Evaluating and improving cover crop performance and adoption

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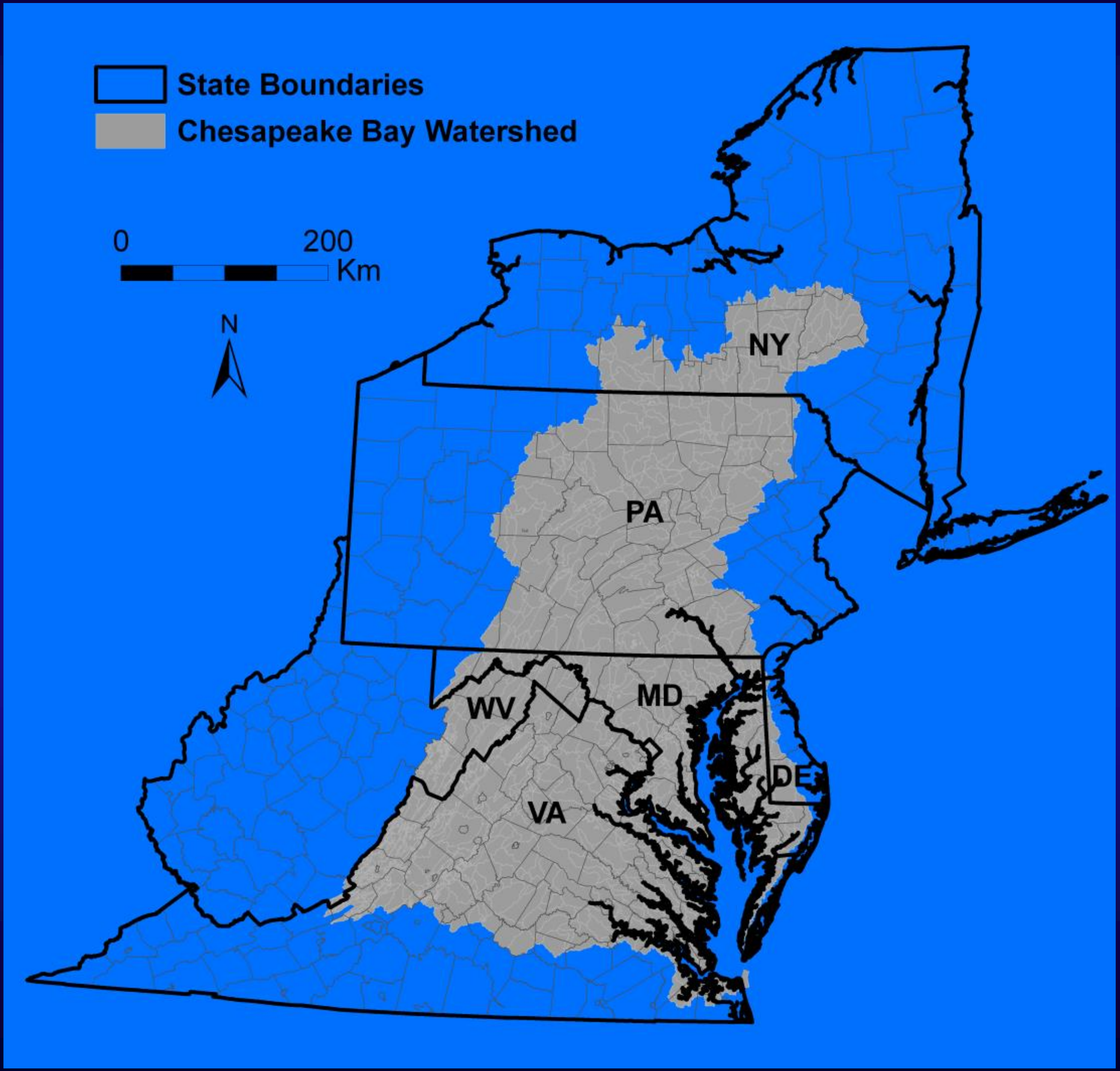
- U.S. Department of the Interior
- U.S. Geological Survey

NESARE Cover Crop Workshop
March 30th, 2016, Baltimore, MD

Chesapeake Bay



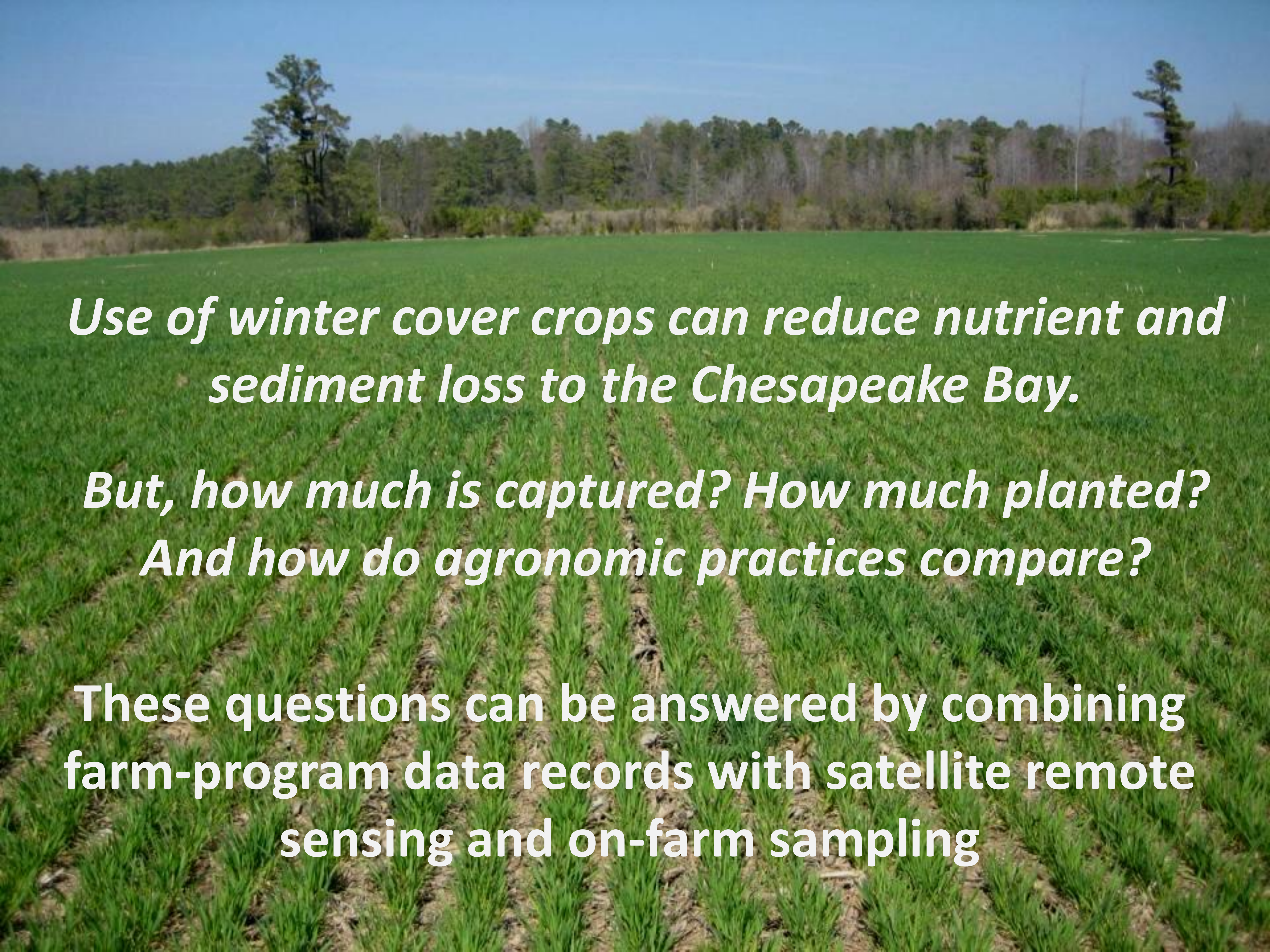
USGS

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 ***

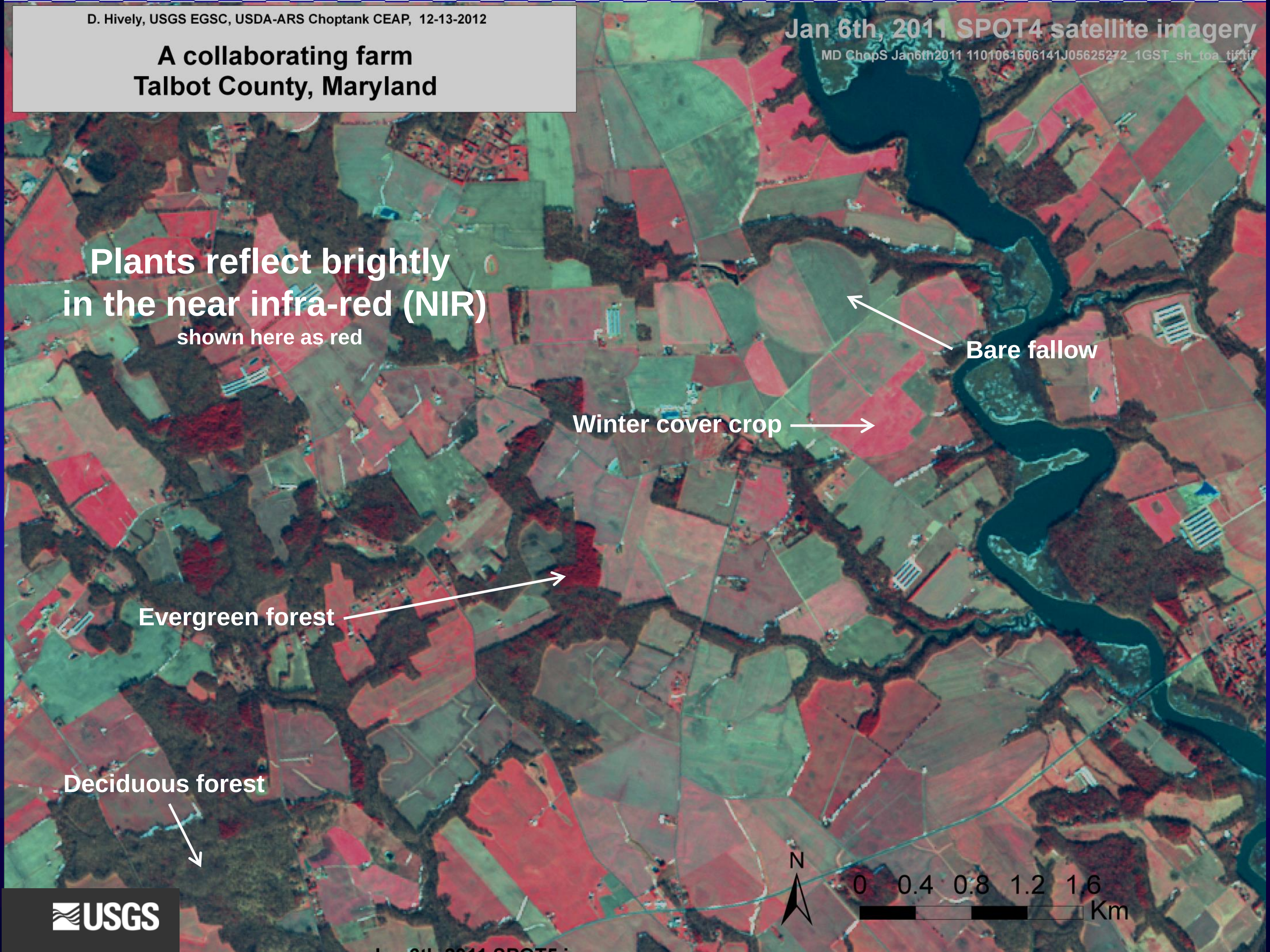
On-farm performance is variable


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

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


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 near infra-red (NIR)
shown here as red
Bare fallow
Winter cover crop
Evergreen forest
Deciduous forest
N
0 0.4 0.8 1.2 1.6
Km
USGS

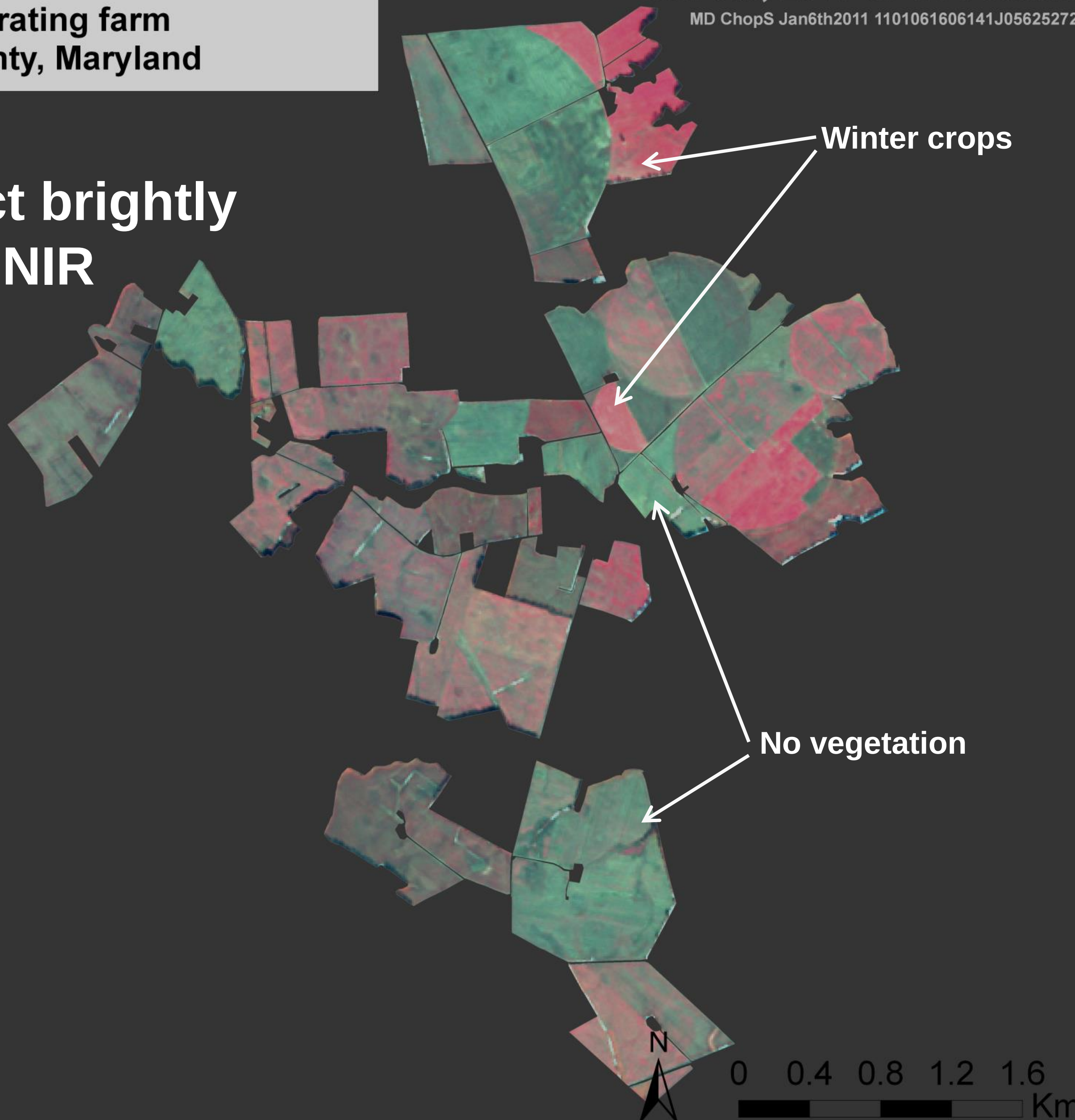
D. Hively, USGS EGSC, USDA-ARS Choptank CEAP, 12-13-2012

