Assessing Maryland cover crop performance with satellite imagery

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- U.S. Department of the Interior
- U.S. Geological Survey

CBP Agricultural Working Group meeting
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Winter cover crops for water quality

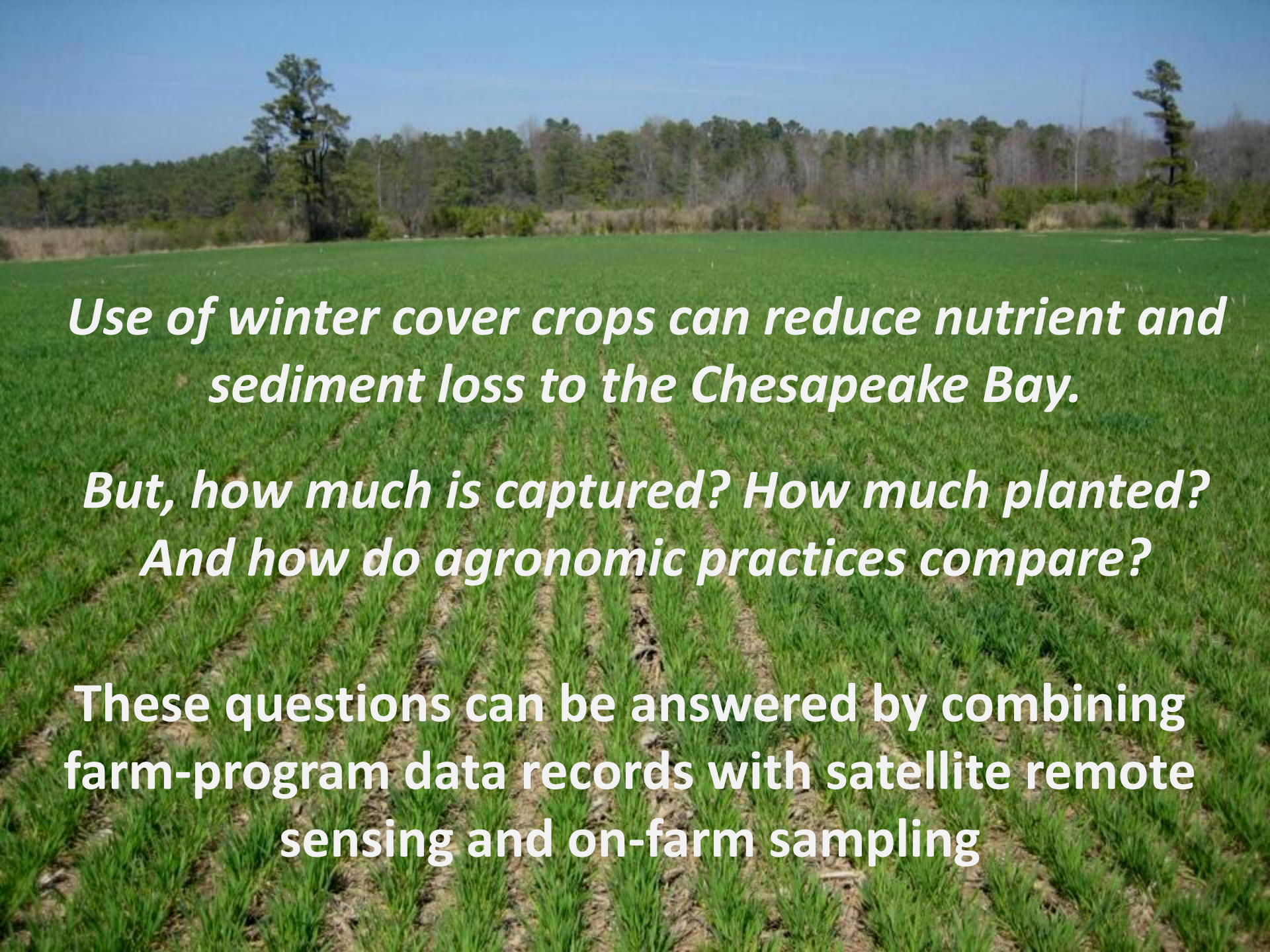
- Improve soil health
- Improve soil aggregate stability, biological activity
- Alleviate compaction, increase trafficability
- Provide groundcover and reduce soil erosion
- Help to manage weeds
- Produce useful products (grain silage, emergency forage, straw harvest, bioenergy)
- Improve nutrient management

*** REDUCE NITROGEN AND SEDIMENT LOSS ***

USGS

On-farm cover crop performance varies

USGS



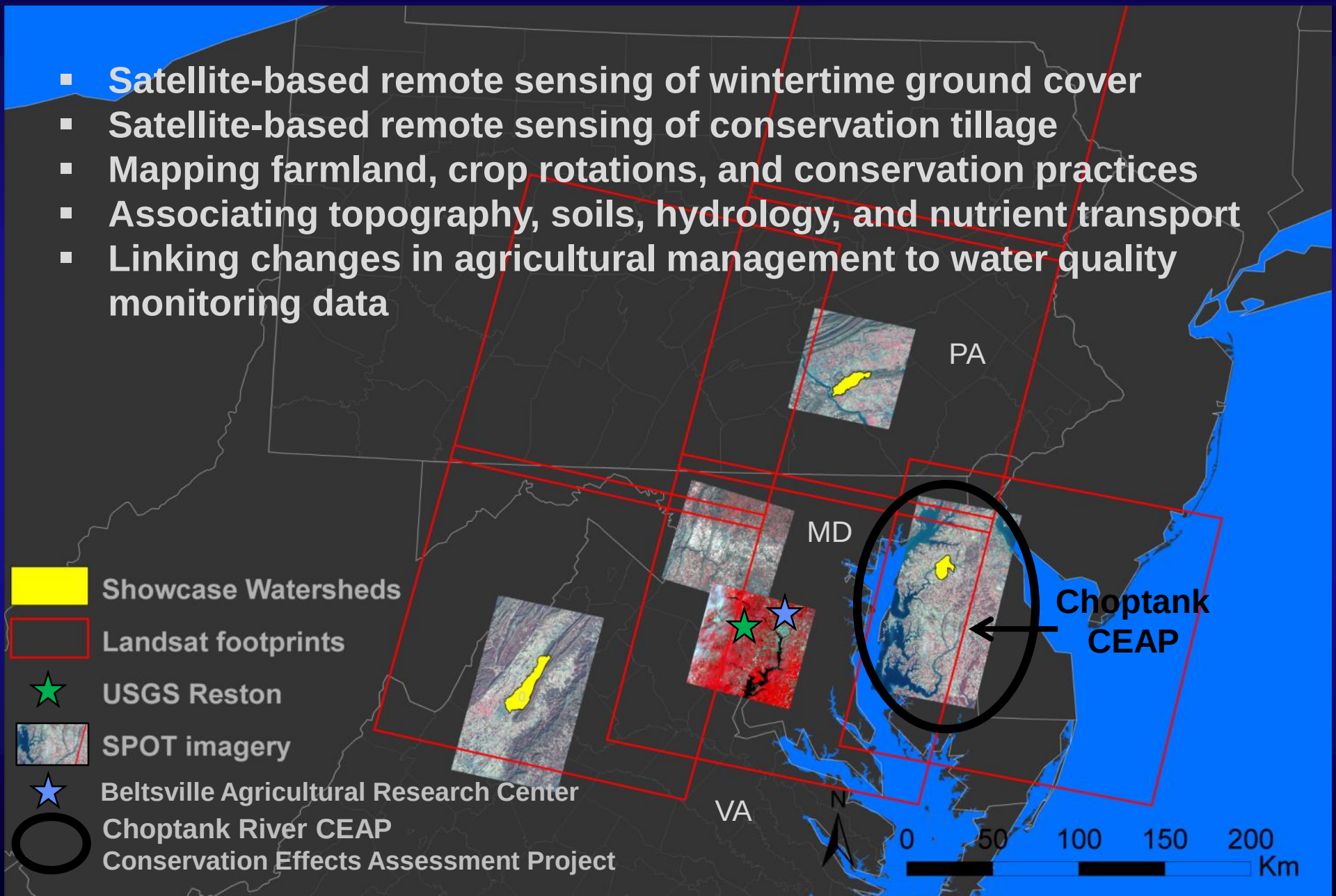
Use of winter cover crops can reduce nutrient and sediment loss to the Chesapeake Bay.

