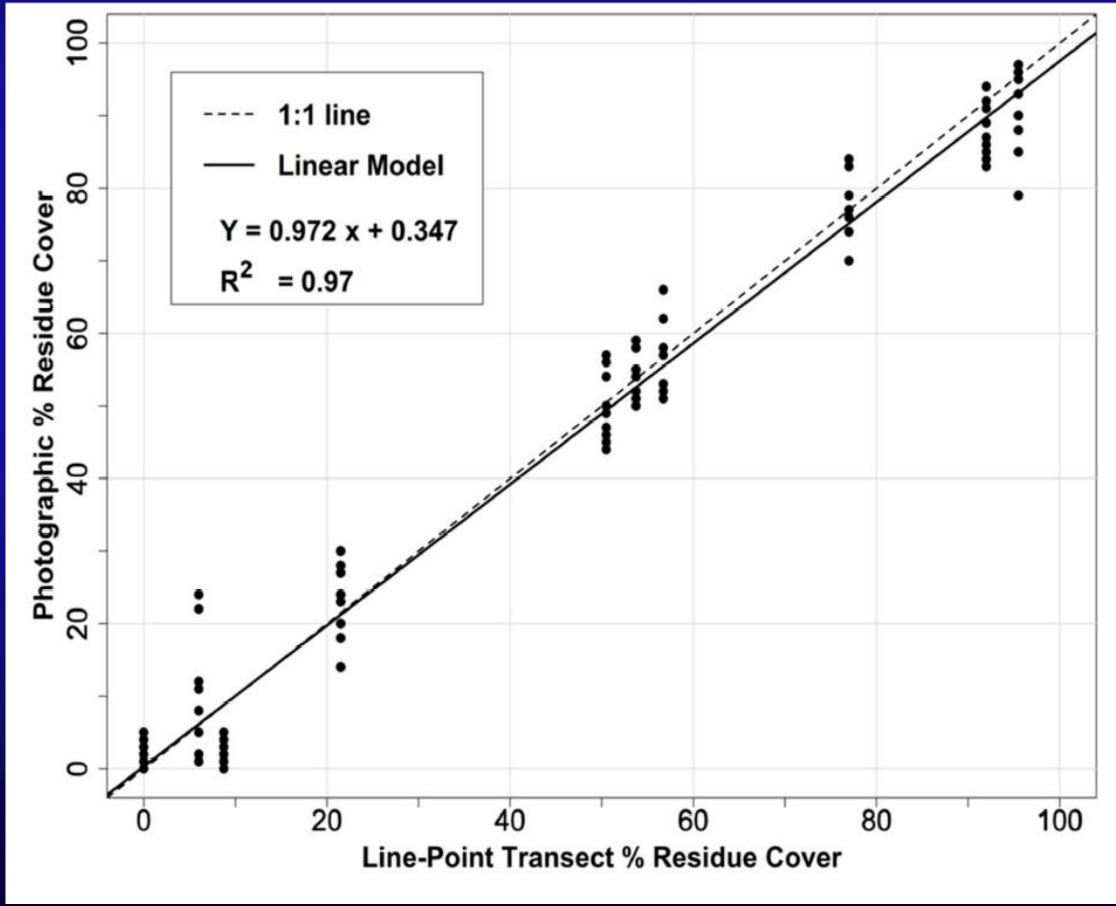
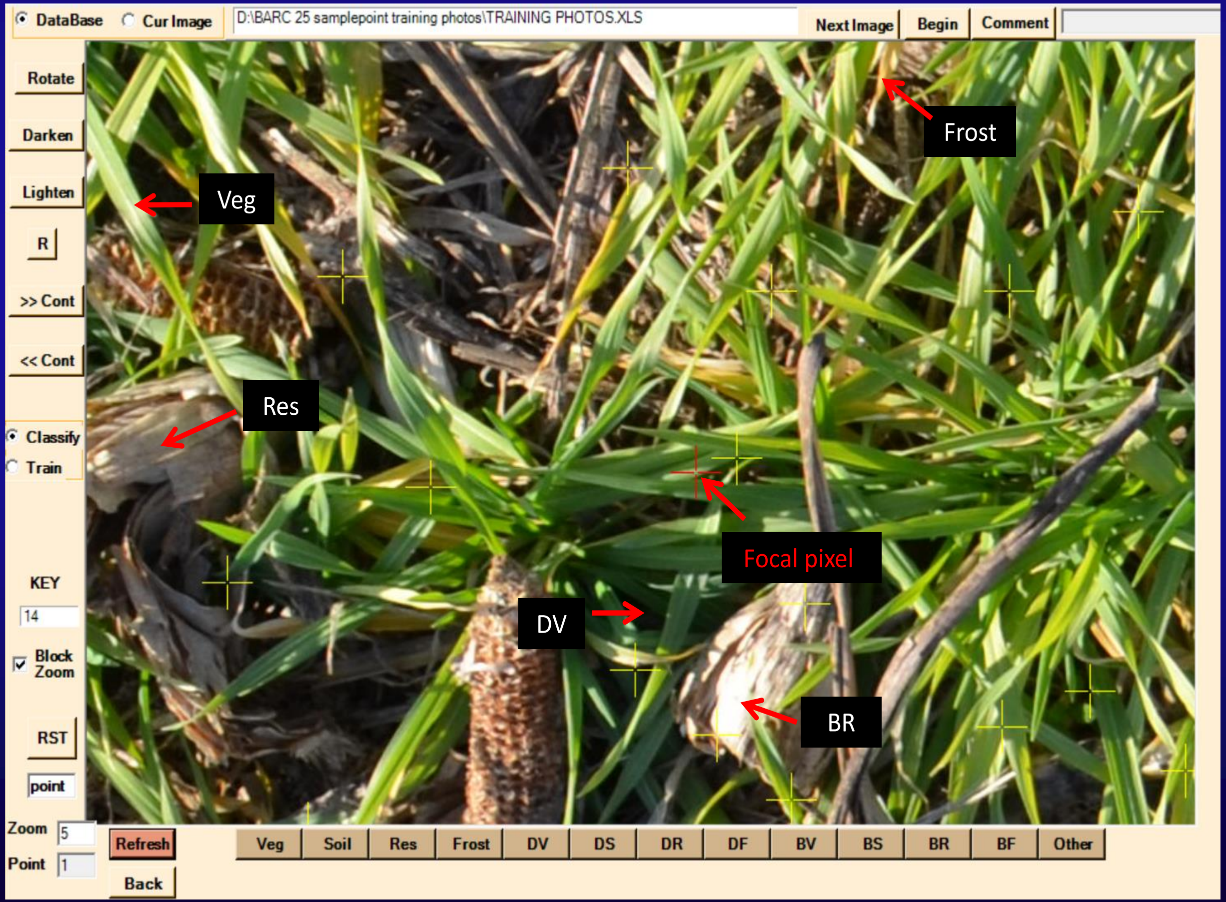
Hively et al., 2018. https://doi.org/10.3390/rs10101657