A collaborating farm
Talbot County, Maryland

Jan 6th, 2011 SPOT4 satellite imagery

MD ChopS Jan6th2011 1101061606141J05625272_1GST_sh_toa_tif.tif

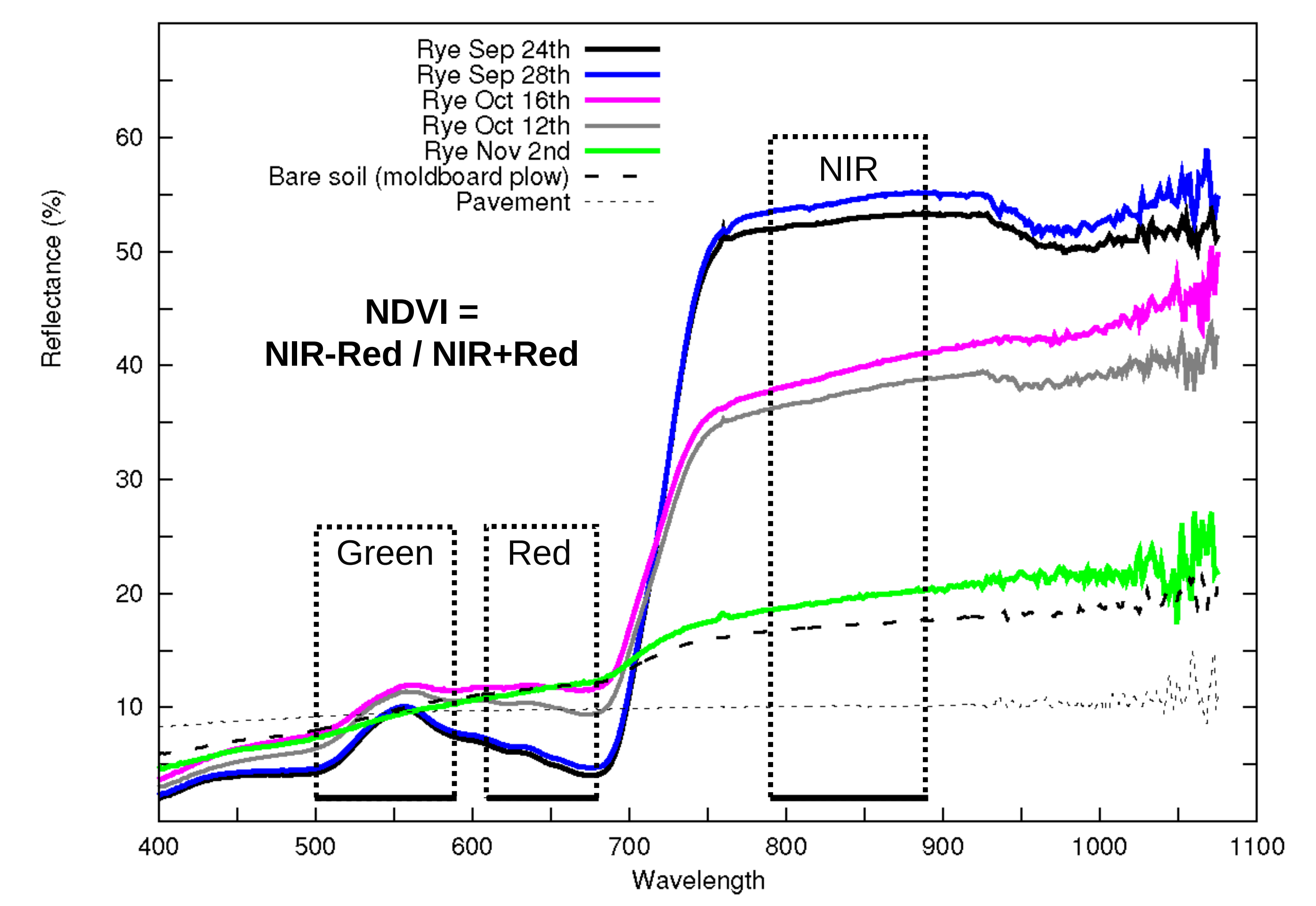
Plants reflect brightly in the NIR



USGS

Calculation of wintertime greenness

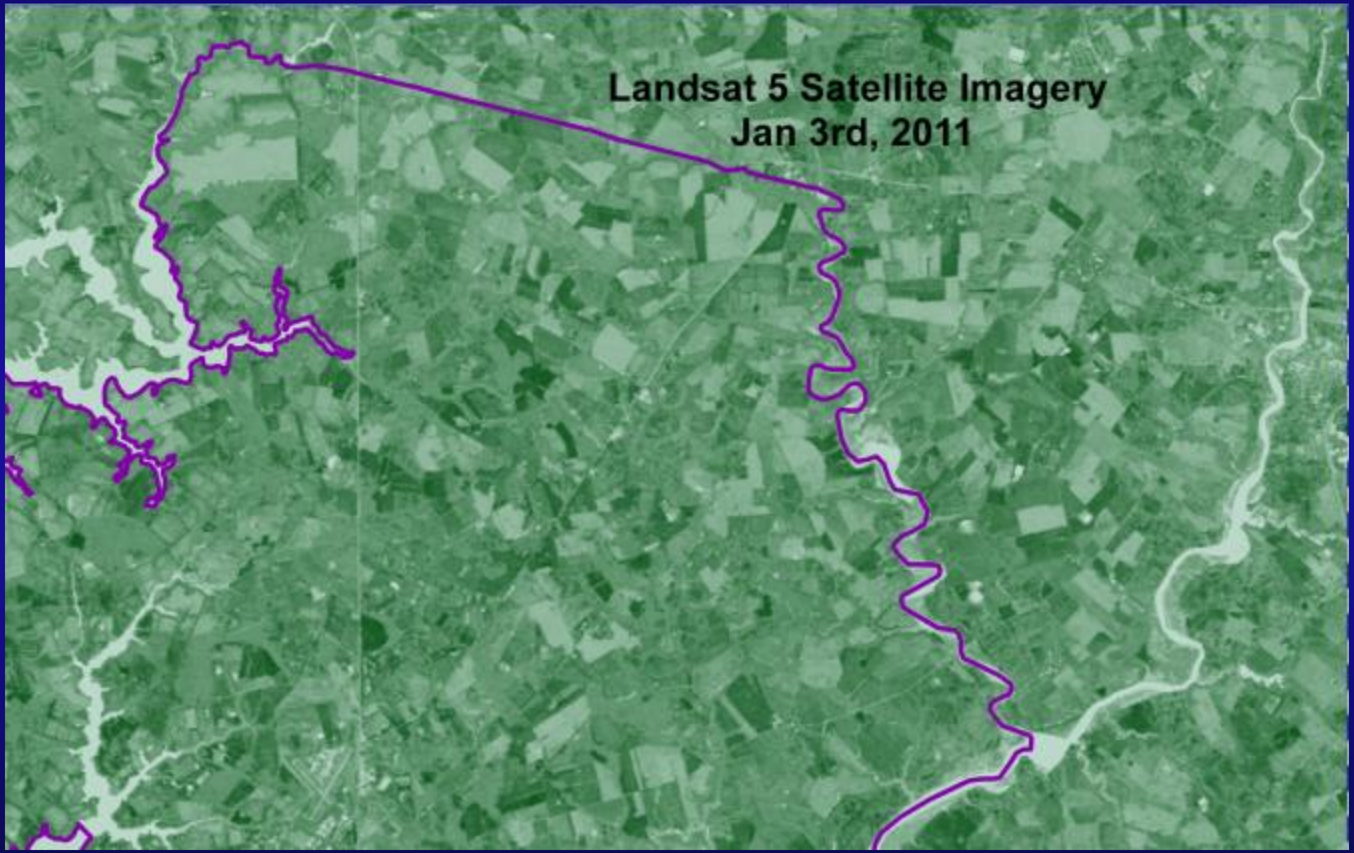
- Multispectral vegetation indices such as NDVI or MSAVI applied to satellite imagery surface reflectance



USGS

Satellite vegetation indices

- Very accurate for within-image comparison of vegetation
- Some between-image calibration issues



Each image is a snapshot in time

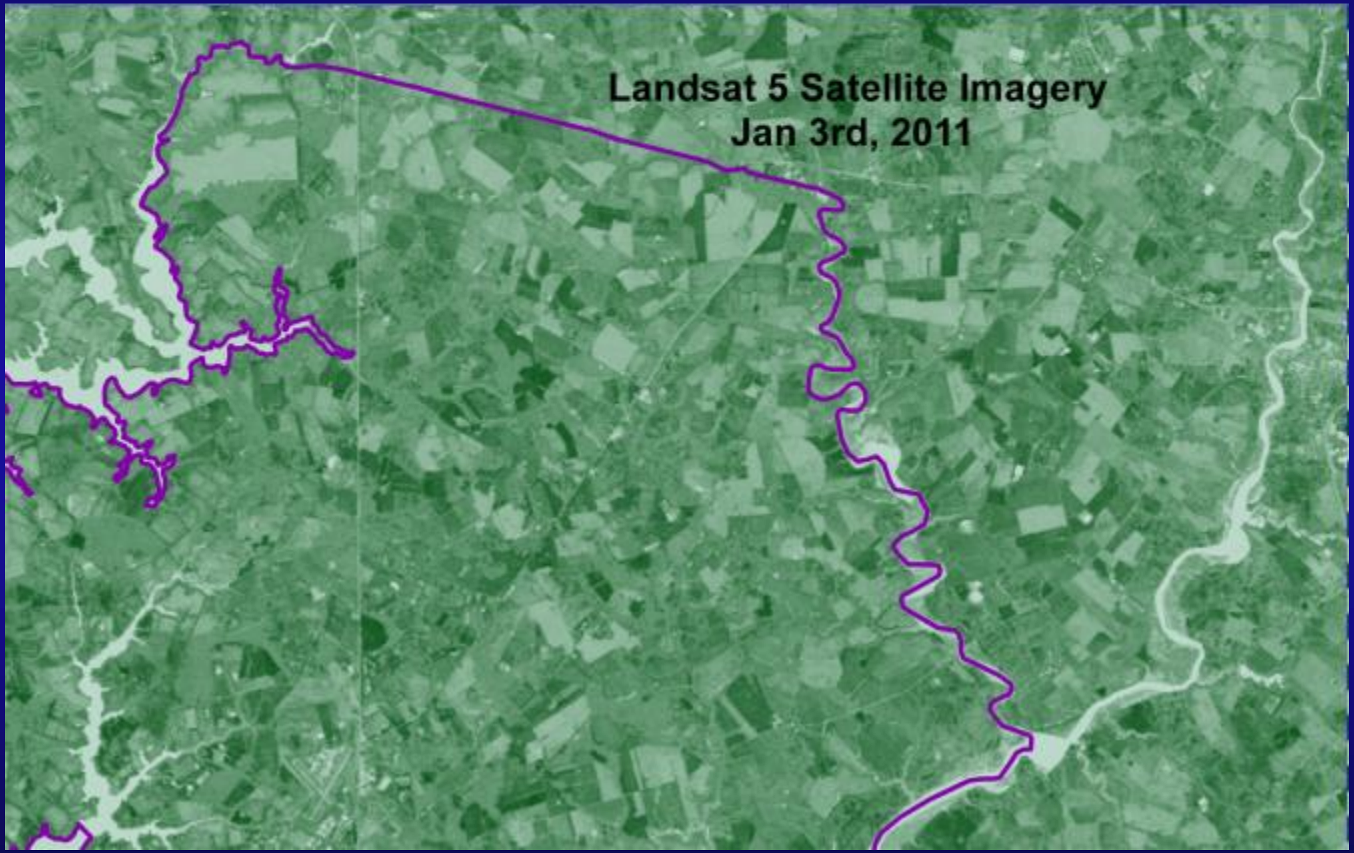
USGS

What can be done with publicly available information?

- Use satellite imagery to map wintertime vegetative ground cover
- Use the USDA-NASS cropland data layer to identify summer crop type (corn, soy, hay, etc…)
- Combine these datasets to evaluate multi-year trends in wintertime agricultural vegetation
- Create reports at county or watershed scale

Satellite vegetation indices

- Very accurate for within-image comparison of vegetation
- Some between-image calibration issues



Each image is a snapshot in time

USGS

Biomass Thresholds

Minimal

Low

Medium

High

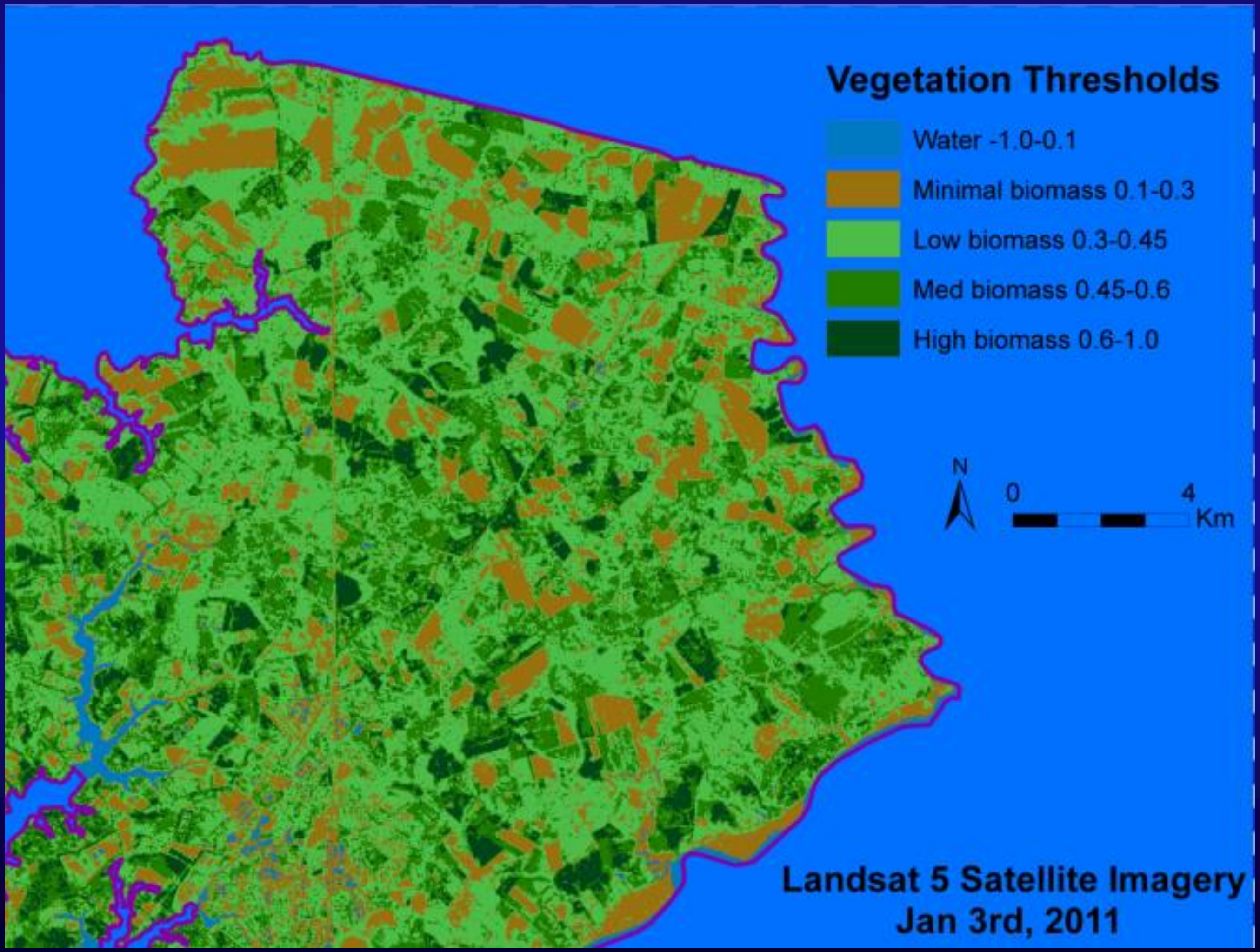
Biomass categories:

- 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%

USGS

Satellite vegetation thresholds

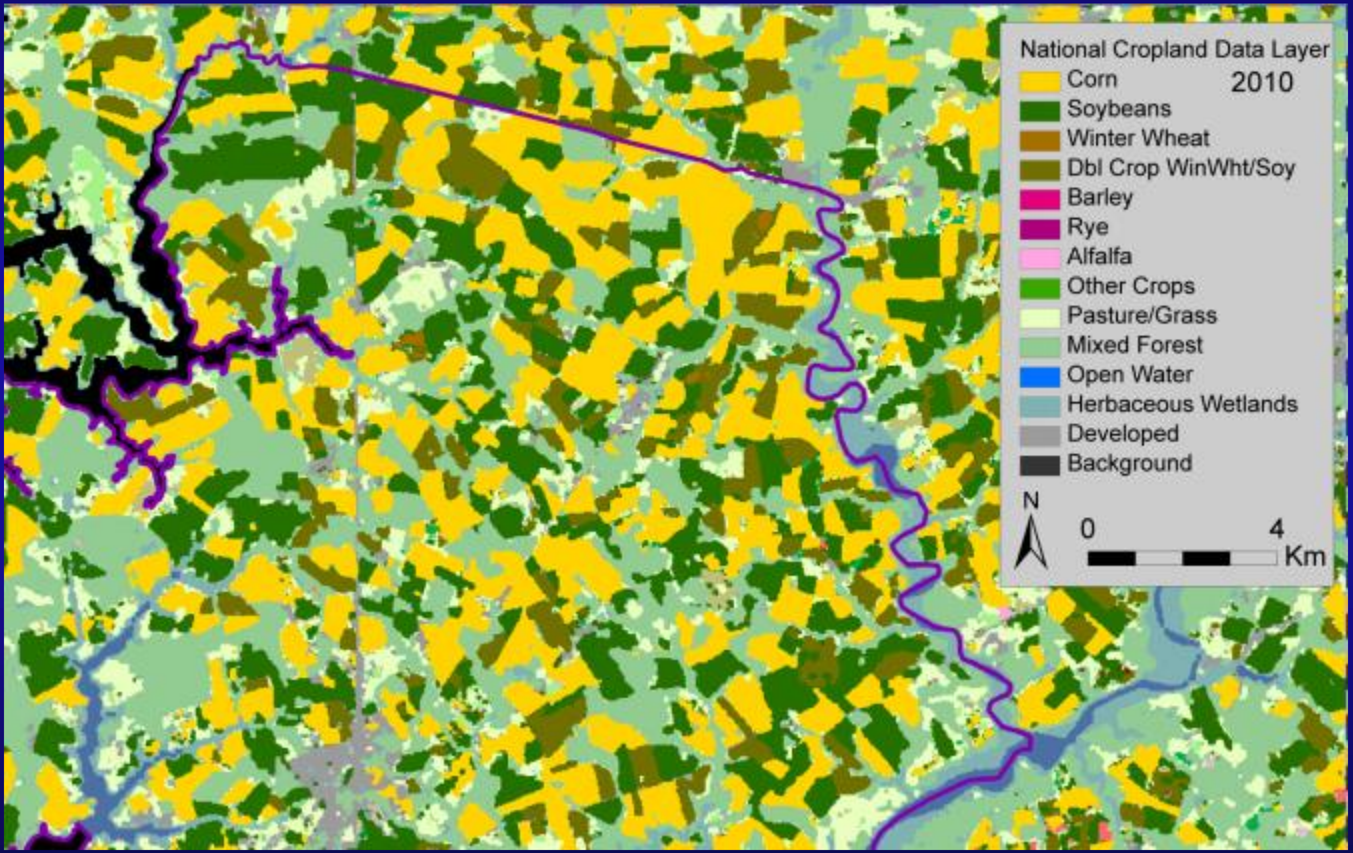
- Classification of satellite vegetation indices
- Fairly accurate but some calibration issues remains



USGS

National Cropland Data Layer (NCDL)

- Satellite-based maps of summer crop type by USDA-NASS
- Fairly accurate for large fields
- Annual maps
- 2008-present

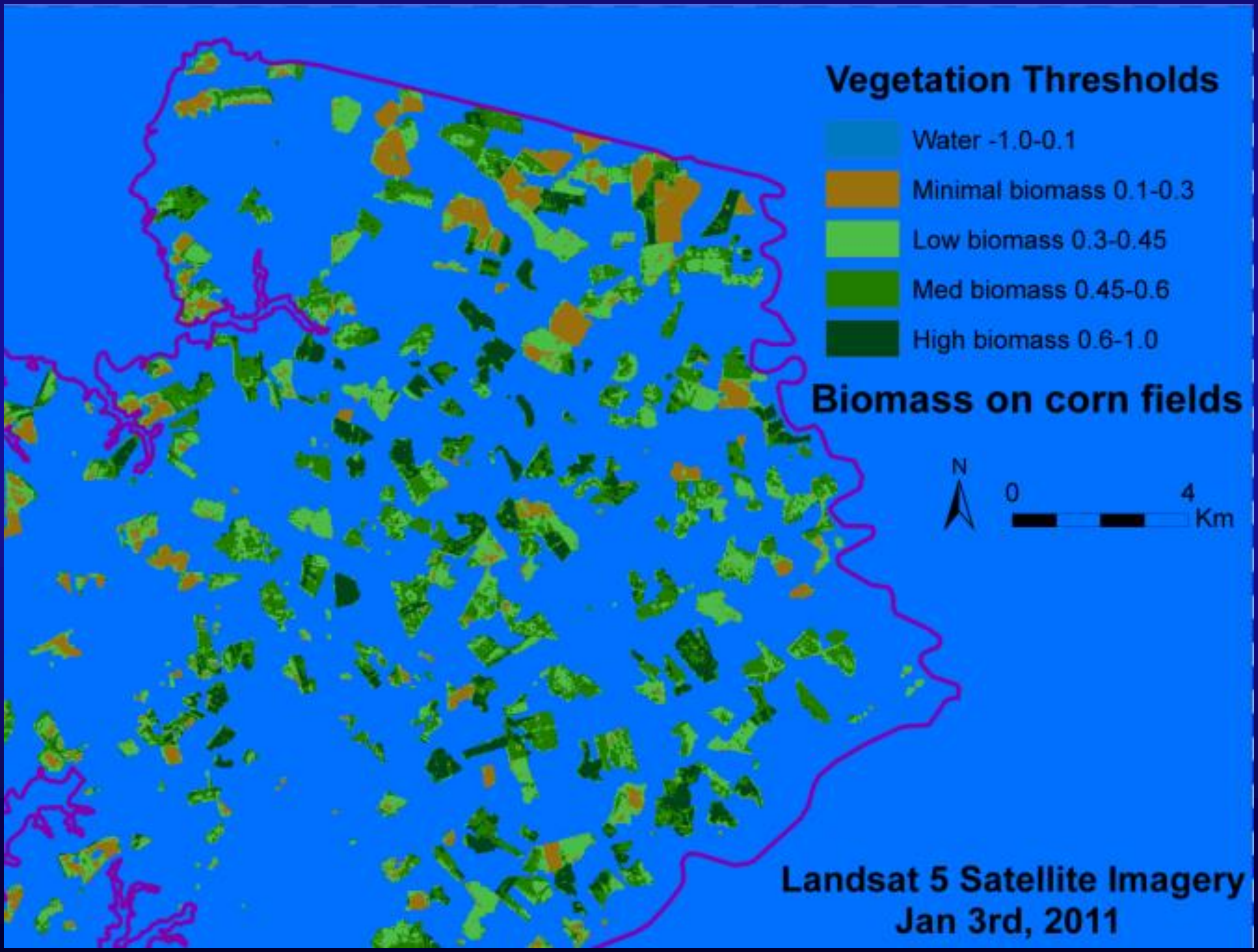


This public dataset allows us to measure winter ground cover by crop type

USGS

Winter vegetation by cropland type

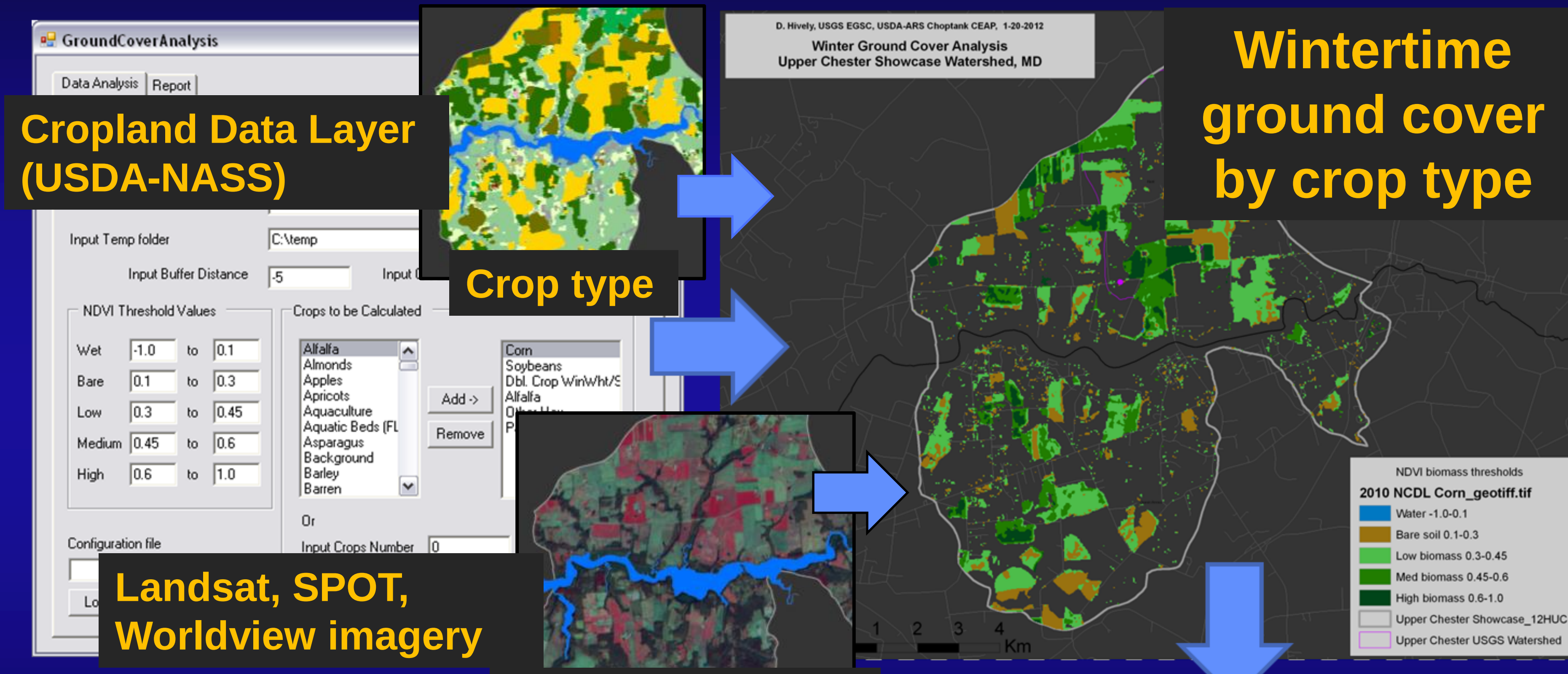
- Combination of satellite vegetation index and crop map
- Uses only public data sources



USGS

Geospatial toolkit for winter ground cover analysis

- **ArcMap toolkit combine satellite imagery with cropland data to evaluate wintertime biomass on agricultural fields**



Results are applied to adaptive management of winter cover crops and soil conservation

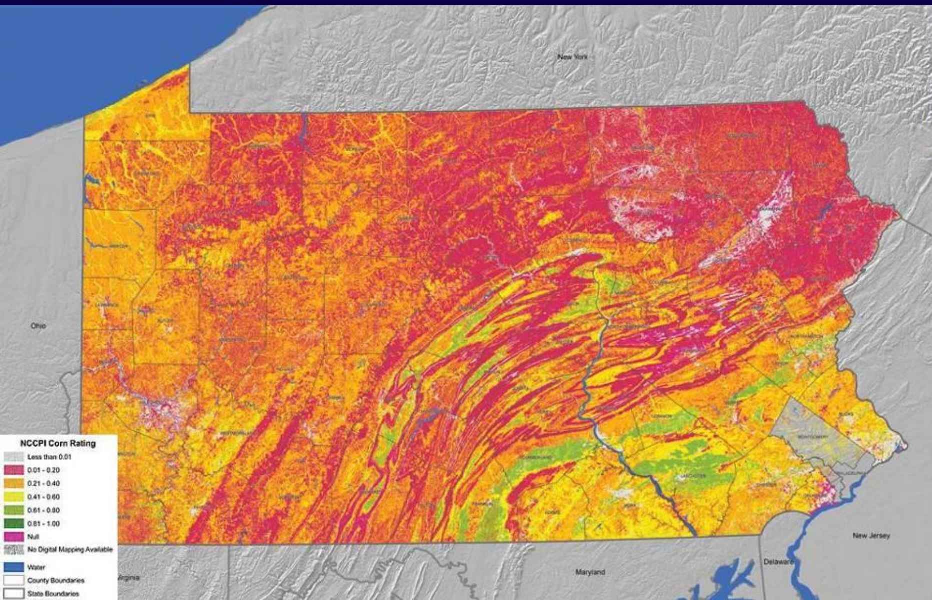
			Bare Soil 0.1<NDVI<0.3		Low Biomass 0.3<NDVI<0.45		Medium Biomass 0.45<NDVI<0.6		High Biomass 0.6<NDVI<1.0	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Entire area of interest	9460	100.0	3111	32.9	4529	47.9	1063	11.2	276	2.9
Corn	2434	25.7	552	22.7	1086	44.6	573	23.6	218	9.0
Deciduous Forest	2027	21.4	339	16.7	1637	80.8	45	2.2	1	0.0
Soybeans	1926	20.4	1024	53.2	730	37.9	153	7.9	17	0.9
Dbl. Crop WinWht/Soy	713	7.5	554	77.6	127	17.8	25	3.6	6	0.9
Pasture/Grass	682	7.2	112	16.4	427	62.6				
Other Crops	658	7.0	216	32.8	366	55.6				
Open Water	406	4.3	11	2.8	1	0.2				