But, how much is captured? How much planted? And how do agronomic practices compare?

These questions can be answered by combining farm-program data records with satellite remote sensing and on-farm sampling

Remote sensing study areas 2006-2019

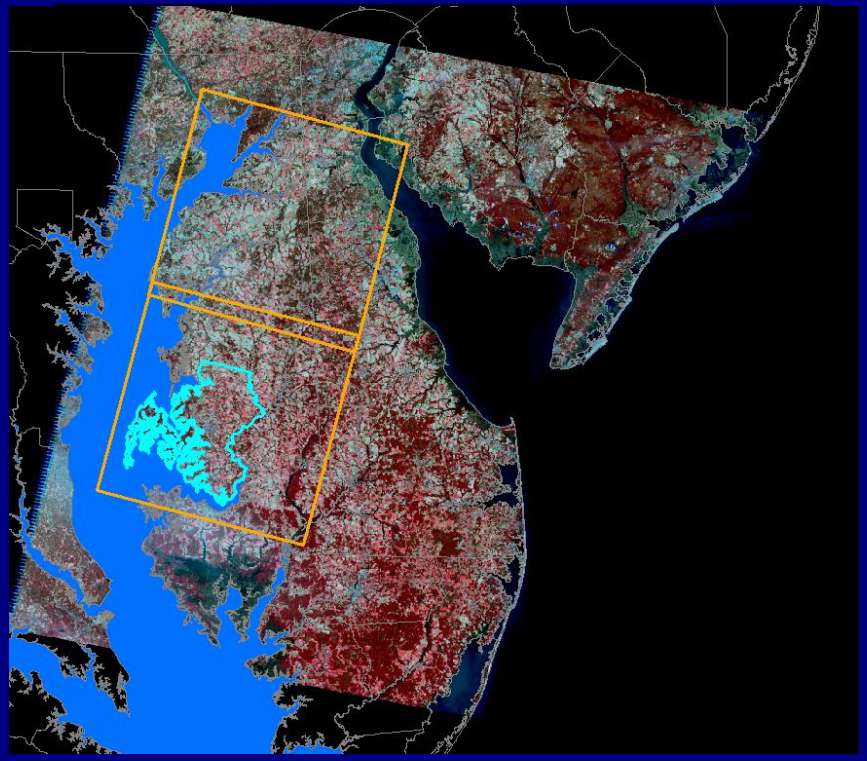
- Satellite-based remote sensing of wintertime ground cover
- Satellite-based remote sensing of conservation tillage
- Mapping farmland, crop rotations, and conservation practices
- Associating topography, soils, hydrology, and nutrient transport
- Linking changes in agricultural management to water quality monitoring data

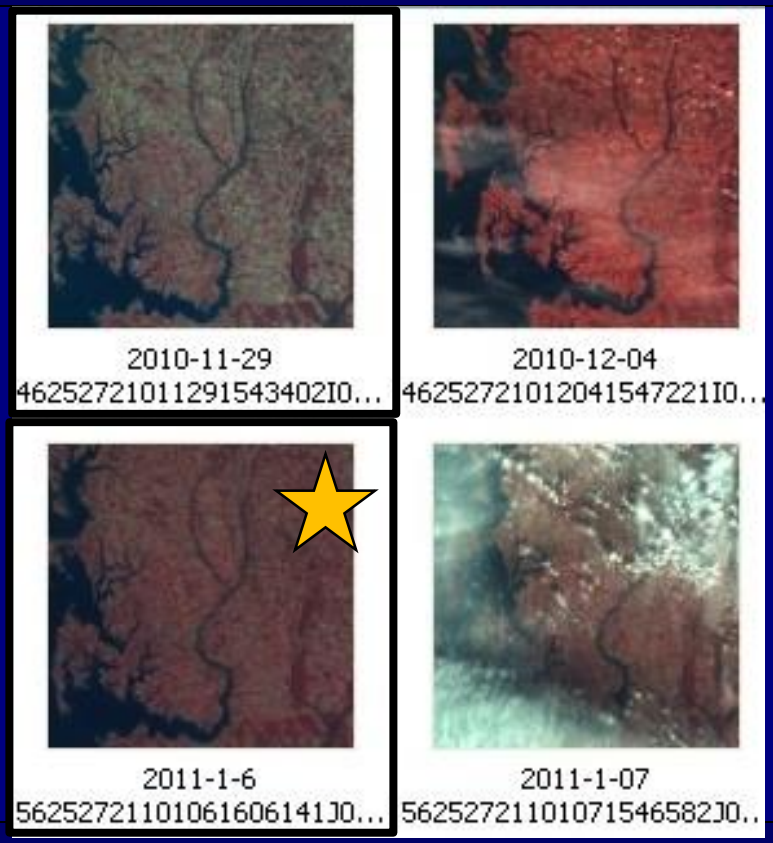


Satellite Imagery

Landsat, SPOT, Worldview3 imagery

Landsat5 Imagery March 8th, 2011





- Sometimes cloudy, sometimes clear
- Each image is a snapshot in time
- Fairly accurate mapping of agricultural vegetation
- We are most interested in mid-winter and early spring