Crop residue field data collection

- Line-point transect method is time consuming, though reliable
- In-field nadir photos analyzed in Sample Point give similar results, faster, >10 per field
- 5 years of sampling data along with WorldView3 SWIR imagery (MD) (>1000 photos)





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Crop residue field data collection

- **Survey data have been problematic, apparently is difficult to separate 30-60% cover from 60-100% cover from edge of field due to view angle and influence of headlands**

  - **Delaware drives an annual roadside survey of > 500 fields with a follow-up team collecting line-point transect data from a subset of field for QAQC**

  - **Survey works best under moist conditions that promote visible contrast between soil and residue, when very dry they have to stop**

Landsat 8, 22 May

	Overall		Survey
Residue Class	Ha	%	%
0–30	72,584	30.9	31.4
30–60	37,157	15.8	8.1
60–100	124,884	53.2	60.5
>30	162,041	69.1	68.6
Total	234,625	100.0	100

Hively et al., 2019 https://doi.org/10.3390/rs11161857

Satellite and survey results match for 0-30 and for 30-100 groupings, but survey is shifted from 30-60 toward 60-100 relative to satellite

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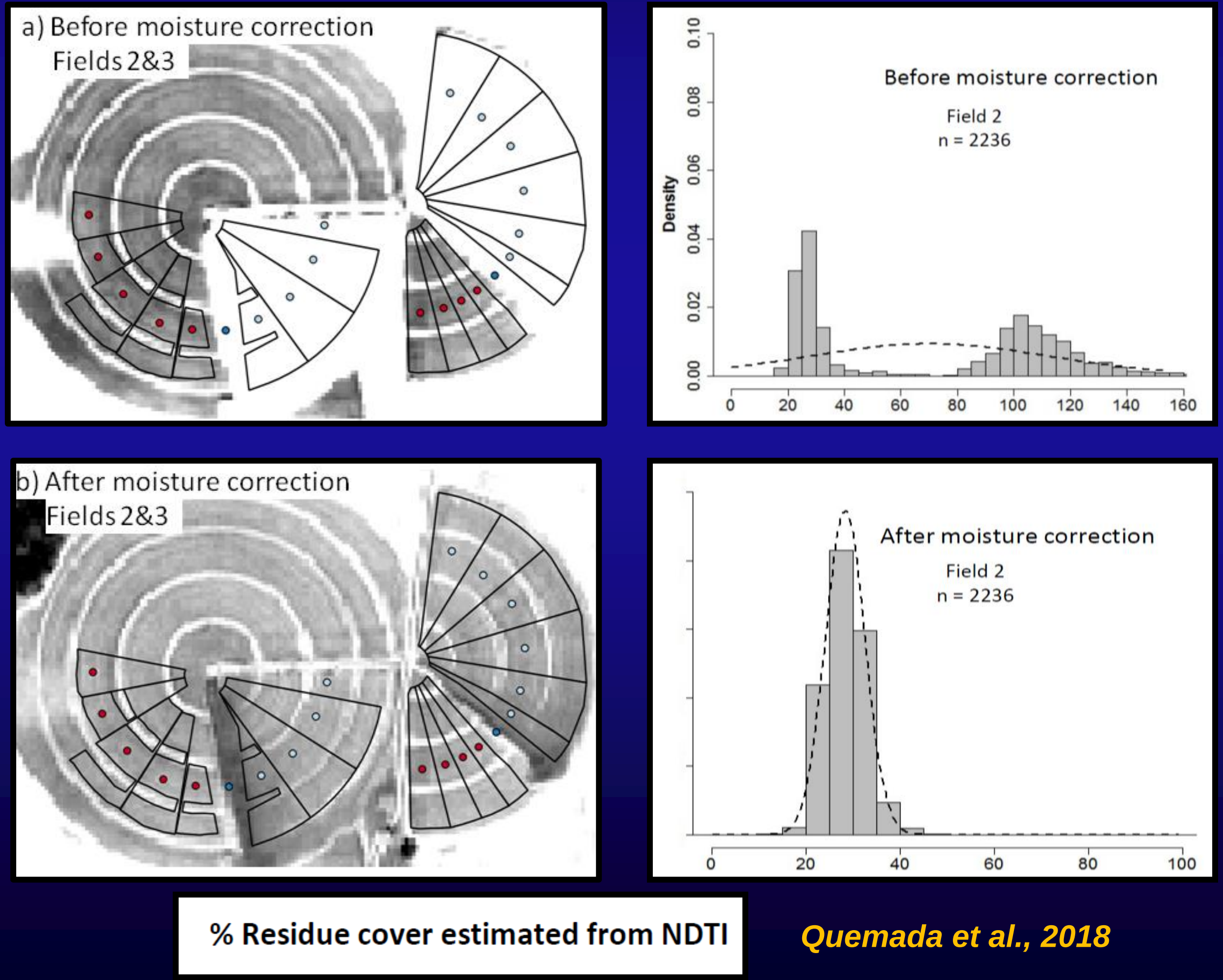
Effects of surface moisture on residue mapping

- Observed 8 fields in mid-irrigation at time of satellite overpass (May 15, 2015)
- Adjusted SWIR residue indices based on satellite water index (1660nm / 2165nm)
- Greatly improved accuracy in wet areas



Quemada et al., 2018

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Summary – crop residue cover

- In-field nadir photos from camera at 4m height is our best tool for calibration data
  - > 10 photos per field, several per satellite pixel
  - In-field spatial variability is significant
  - Avoid field edge areas – walk a long distance in each field
- Photos processed in SamplePoint, 200 points per photo = time consuming
  - Working on AI machine learning applications for photo classification
- Survey data had difficulty distinguishing 30-60% cover from 60-100% cover
  - Over-estimated >60% class, underestimated 30-60% class

Hively et al., 2018. https://doi.org/10.3390/rs10101657

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Quemada, M., W.D. Hively, C.S. Daughtry, B.T. Lamb, and J. Shermeyer. 2018. Improved crop residue cover estimates obtained by coupling spectral indices for residue and water. Remote Sensing of Environment 206 (2018) 33-34; https://doi.org/10.1016/j.rse.2017.12.012