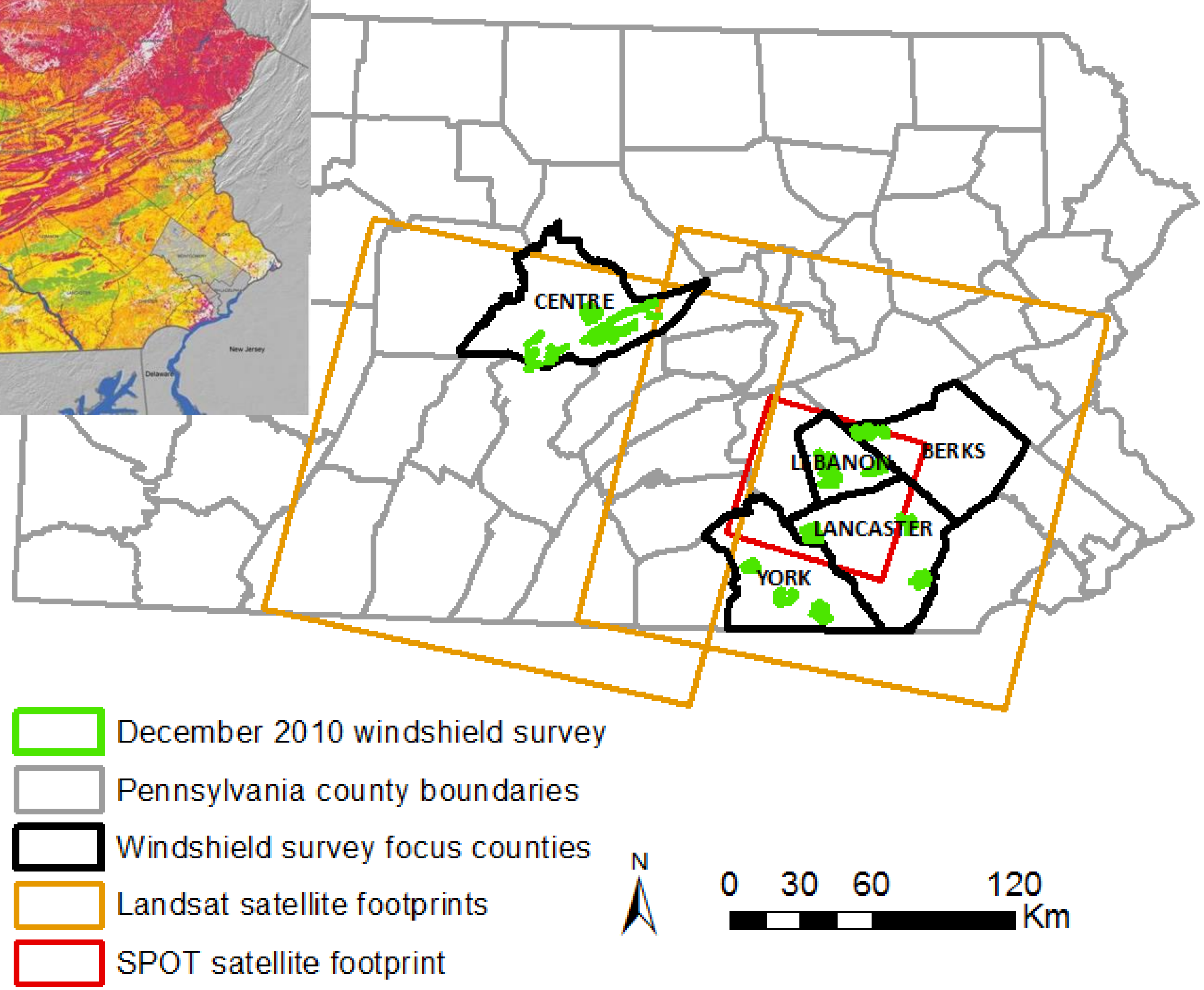
Reports

USGS

Remote sensing study in Pennsylvania

JOURNAL OF SOIL AND WATER CONSERVATION
NOV/DEC 2015—VOL. 70, NO. 6 pp 340-352





2009-2012 wintertime groundcover analysis

Collaboration among USGS, USDA-ARS, Penn State, UMD

USGS

Without carrot or stick

- Penn State extension project promoting use of cover crops following corn silage harvest (best niche)
- Several years of on-farm trials, farmer field days, and farmer education and outreach
- Most active from 2010-2012
- Sjoerd Duiker, coordinator, funded by NFWF CIG
- Working from the theory that outreach can be more effective than incentives (the carrot) or regulation (the stick)

~ Can we measure the implementation results using remote sensing? ~

USGS

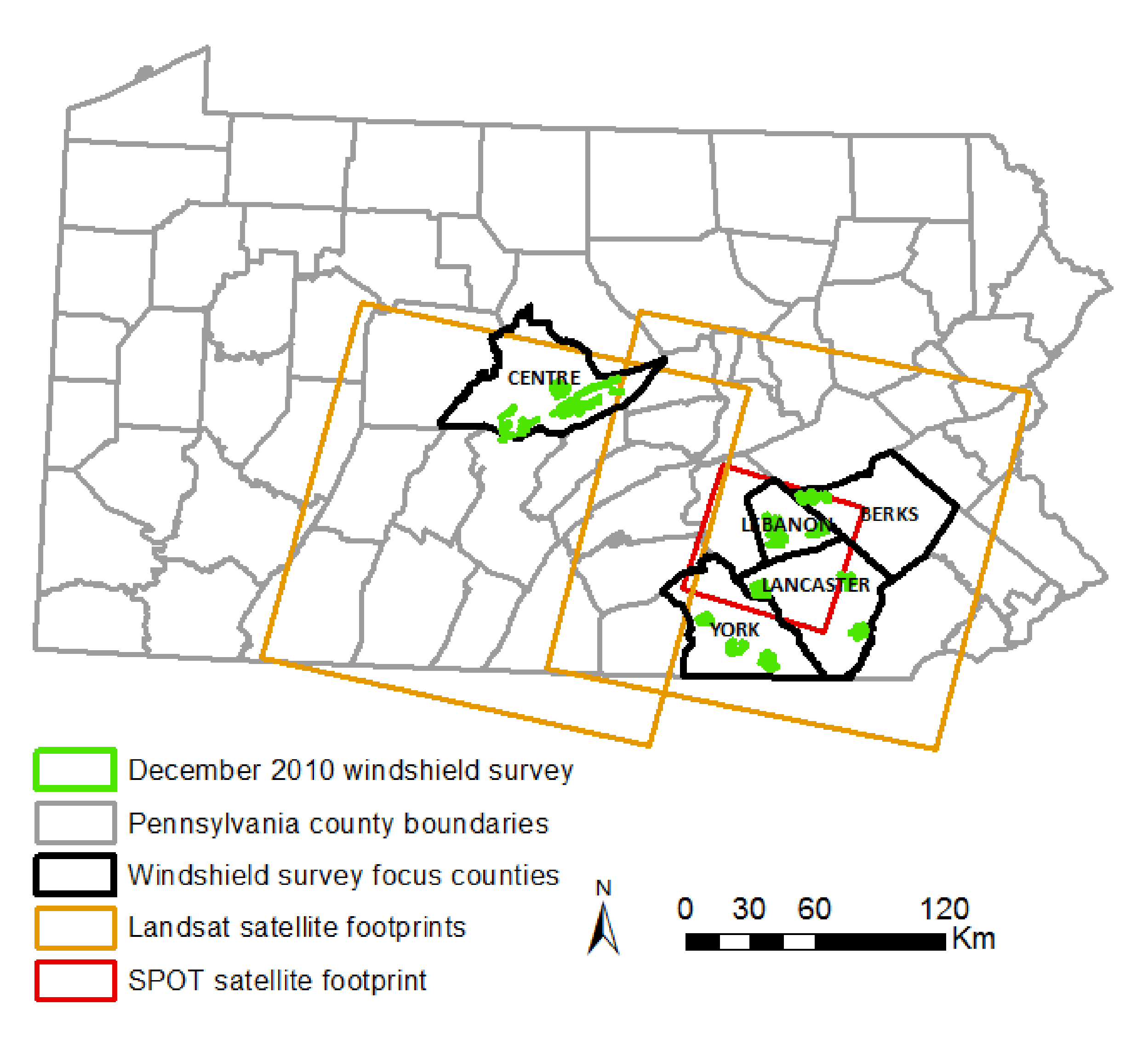
Windshield survey (Dec 2010)

- Mapped routes driven by collaborators

- They scored fields for apparent vegetative ground cover and previous crop

- Data collection in December 2010

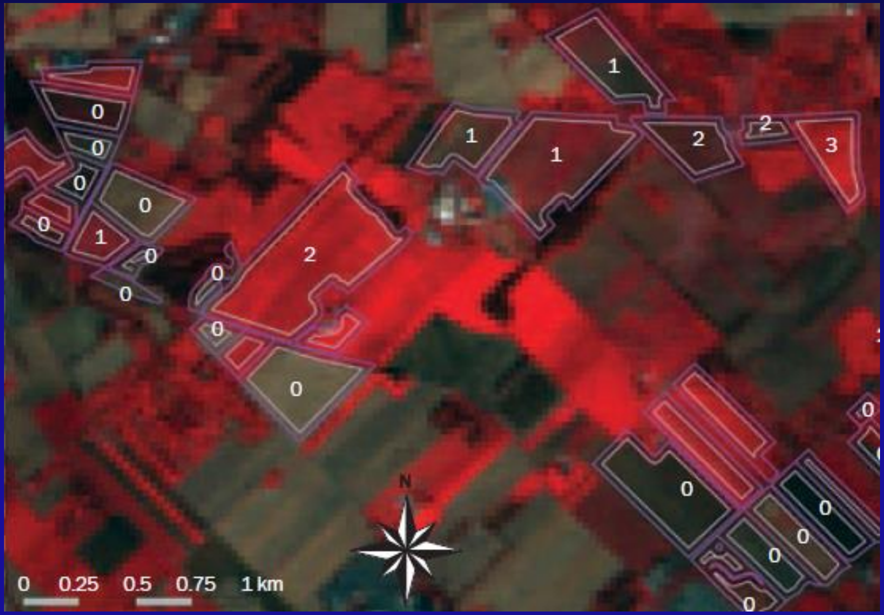
- Established a baseline, data also used for calibrating satellite imagery



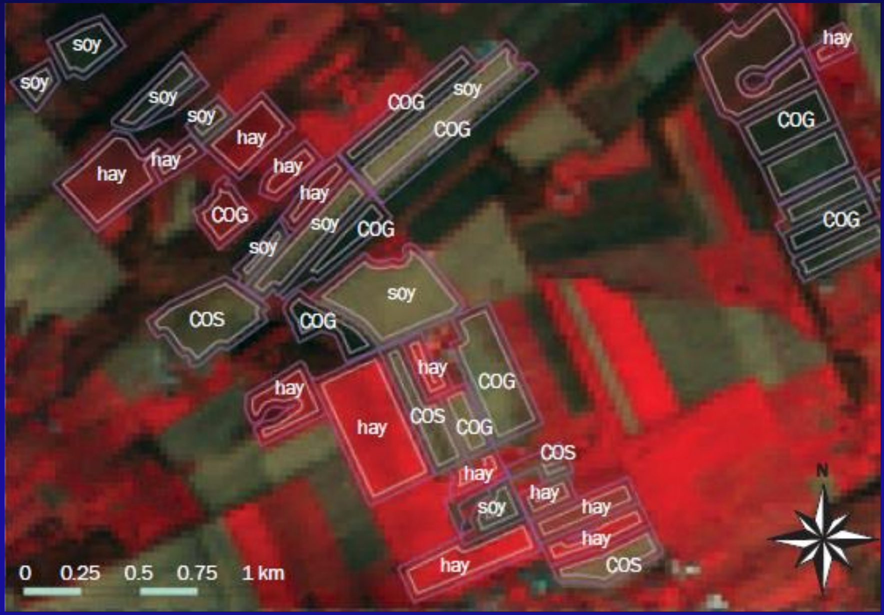
Nov 14, 2010 Landsat 5 image was used to match windshield survey data

Windshield Survey (Dec 2010)

vegetative groundcover



previous crop type



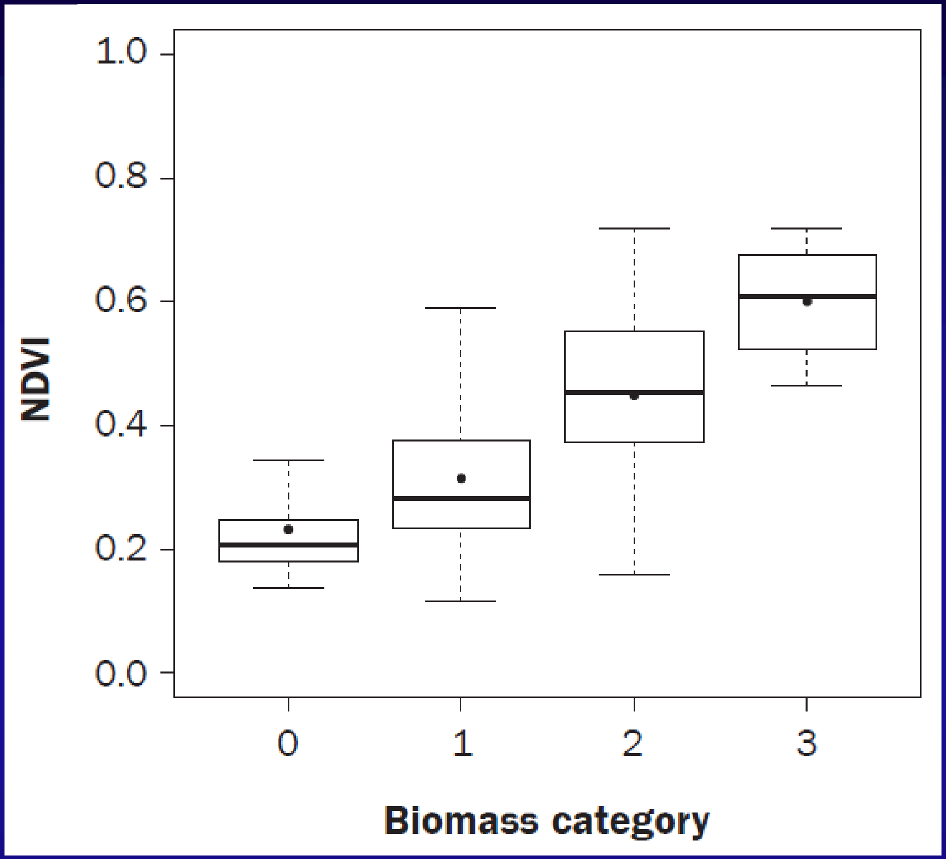
0 = Minimal **1 = Low** **2 = Medium** **3 = High**