USGS

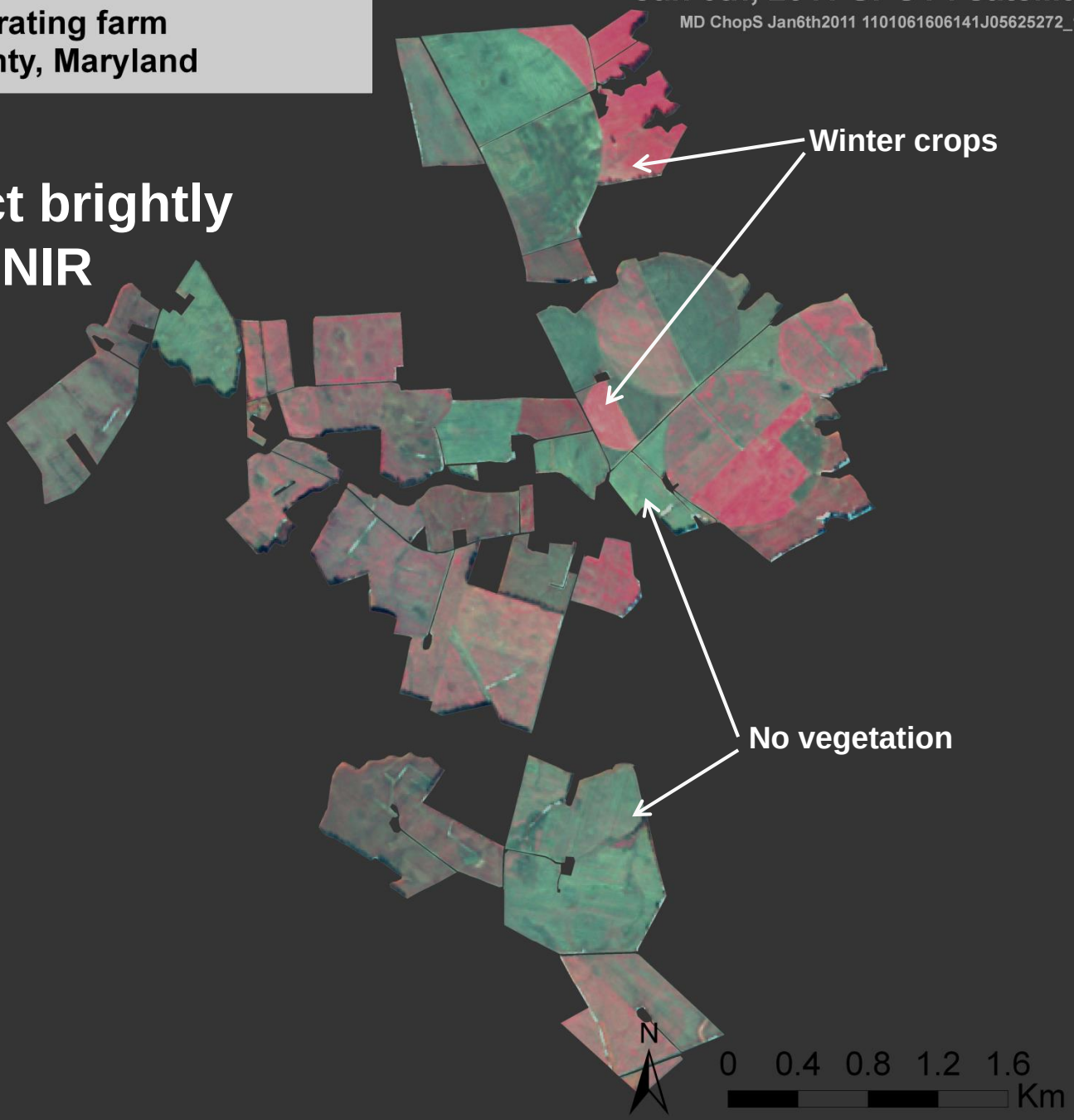
D. Hively, USGS EGSC, USDA-ARS Choptank CEAP, 12-13-2012

A collaborating farm
Talbot County, Maryland

Jan 6th, 2011 SPOT4 satellite imagery

MD ChopS Jan6th2011 1101061606141J05625272_1GST_sh_toa_tif.tif

Plants reflect brightly in the NIR



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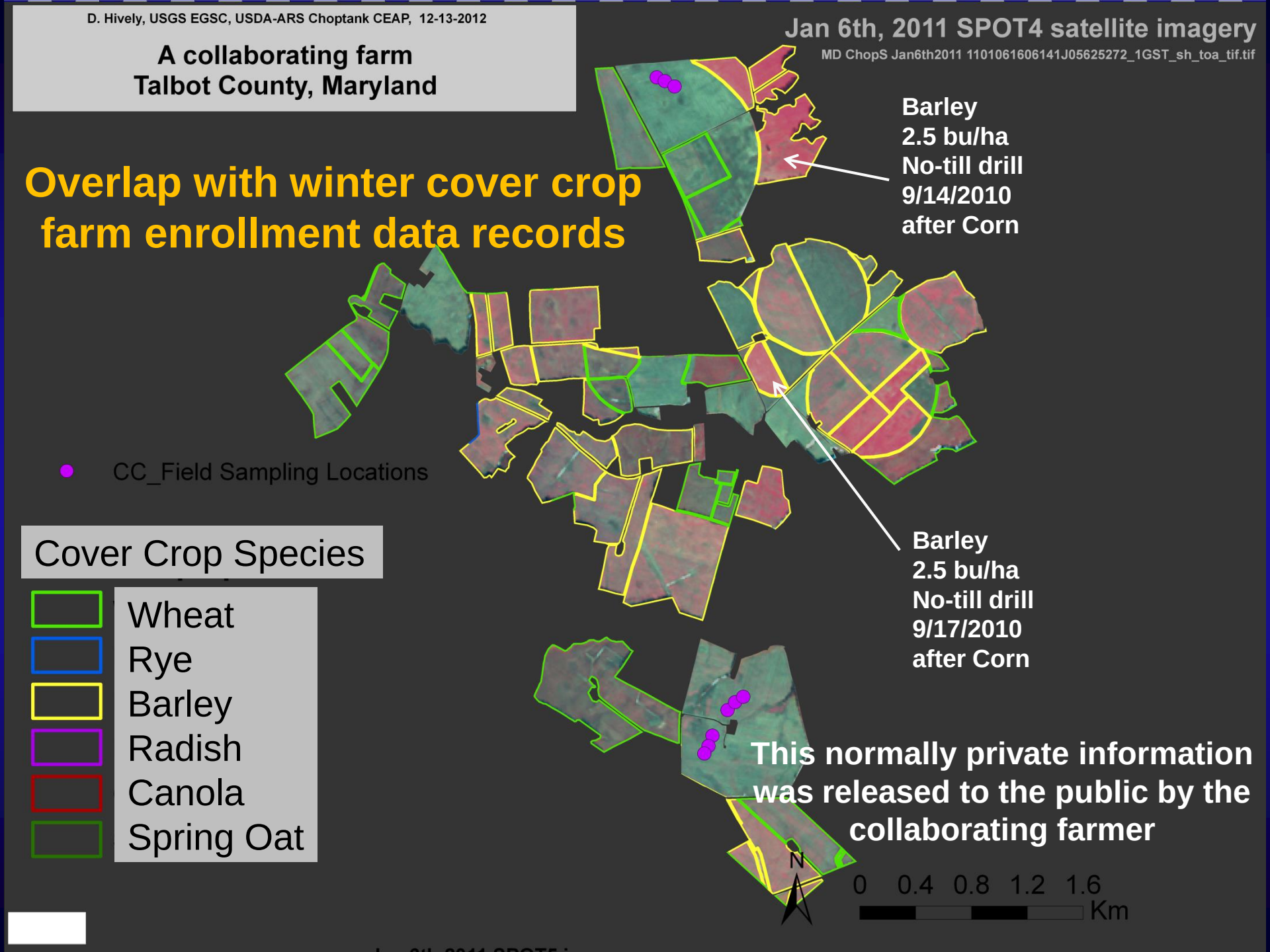
MDA provides cost-share program farm enrollment data