Remote Sensing special issue publications on crop residue and nonphotosynthetic vegetation : https://www.mdpi.com/journal/remotesensing/special_issues/Crop_Residue_Non-Photosynthetic_Vegetation#published

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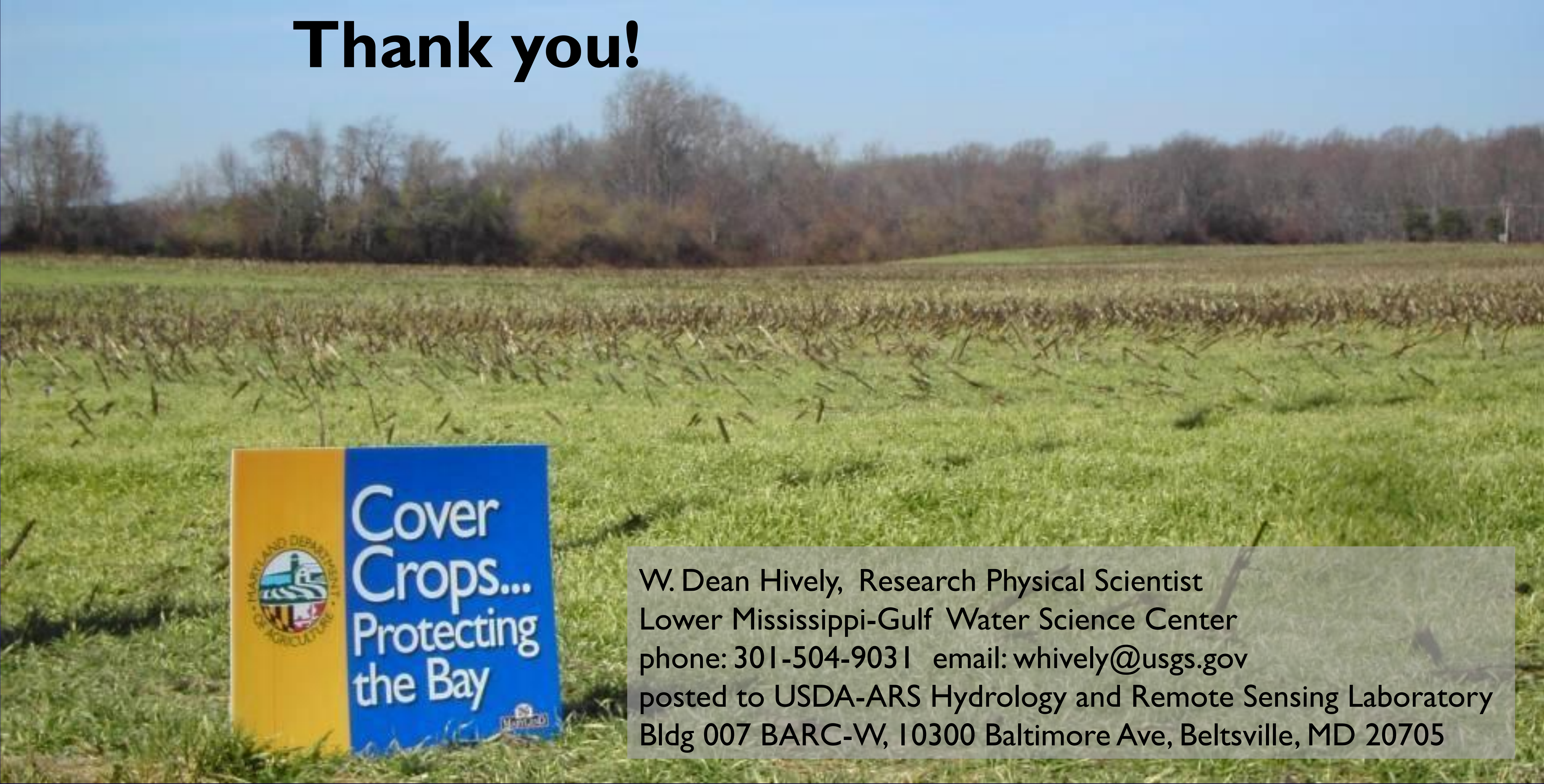
Green = cover crop publications ; orange = crop residue publications

Thank you!



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