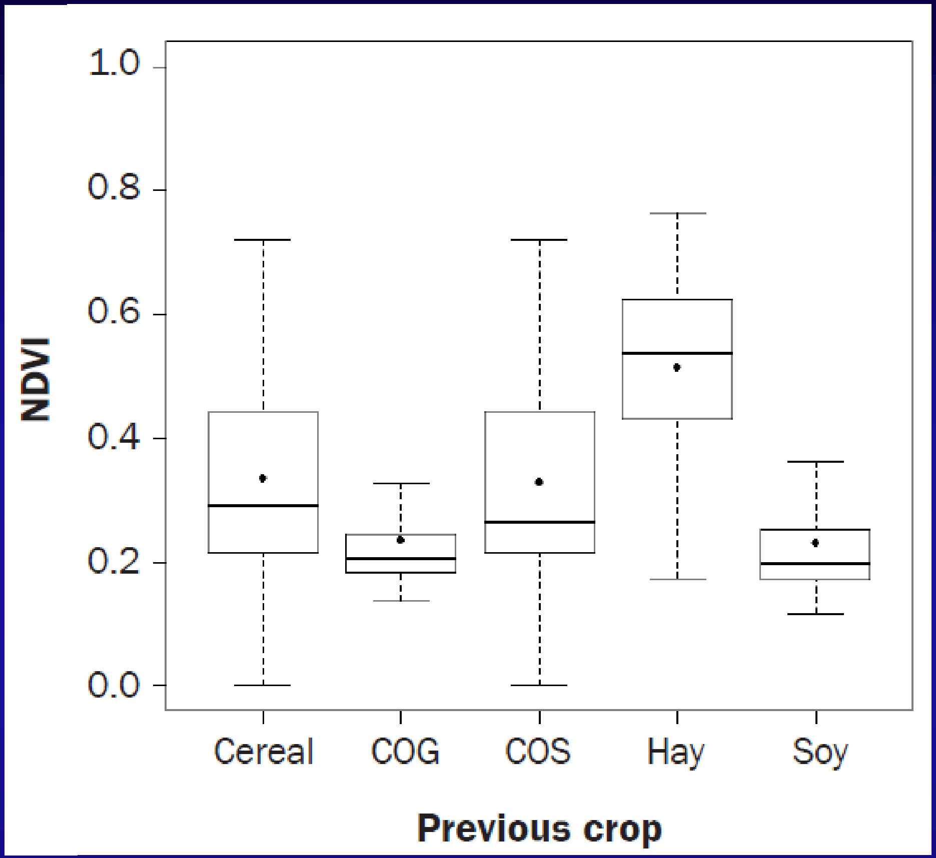
Windshield survey results

Windshield survey results for four Pennsylvania counties, December of 2010.

Summer crop	Vegetative biomass category					Percent
	*n**	Minimal	Low	Medium	High	vegetated†
Lancaster County						
All corn	65	24	19	10	12	63
Corn grain	31	18	12	1	0	42
Corn silage	34	6	7	9	12	82
Hay	17	0	0	8	9	100
Soy	17	10	5	2	0	41
Lebanon County						
All corn	96	34	3	26	33	65
Corn grain	22	21	0	1	0	5
Corn silage	74	13	3	25	33	82
Hay	0	0	0	0	0	na
Soy	48	35	3	6	4	27

NDVI of windshield survey fields

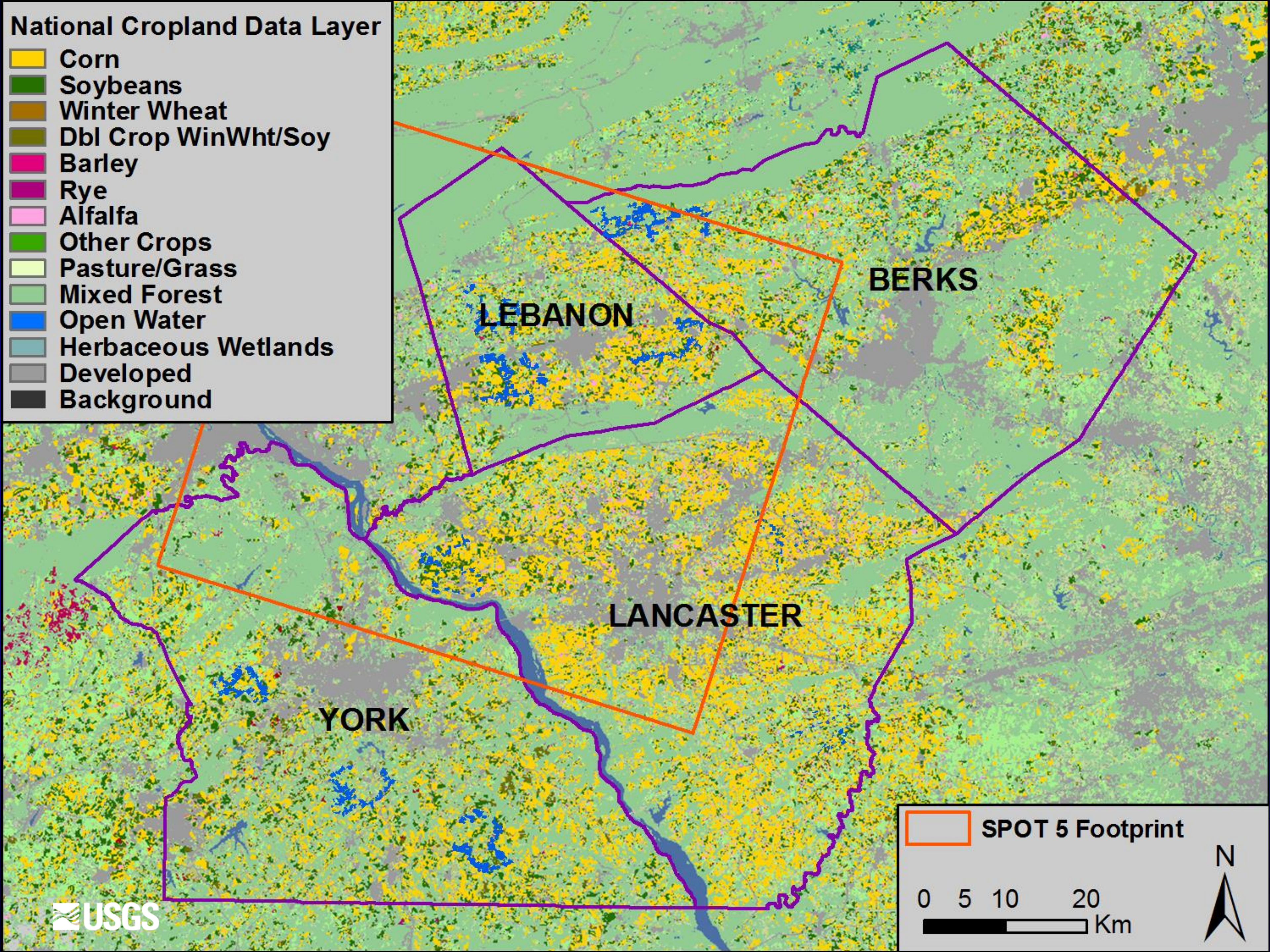




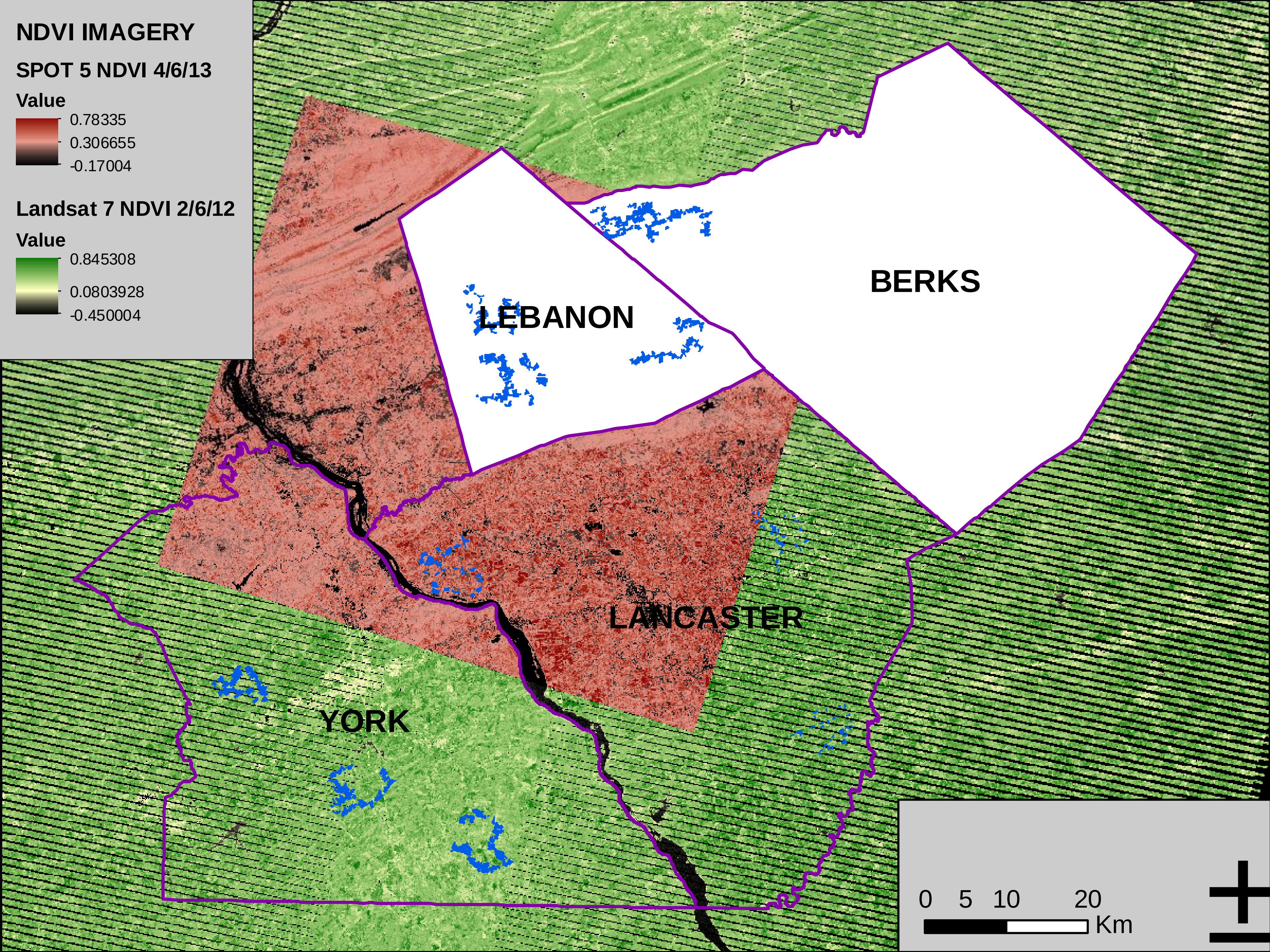
- **NDVI threshold values for vegetative groundcover classes were established at minimal < low 0.29 < medium 0.40 < high 0.53**
- **More vegetation (higher NDVI) was observed following corn silage harvest (COS) relative to corn grain harvest (COG)**

USGS

December 2010 Landsat 7 imagery



National Cropland Data Layer
Corn
Soybeans
Winter Wheat
Dbl Crop WinWht/Soy
Barley
Rye
Alfalfa
Other Crops
Pasture/Grass
Mixed Forest
Open Water
Herbaceous Wetlands
Developed
Background
LEBANON
BERKS
LANCASTER
YORK
SPOT 5 Footprint
0 5 10 20
Km
N
USGS



NDVI IMAGERY
SPOT 5 NDVI 4/6/13
Value
0.78335
0.306655
-0.17004
Landsat 7 NDVI 2/6/12
Value
0.845308
0.0803928
-0.450004
LEBANON
BERKS
LANCASTER
YORK
0 5 10 20
Km

Groundcover tool output

Lebanon, PA Landsat7 February 6th 2012

Ground Cover Thresholds

	Entire Area 0.1<NDVI<1.0		Minimal Biomass 0.1<NDVI<0.29		Low Biomass 0.29<NDVI<0.40		Medium Biomass 0.40<NDVI<0.53		High Biomass 0.53<NDVI<1.0	
	Area	pct	Area	pct	Area	pct	Area	pct	Area	pct
	ha	%	ha	%	ha	%	ha	%	ha	%
Entire area of interest	90734	100.0	31077	34.3	38878	42.8	16184	17.8	3452	3.8
Deciduous Forest	37477	41.3	13403	35.8	20081	53.6	3531	9.4	318	0.8
Corn	15685	17.3	6771	43.2	4629	29.5	2906	18.5	1371	8.7
Other Hay	7843	8.6	1034	13.2	3604	46.0	2701	34.4	500	6.4
Developed/Low Intensity	6778	7.5	1828	27.0	2799	41.3	1908	28.2	186	2.8
Developed/Open Space	5132	5.7	1256	24.5	2045	39.8	1418	27.6	393	7.7
Shrubland	4476	4.9	762	17.0	1968	44.0	1518	33.9	215	4.8
Soybeans	3833	4.2	2105	54.9	1159	30.2	486	12.7	81	2.1
Alfalfa	2387	2.6	277	11.6	1165	48.8	823	34.5	123	5.2
Developed/Medium Intensity	1805	2.0	1093	60.5	407	22.6	128	7.1	14	0.8
Developed/High Intensity	1081	1.2	513	47.5	73	6.7	23	2.1	2	0.2

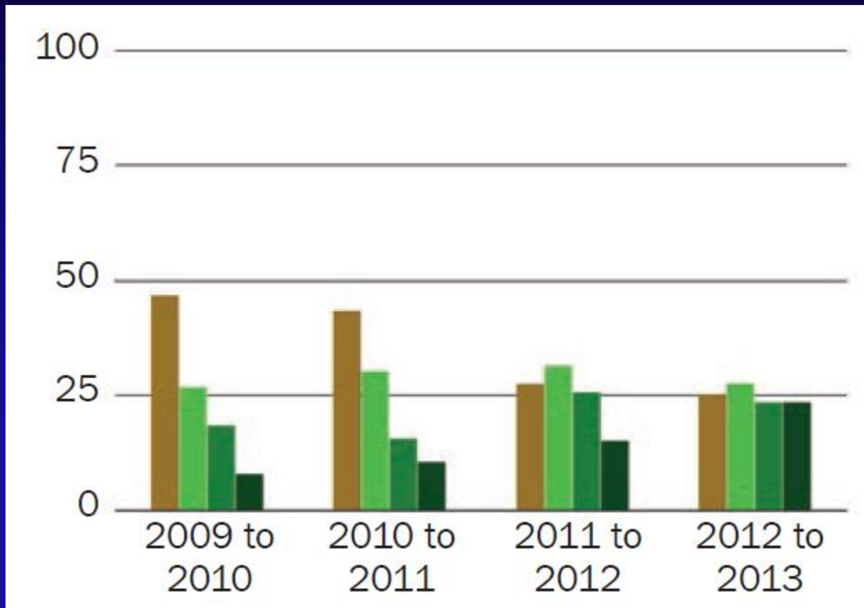
Area of Interest shapefile name: LEBANON.shp