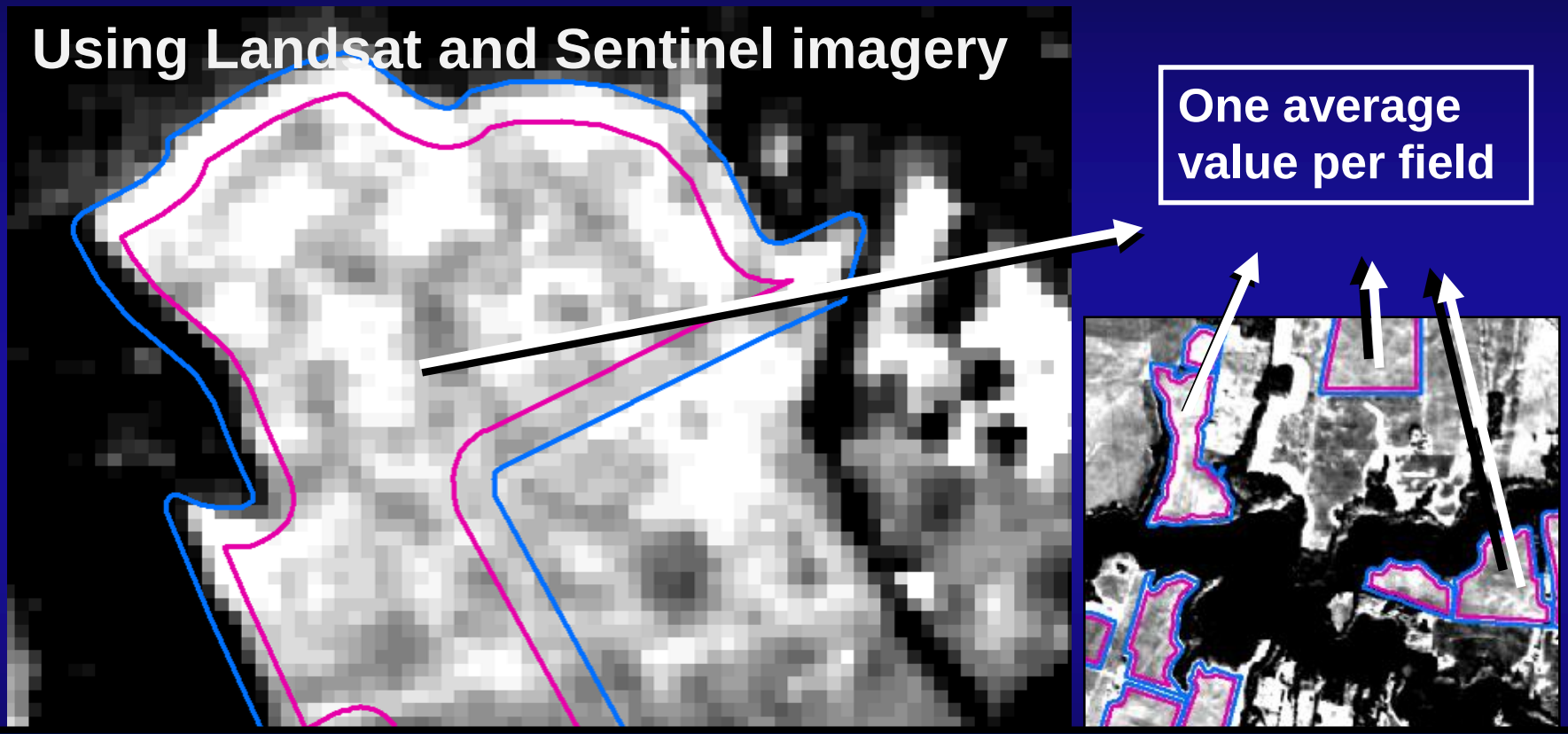
- Field location
- Species (rye, barley, wheat, brassicas)
- Planting method (drilled, broadcast, aerial)
- Planting date (Mid-September to Nov 5th)
- Previous crop (corn grain, corn silage, soy)

This allows us to use remotely sensed measures of aboveground biomass as a *response variable*

USGS


D. Hively, USGS EGSC, USDA-ARS Choptank CEAP, 12-13-2012
A collaborating farm
Talbot County, Maryland
Jan 6th, 2011 SPOT4 satellite imagery
MD ChopS Jan6th2011 1101061606141J05625272_1GST_sh_toa_tif.tif
Overlap with winter cover crop farm enrollment data records
Barley
2.5 bu/ha
No-till drill
9/14/2010
after Corn
CC_Field Sampling Locations
Barley
2.5 bu/ha
No-till drill
9/17/2010
after Corn
Cover Crop Species
Wheat
Rye
Barley
Radish
Canola
Spring Oat
This normally private information was released to the public by the collaborating farmer
N
0 0.4 0.8 1.2 1.6
Km

Calculate vegetation index (NDVI) for each cover crop field



Use calibrations to translate vegetation indices into performance measures:

- Biomass
- N content
- % ground cover

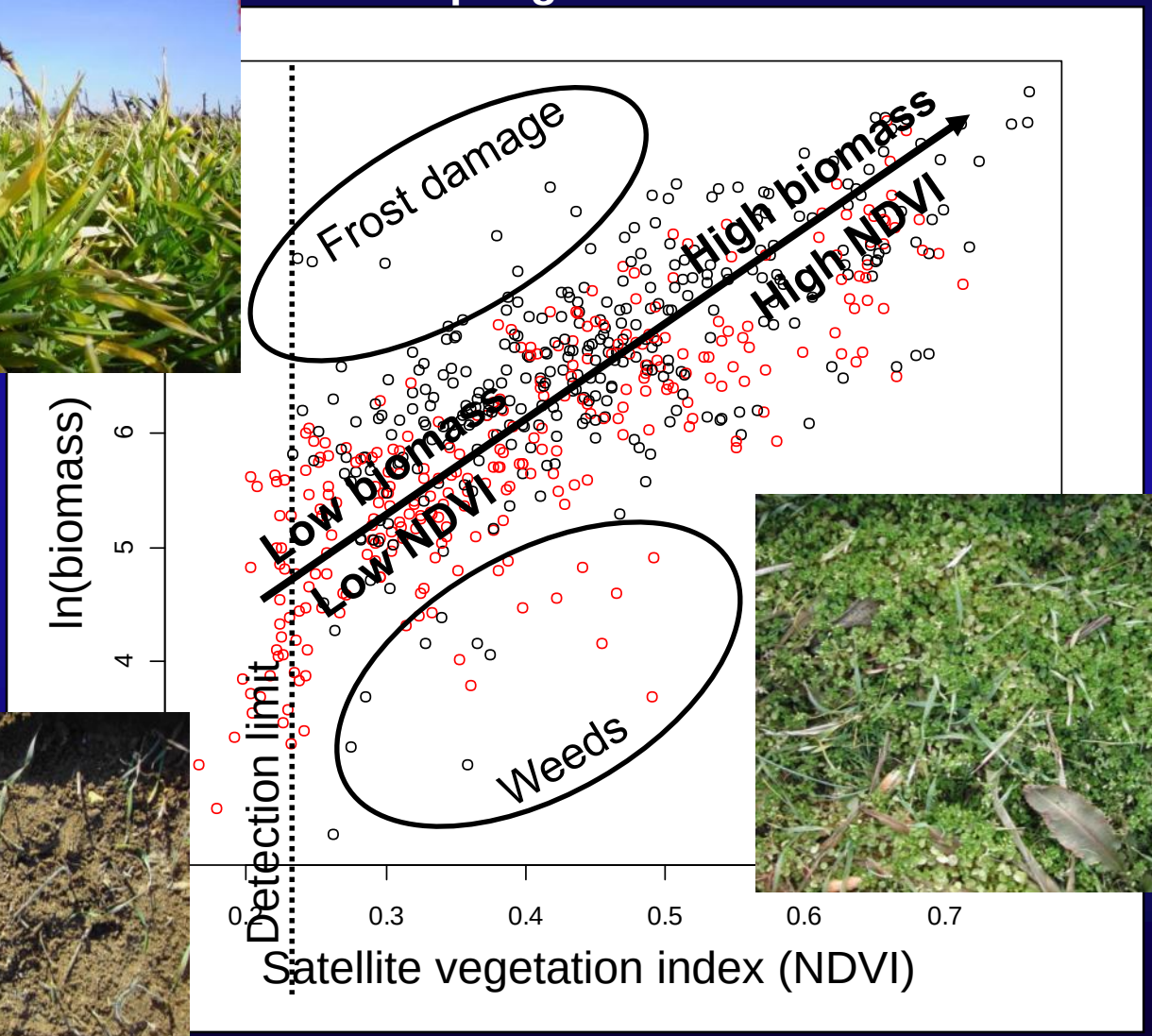
On-farm field sampling for calibration

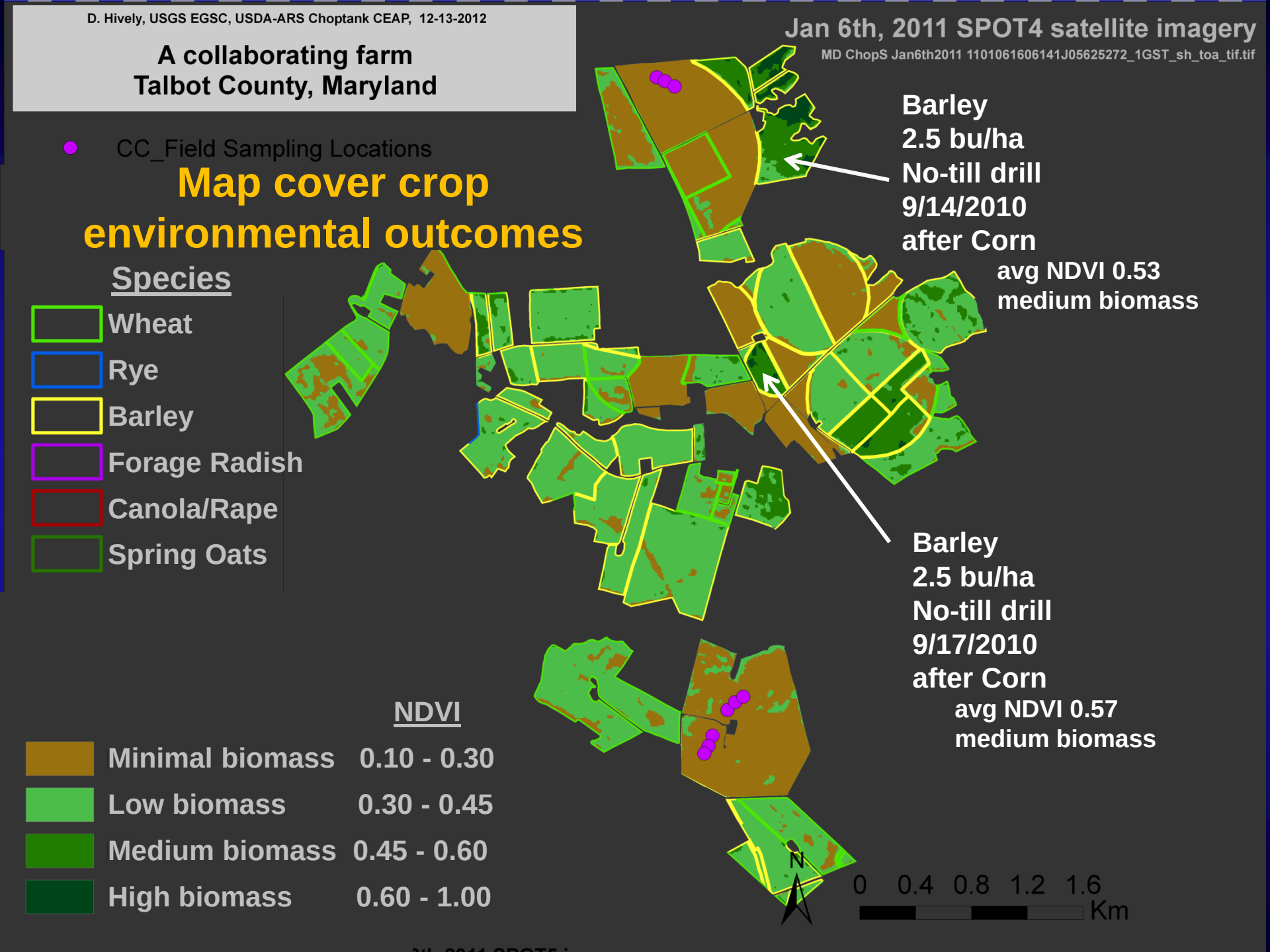
- Aboveground biomass
- Plant N, chlorophyll
- Surface reflectance
- % cover (RGB photos)
- Soil nitrate content
- ~ 30 fields per season
  - Dec/Jan (fall)
  - Mar/Apr (spring)
- ~ 1200 samples in 7 yrs

Extract vegetation index (e.g. NDVI) for each sampling location from satellite imagery

Use satellite imagery to predict biomass

2005-2010 field sampling data

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A collaborating farm
Talbot County, Maryland
Jan 6th, 2011 SPOT4 satellite imagery
MD ChopS Jan6th2011 1101061606141J05625272_1GST_sh_toa_tif.tif
CC_Field Sampling Locations
Map cover crop environmental outcomes
Species
Wheat
Rye
Barley
Forage Radish
Canola/Rape
Spring Oats
Barley
2.5 bu/ha
No-till drill
9/14/2010
after Corn
avg NDVI 0.53
medium biomass
Barley
2.5 bu/ha
No-till drill
9/17/2010
after Corn
avg NDVI 0.57
medium biomass
NDVI
Minimal biomass 0.10 - 0.30
Low biomass 0.30 - 0.45
Medium biomass 0.45 - 0.60
High biomass 0.60 - 1.00
N
0 0.4 0.8 1.2 1.6
Km

Biomass Thresholds

Minimal

Low

Medium

Biomass categories:

Min = no cover crop; up to 10% light weed cover

Low = cover crop early growth; groundcover <25%

Med = good cover crop growth; groundcover >25%

High = lush cover crop growth; groundcover >60%

High

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Analysis (example data for Jan 6th, 2011)

Satellite + NCDL + Records →

	Cover Crop Enrolled Fields		Observed NDVI	Predicted Biomass	Predicted N Content
	#	ha	NDVI	kg ha^{-1}	kg ha^{-1}
Species					
Wheat	1726	15039	0.36	224	4.5
Rye	123	878	0.35	226	4.5
Barley	236	2761	0.36	248	5.0
Planting Date					
Early < Oct 1	1050	8492	0.38	279	5.6
Standard Oct 1-15	630	6183	0.36	206	4.1
Late > Oct15	487	4713	0.30	128	2.6
Planting method					
Aerial	242	1404	0.31	139	2.8
Broadcast	100	651	0.32	155	3.1
Broadcast Stalk Chop	38	185	0.34	195	3.9
Broadcast Light Disk	659	5524	0.36	255	5.1
Conventional Drill	50	702	0.40	272	5.4
No-Till Drill	1078	10922	0.36	230	4.6

Assuming 2% N content for all cover crops. Data for use as example only. These data are preliminary and are subject to revision. They are being provided to meet the need for timely 'best science' information.