CLU shapefile name: .shp

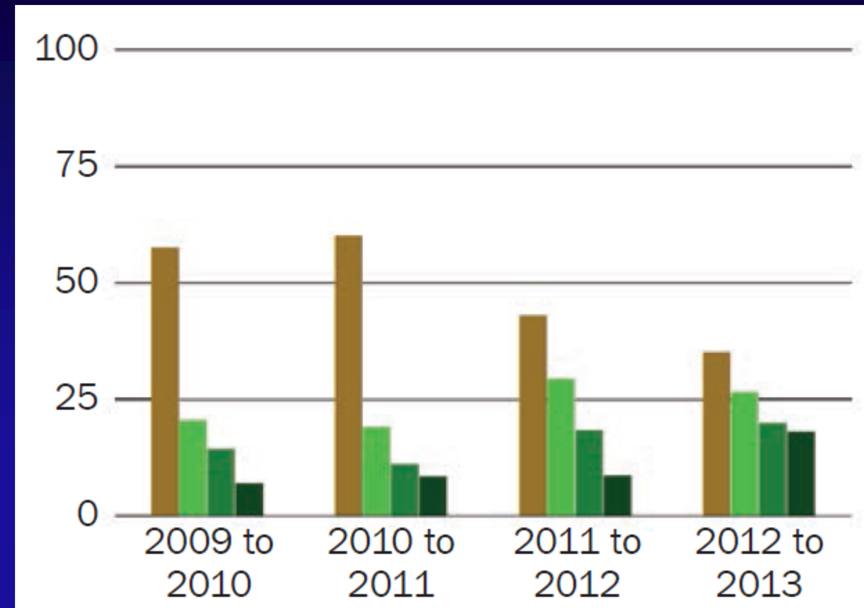
NDVI image file name: LE70150322012037EDC00_toa_06_FEB_2012_NDVI_WGS84.tif

Cropland data file name: cdl_pa_2011_30m_utm18_8majBclean.tif

Multi-year trends in vegetative groundcover



Lancaster



Lebanon

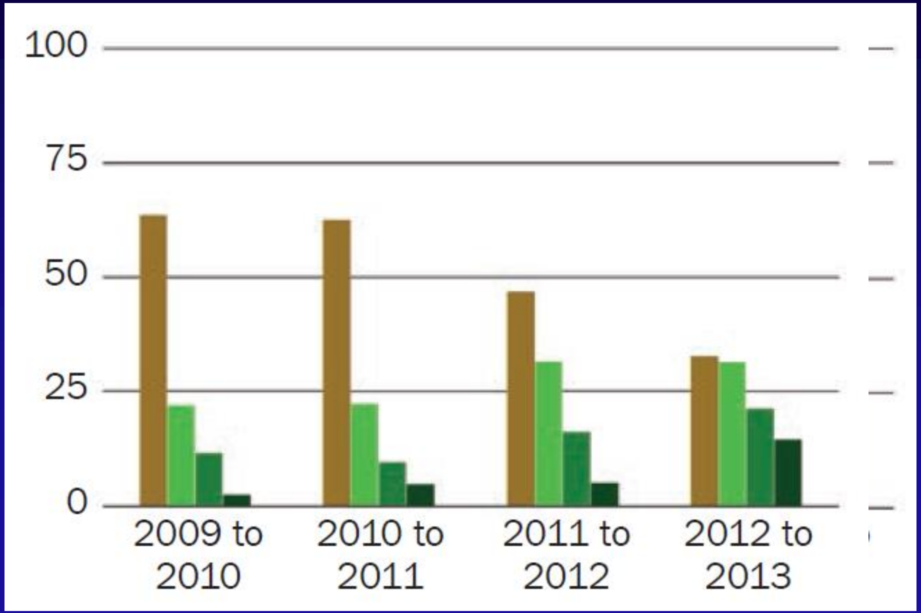
Vegetation class

Minimal Low Medium High

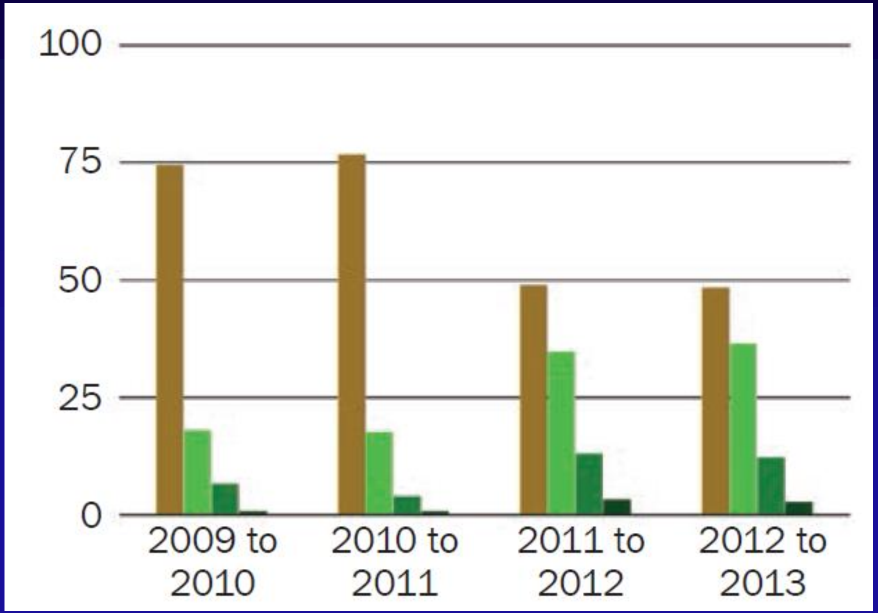
0 = Minimal 1 = Low 3 = Medium 4 = High

USGS

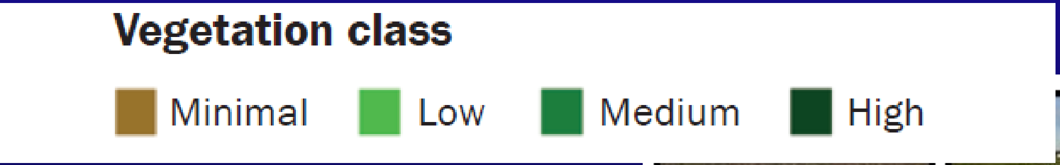
Multi-year trends in vegetative groundcover



Berks

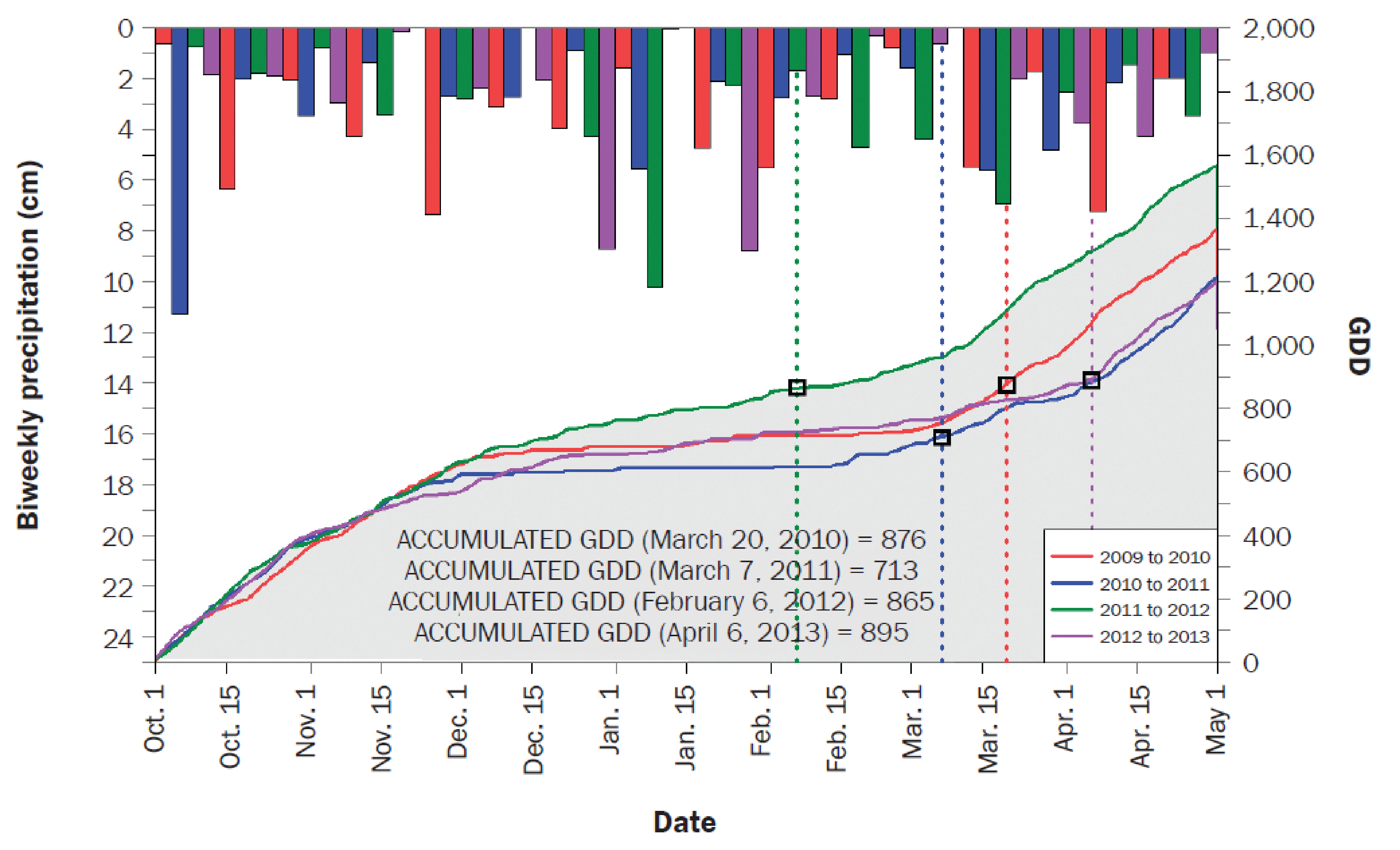


York



0 = Minimal 1 = Low 3 = Medium 4 = High

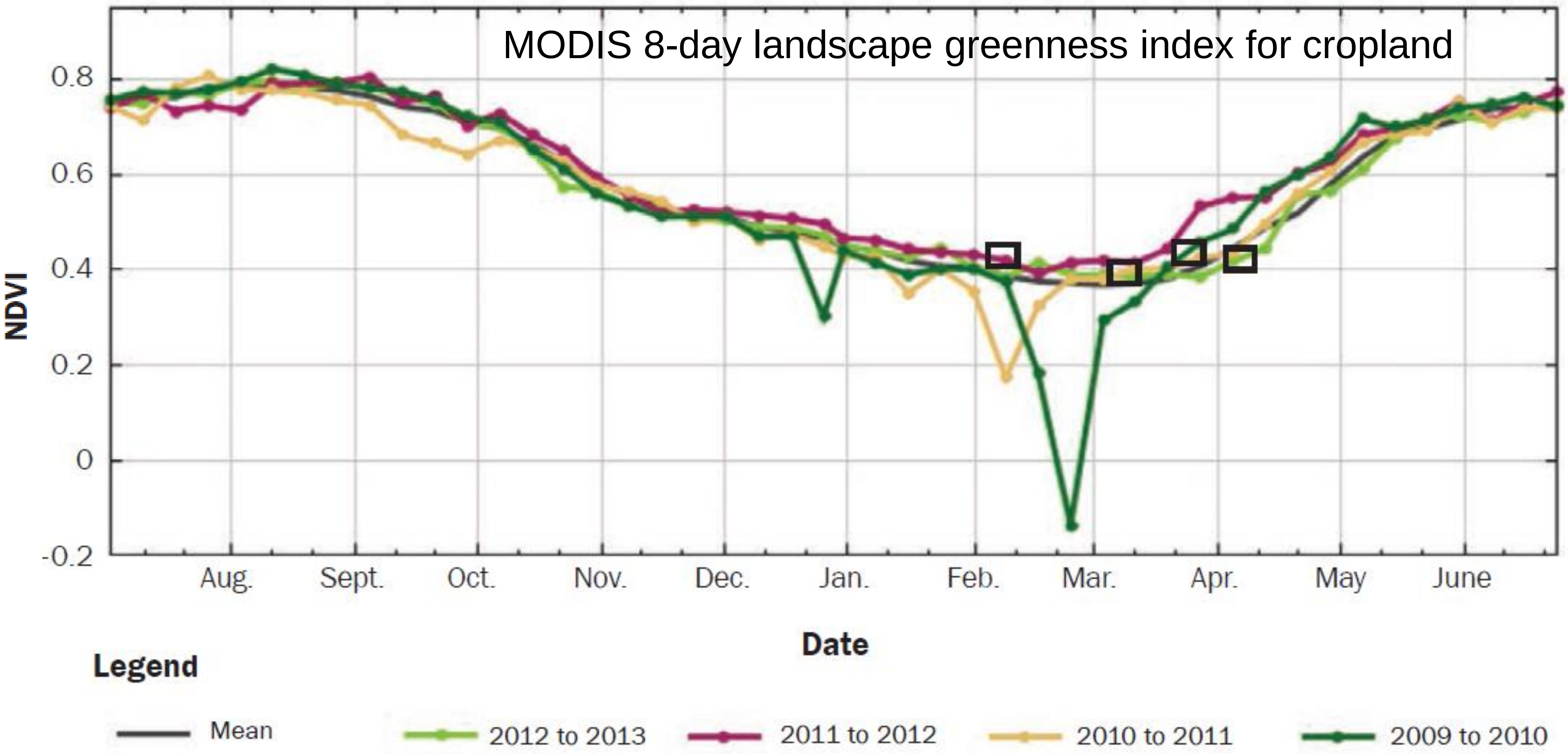
Are the trends from weather ?



Images depicted similar growing degree totals

USGS

Are trends from weather ?



Images depicted wintertime conditions prior to springtime 'green up'

USGS

Results

- Remote sensing analysis was successfully applied to four PA counties where the ‘without carrot or stick’ cover crop projects was promoting the planting of cover crops after corn silage harvest
- Detected 5 year trends in wintertime ground cover that were likely associated with farmer adoption of cover cropping practices

Caveats

- Landsat 30m pixels were too large to measure strip cropped fields
- Imagery coverage was insufficient for 3 of 7 counties

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Special issue on Cover Crops

RESEARCH SECTION:

COVER CROPS

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Remote sensing to monitor cover crop adoption in southeastern Pennsylvania

W.D. Hively, S. Duiker, G. McCarty, and K. Prabhakara

USGS

Measuring cover crops in the field

Physical sampling of plants

- **Biomass (fresh – dry weight = water content)**
- **Ground cover (% vegetation measured by beaded string, or RGB photo analysis,)**
- **Plant nitrogen content, C:N ratio**
- **Plant growth stage, tillering, etc…**







Measuring cover crops in the field

Physical sampling of soils

- Nitrogen content (nitrate/nitrite), carbon content
  - Soil cores to 12” give N availability in surface horizon
  - Deep core sampling to groundwater (1-3m) gives N leaching profile
- Permeability, aggregate stability, soil health

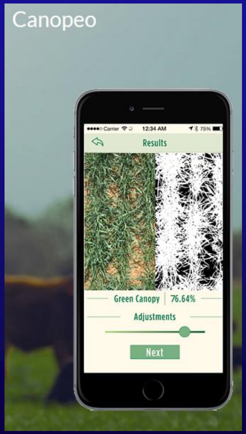
Measuring cover crops in the field

Proximal reflectance sensors

- Greenseeker (G,R,RE,NIR)
- Crop Circle (G,R,RE,NIR)
- Cropscan (16 bands in visible-NIR)
- ASD (hyperspectral vis-NIR and SWIR)
- RGB cameras and cellphones
- Human eyeballs


Crop Circle


ASD



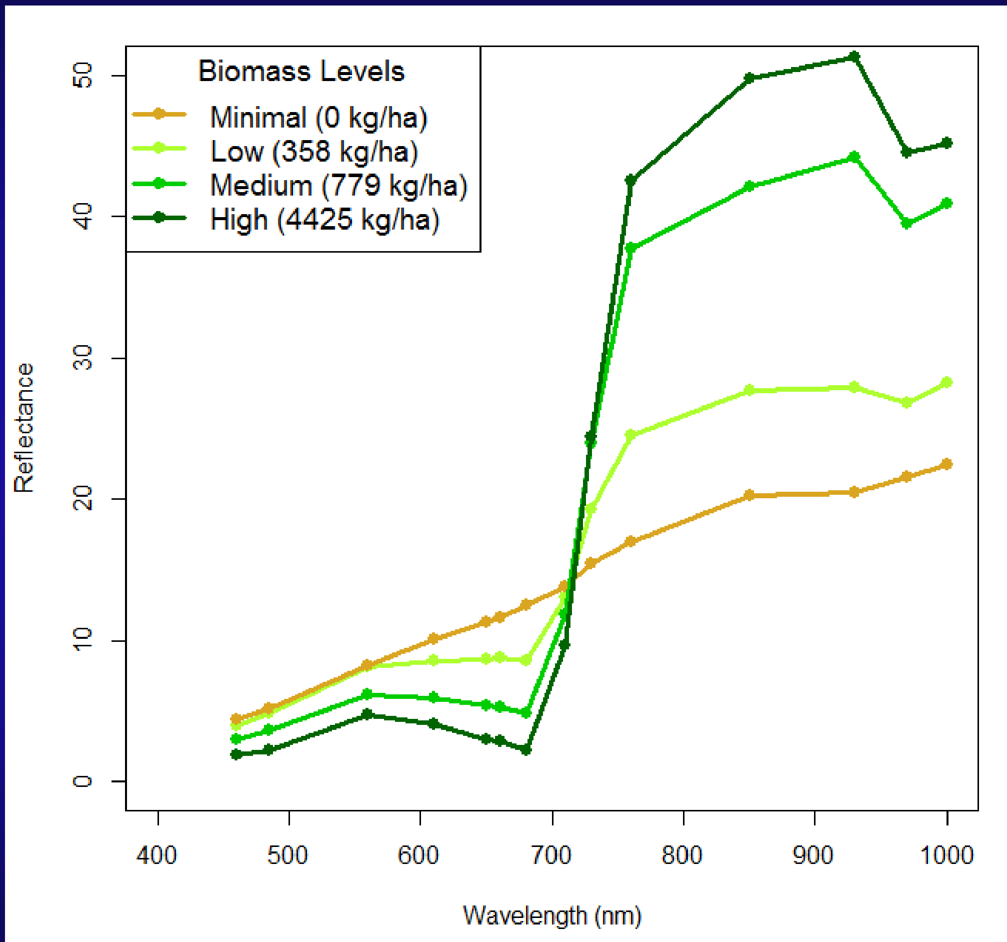
Cameras


Crop Scan

USGS

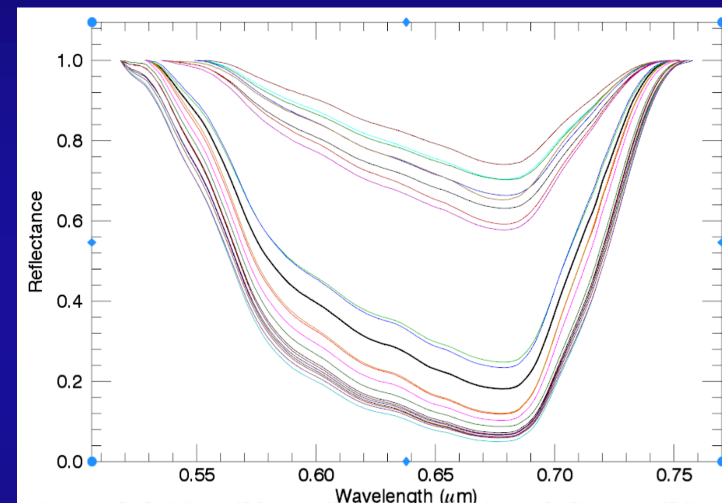
Wintertime field reflectance spectra

460 | 485 | 559 | 560 | 610 | 650 | 660 | 680 | 710 | 730 | 760 | 850 | 930 | 970 | 1000 | 1640



Surface reflectance of triticale cover crops (CropScan, 16 bands)

Various band ratio indices can be calculated to measure vegetative biomass and ground cover (NDVI, etc…)



680nm chlorophyll adsorption feature (ASD)

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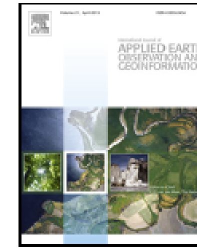
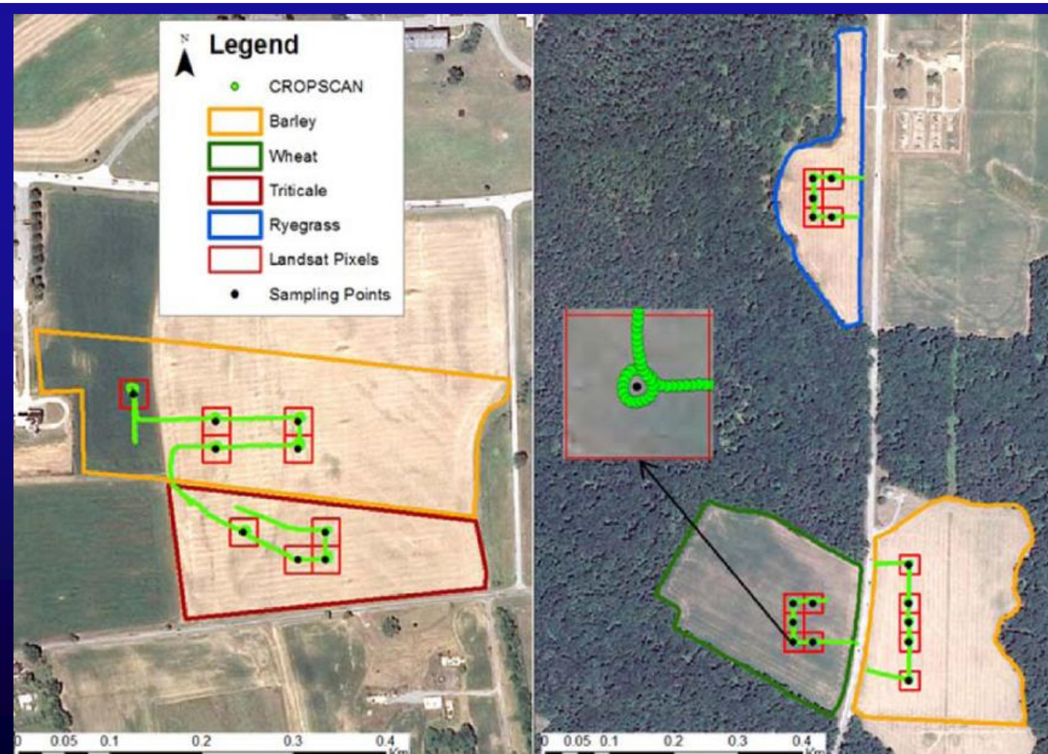


Evaluating the relationship between biomass, percent groundcover and remote sensing indices across six winter cover crop fields in Maryland, United States

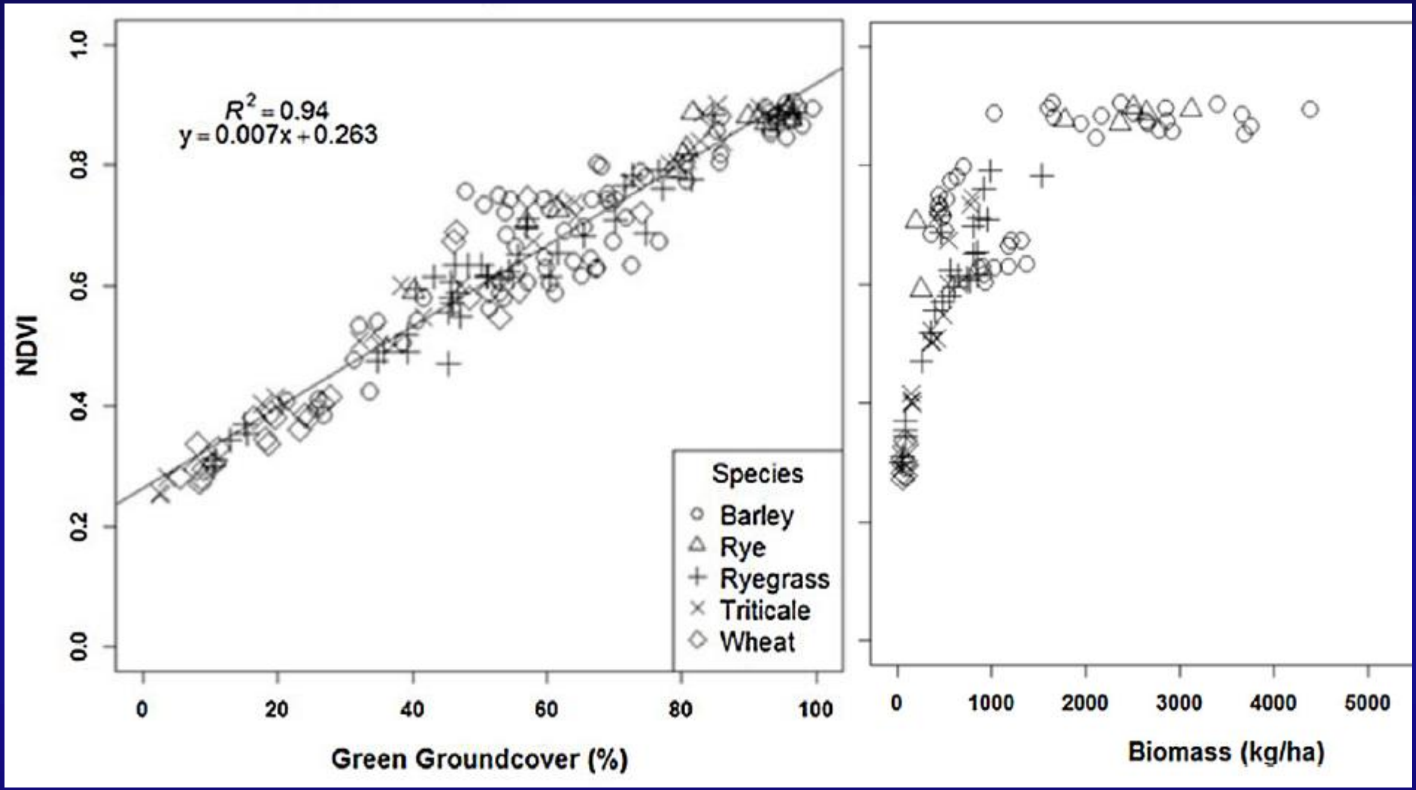
Kusuma Prabhakara[a,*], W. Dean Hively[b], Gregory W. McCarty[c]



Proximal Sensors

Some results:

Index	Wheat1
	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



Various indices are about equivalent

NDVI is aok

Indices saturate at high growth

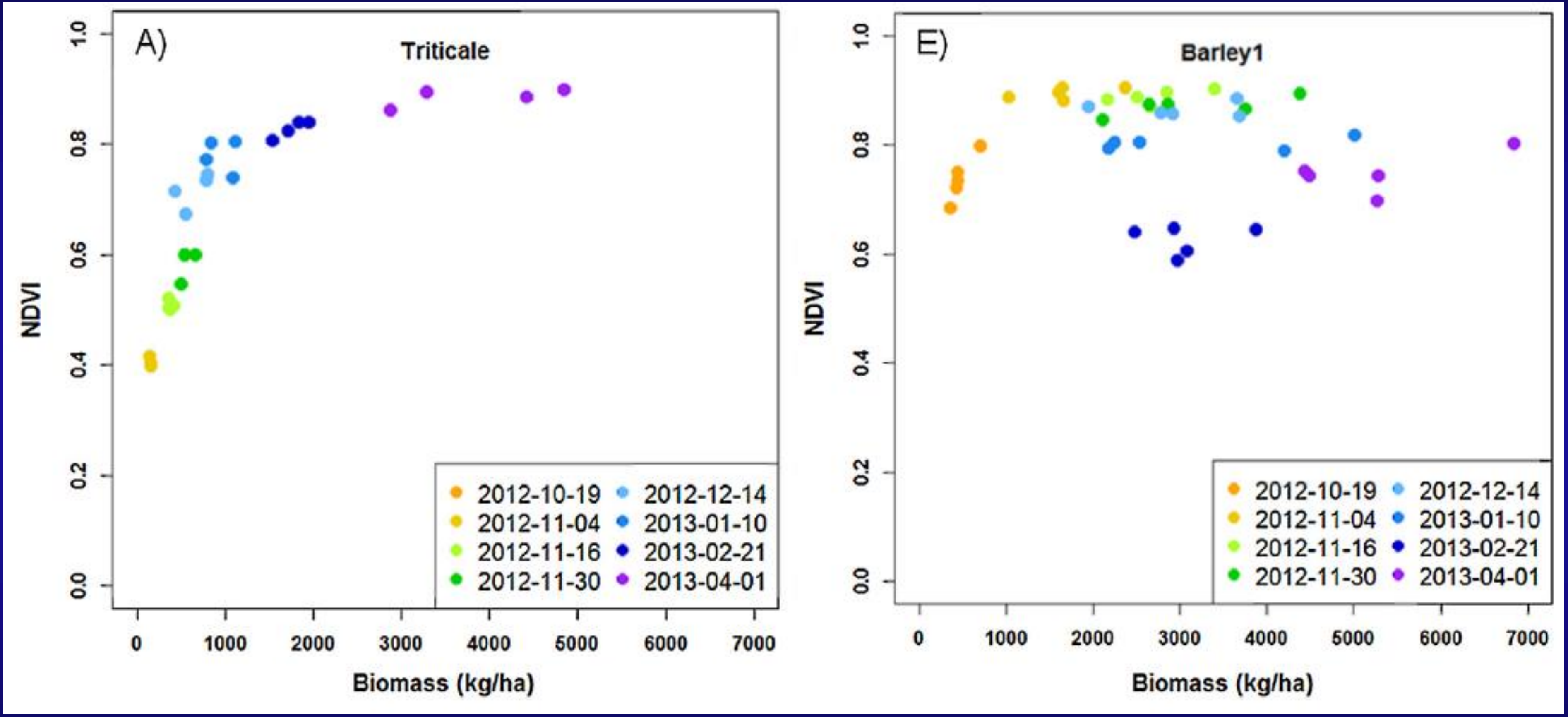
- **~2000 kg/ha biomass**
- **~80% ground cover**