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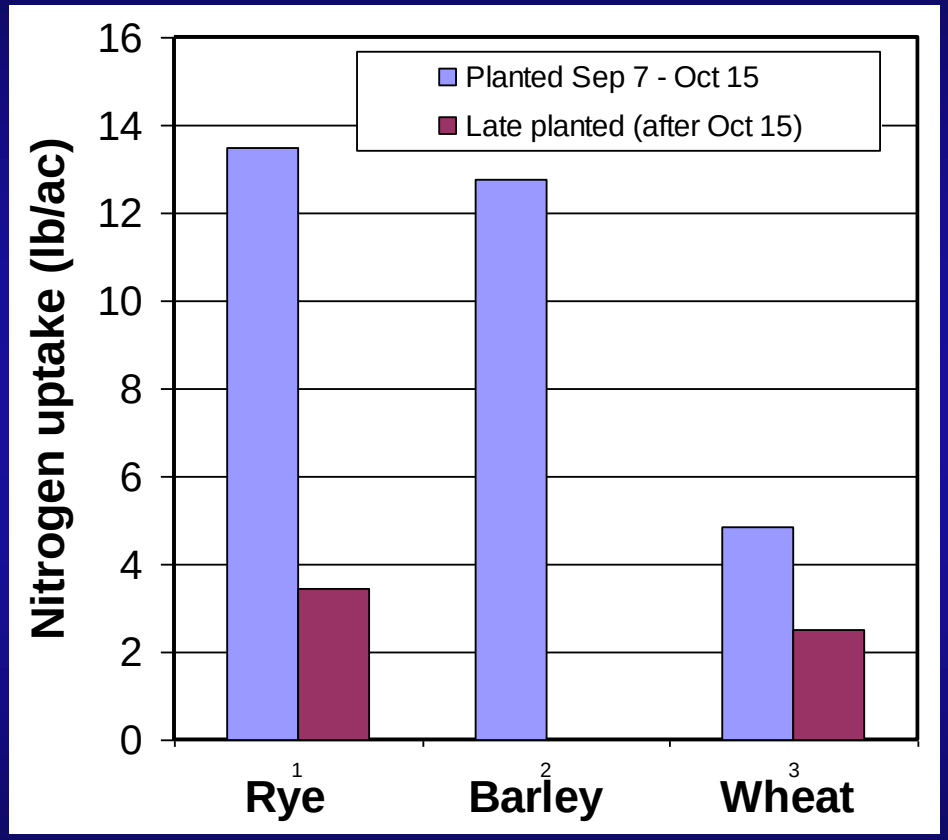
Summarize cover crop performance

(2005-6 data from Hively et al., 2009)



Planting date	Cost per lb of N uptake
Rye	
before Oct 15	$ 3.07
after Oct 15	$ 7.02
Barley	
before Oct 15	$ 3.46
after Oct 15	-
Wheat	
before Oct 15	$ 8.99
after Oct 15	$ 9.36

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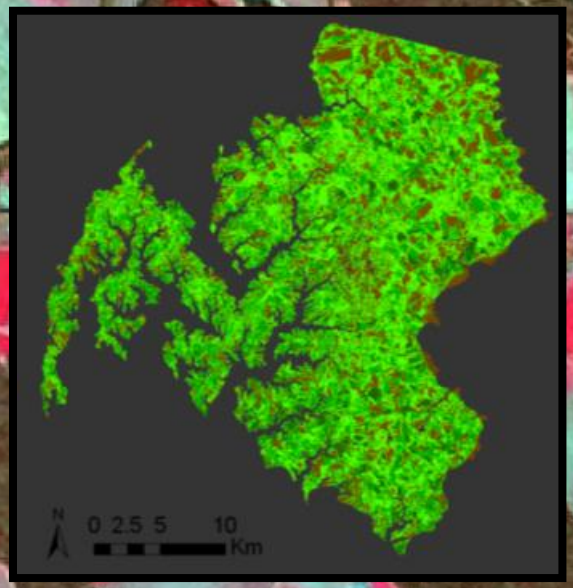
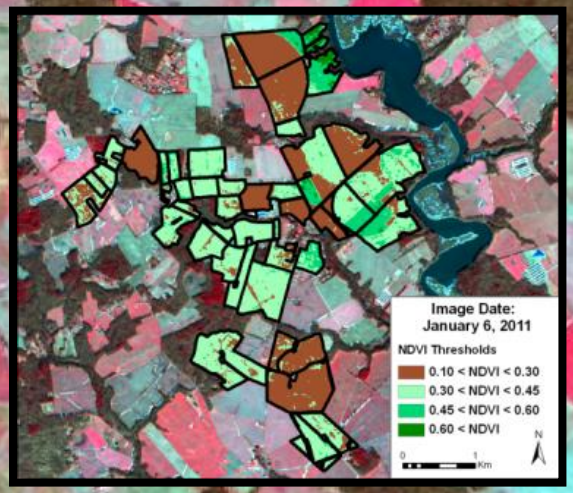
Adaptive Management of Winter Cover Crops



Produce county/watershed reports for local partners

Provide field-specific information to farmers

Target low-productivity fields for site visits



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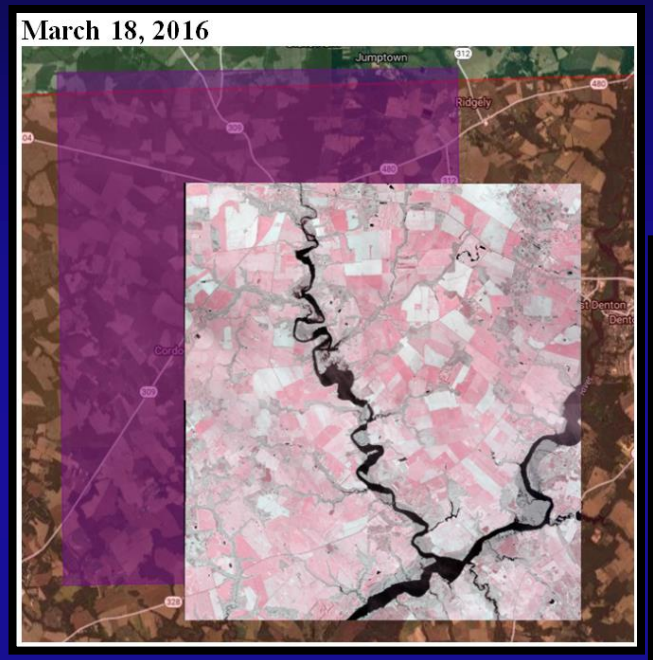
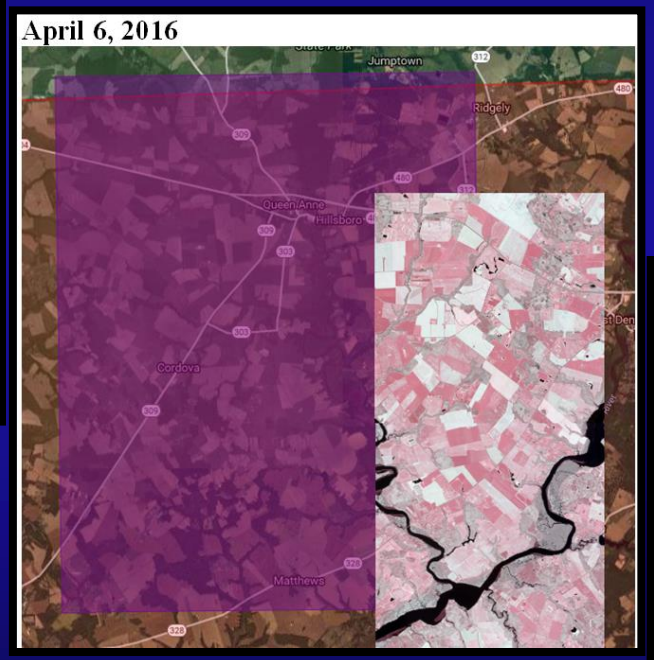
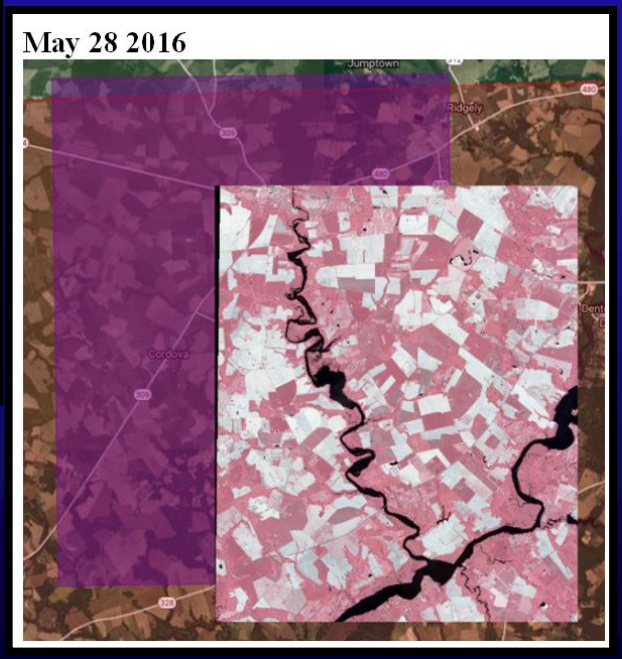
Time series analysis - winter into spring

Sequential images reveal timing and distribution of management (tillage, cover crops, phenology)







Wintertime greenness of cover crops

Cover crop termination

Tillage and planting

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Project history

- 2006 – Targeted Watersheds grant - Choptank River
  - Field sampling, develop remote sensing methods, other BMPs
- 2007 – Targeted Watersheds grant - Chester River
  - Field sampling, develop remote sensing methods, on farm trials
- 2009 – Small Watersheds grant - Talbot County
  - Field sampling, prototype digitization of field boundaries
- 2010 – INSRI grant - MD, PA, VA
  - Field sampling, expand digitization, develop public toolkit
- 2013 – Conservation Innovation Grant - NY
  - Field sampling, expand digitization, develop public tool

USGS

Project history

- 2016 – NASA DEVELOP I
  - Prototype toolkit for operational wintertime analysis
- 2018 – NASA DEVELOP II
  - Continue toolkit development for operational wintertime analysis
- 2019 – NASA DEVELOP III
  - Finish toolkit for operational wintertime and springtime analysis
- 2013 - 2019 – supported by USGS Land Change Science and USDA-ARS Conservation Effects Assessment Project

Current status

- MDA digitizes location of all enrolled cover crop fields
  - 2006 to 2017 digited in Talbot County only
  - 2017-18 and 2018-19 have statewide coverage
- DEVELOP has programmed tools to support statewide remote sensing analysis
  - Wintertime performance, verification of spring management dates
- USGS / USDA field sampling data used for calibration
  - >1200 biomass samples collected between 2006 and 2013
  - RGB photo analysis for percent groundcover calibration
- Goals
  - Support operational performance analysis by MDA
  - Expand applications in other Chesapeake Bay states

Kent county performance winter 2017-18

Species	# Fields	NDVI	Biomass	Ground Cover
			kg/ha	%
Early Wheat (pre Oct 1)	413	0.47	550	32
Mid Wheat (Oct 1 - Oct 15)	314	0.46	506	31
Late Wheat (post Oct 15)	332	0.38	298	22
Total Wheat	1059	0.44	458	29
Early Rye (pre Oct 1)	75	0.52	791	38
Mid Rye (Oct 1 - Oct 15)	19	0.52	656	38
Late Rye (post Oct 15)	61	0.4	380	25
Total Rye	155	0.47	613	33
Early Barley (pre Oct 1)	179	0.52	784	39
Mid Barley (Oct 1 - Oct 15)	109	0.54	867	41
Late Barley (post Oct 15)				
Total Barley	2			
Early Triticale (pre Oct 1)	1			
Mid Triticale (Oct 1 - Oct 15)				
Late Triticale (post Oct 15)				
Total Triticale	2			

Previous Crop	# Fields	NDVI	Biomass	Ground Cover
			kg/ha	%
Corn	831	0.47	634	33
Soybeans	793	0.45	512	31
Vegetables	12	0.61	1332	49
Double-crop Soybeans	26	0.35	261	19
Sorghum	8	0.58	830	45
All Fields	1670	0.46	576	32

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Kent county performance winter 2017-18

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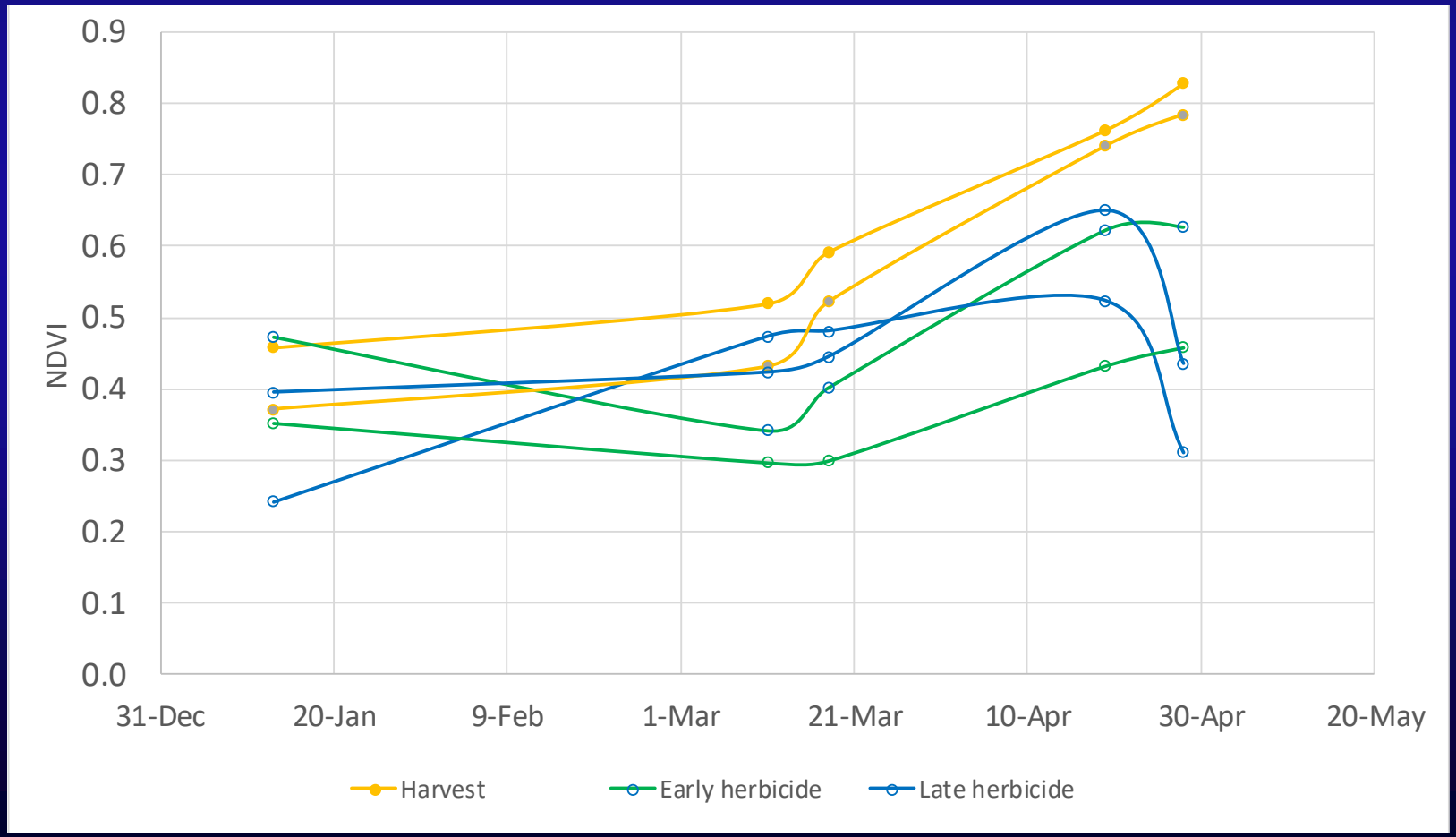
USGS

Spring time series

NDVI value for each field with every satellite overpass

- **Allows determination of spring kill date**
- **Allows identification of fields taken to harvest**



Project history

- 2006 – Targeted Watersheds grant - Choptank River - 600K
  - Field sampling, develop remote sensing methods, other BMPs
- 2007 – Targeted Watersheds grant - Chester River - 375K
  - Field sampling, develop remote sensing methods, on farm trials
- 2009 – Small Watersheds grant - Talbot County – 190K
  - Field sampling, prototype digitization of field boundaries
- 2010 – INSRI grant - MD, PA, VA - 600K
  - Field sampling, expand digitization, develop public toolkit
- 2013 – Conservation Innovation Grant - NY – 30K
  - Field sampling, expand digitization, develop public tool

USGS

Research strategy

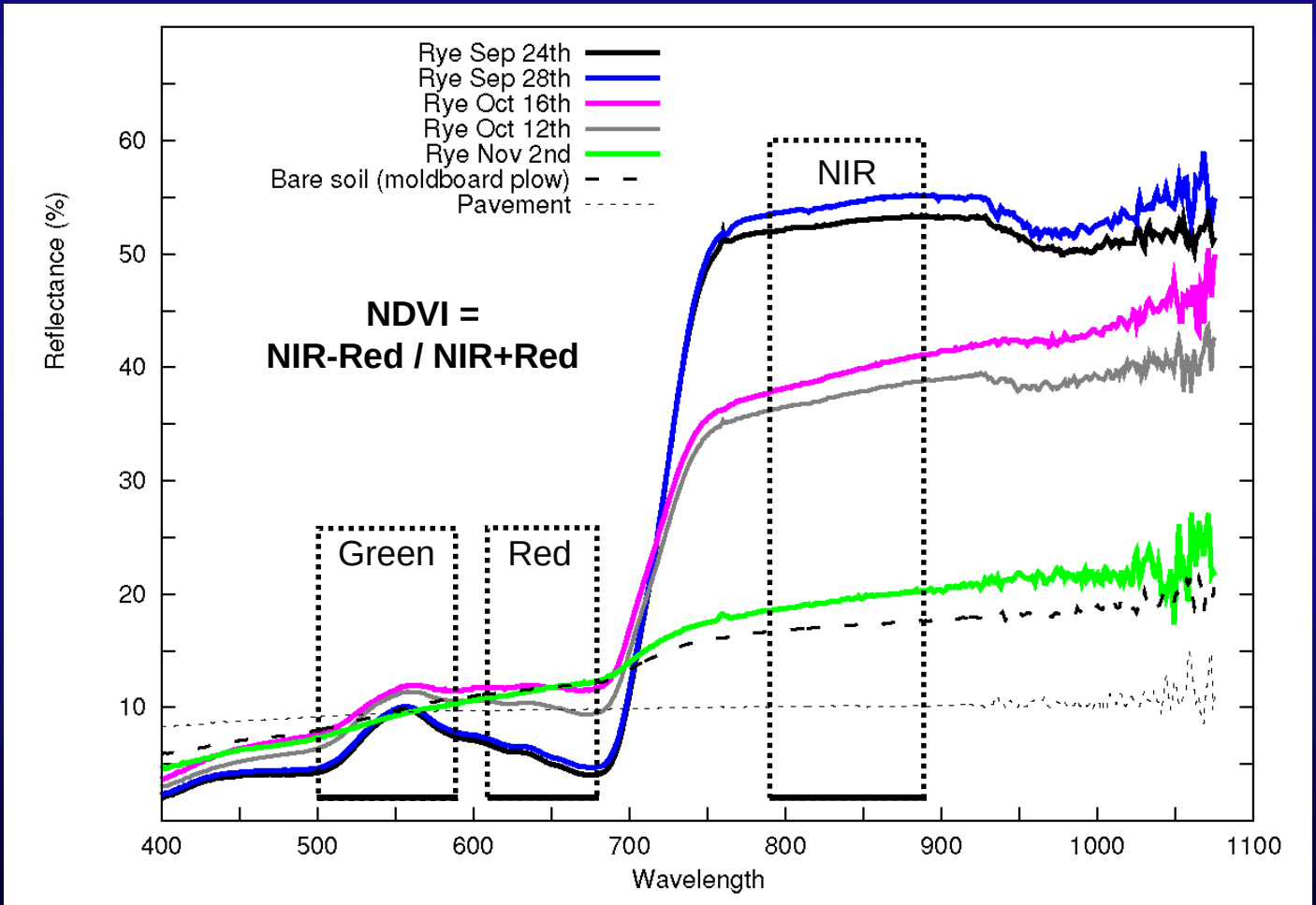
- Use remote sensing to estimate winter ground cover, biomass and nutrient uptake on agricultural fields
- Combine remote sensing analysis with site-specific knowledge of agricultural field management
- Support conservation adaptive management, with a focus on winter cover crops
- Applications on farmland throughout the Chesapeake Bay watershed

USGS


What factors affect cover crop success?
USGS

Calculation of wintertime greenness

- Multispectral vegetation indices such as NDVI or MSAVI applied to satellite imagery surface reflectance



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Talbot County 2010-2011 Cover Crop Performance