USGS

Prabhakara et al., 2015 IJAEOG

Proximal Sensors

Some results:



Winter conditions can affect the relationship between biomass and NDVI

USGS

Prabhakara et al., 2015 IJAEOG

In-field instruments

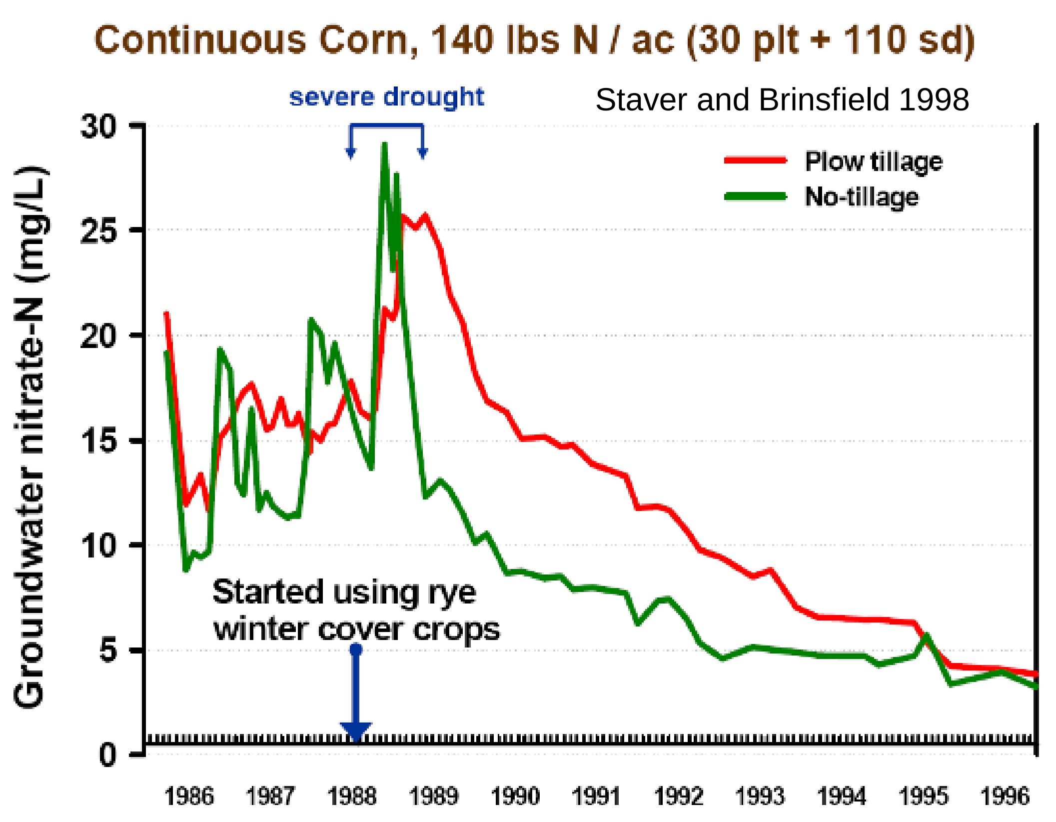
- **Linking sensors to biomass, vegetated ground cover**
- **Providing calibration for satellite interpretation**

- **Automated daily measurements of NDVI, PRI, and RGB photos**

USGS

Catchment scale measurements – closing the N balance

- **Lysimiters** (buried in soil to detect N leaching)
- **Anion resin bags** (buried in soil to detect N leaching)
- **Stream weirs**
- **N isotopes**

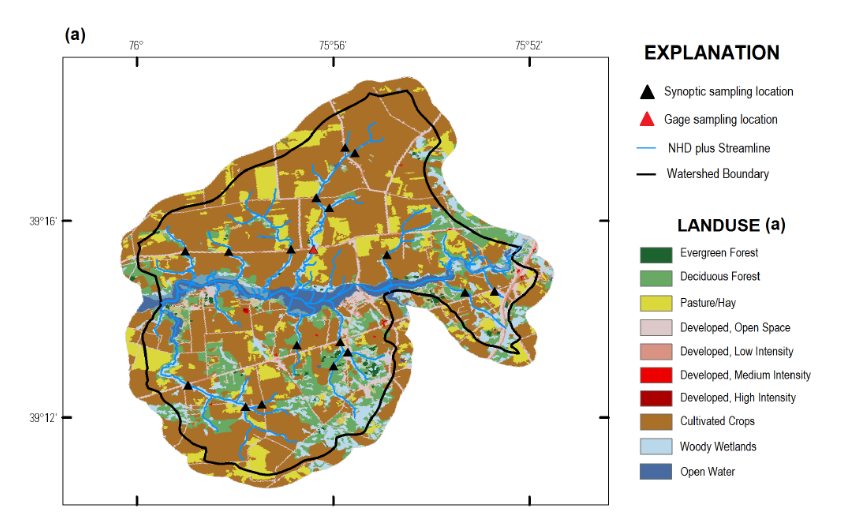


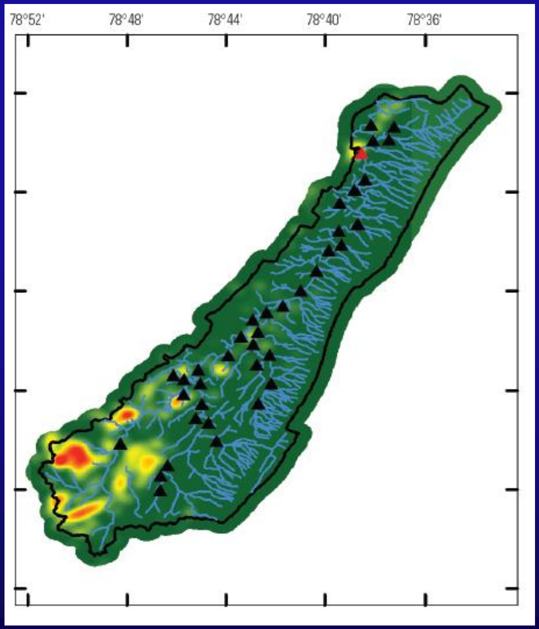
USGS

Lansdscape scale measurements

Stream water monitoring ~ can we detect changes in water quality resulting from implementation of sustainable management practices?

- **Continuous or synoptic sampling of stream flow and chemistry: nitrogen, phosphorus, sediment, agrichemicals, organic mater, stream health**



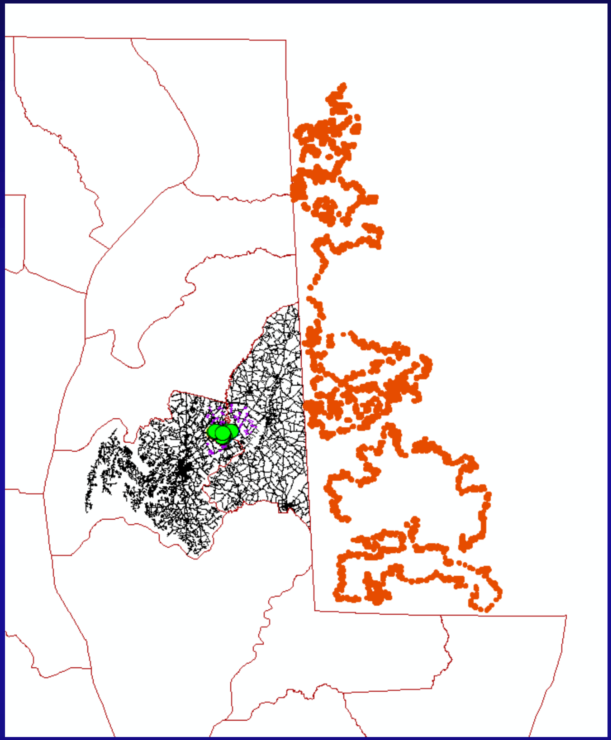


Can we detect (and support) increased use of cover crop practices?

Lansdscape scale measurements

Mapping winter groundcover

- **Windshield surveys**
- **Farmer surveys**
- **Cost-share implementation data**
- **Remote sensing imagery analysis**



USGS

Cropland remote sensing analysis

Satellites (also planes and UAV's)

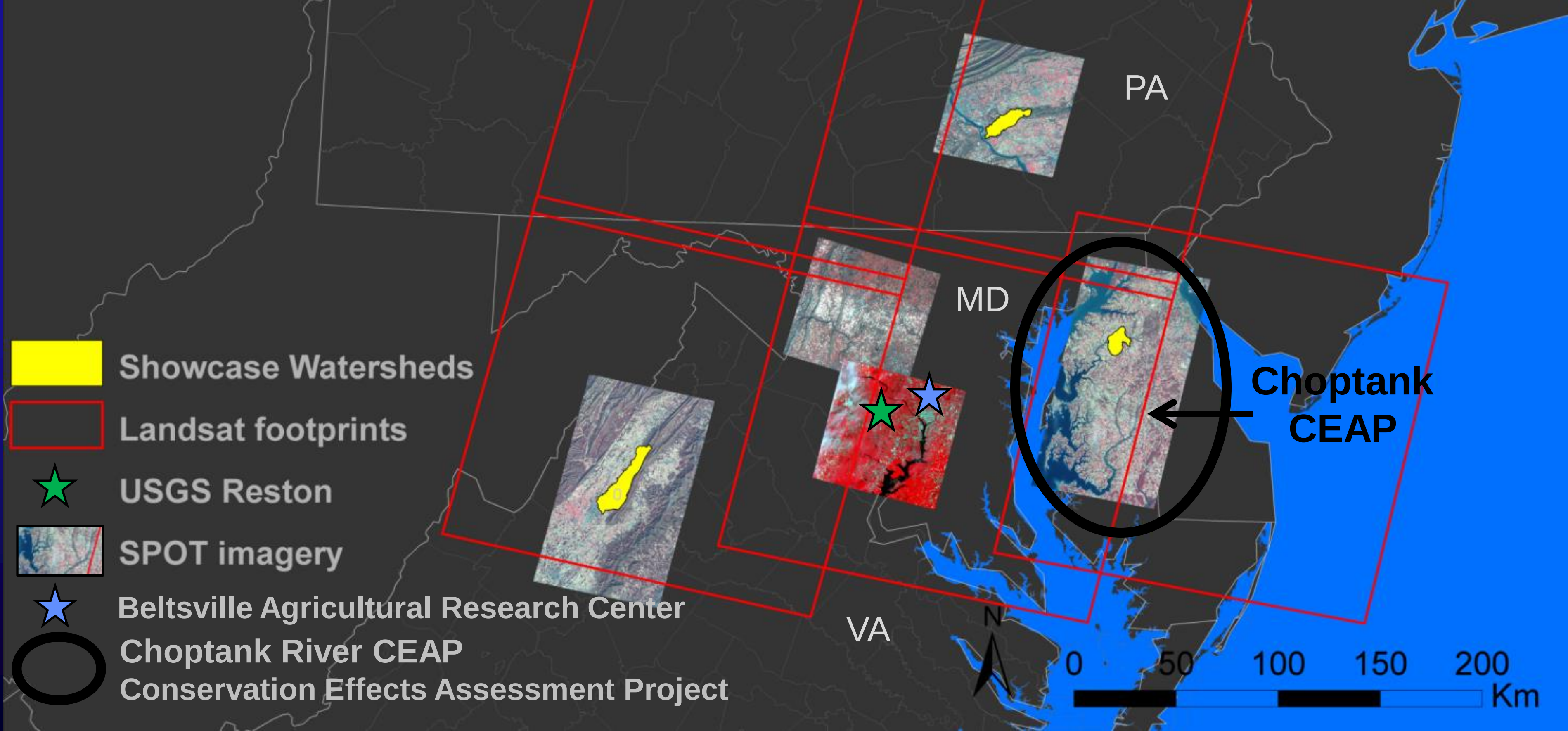
- Reflectance measurements of plant growth: biomass, groundcover, N content, canopy structure

Winter groundcover analysis (Landsat, SPOT, Worldview)

- Detected multi-year trends in PA (Hively Duiker et al.)
- Similar project in NY (Cortland SWCD CIG grant)
- Similar applications in Showcase Watersheds (PA, MD, VA) and on the Eastern Shore
- The groundcover tool is available and relatively easy to apply in ArcGIS, our calibration research is ongoing

Remote sensing study areas

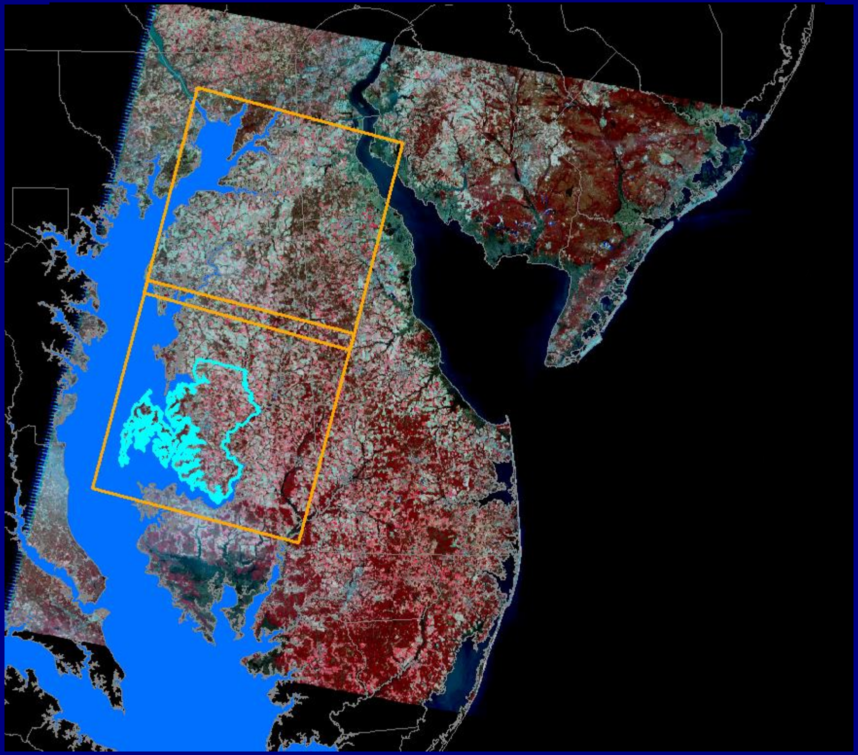
- Satellite-based remote sensing of wintertime ground cover
- Mapping farmland, crop rotations, and conservation practices
- Associating topography, soils, hydrology, and nutrient transport
- Linking changes in agricultural management to water quality monitoring data

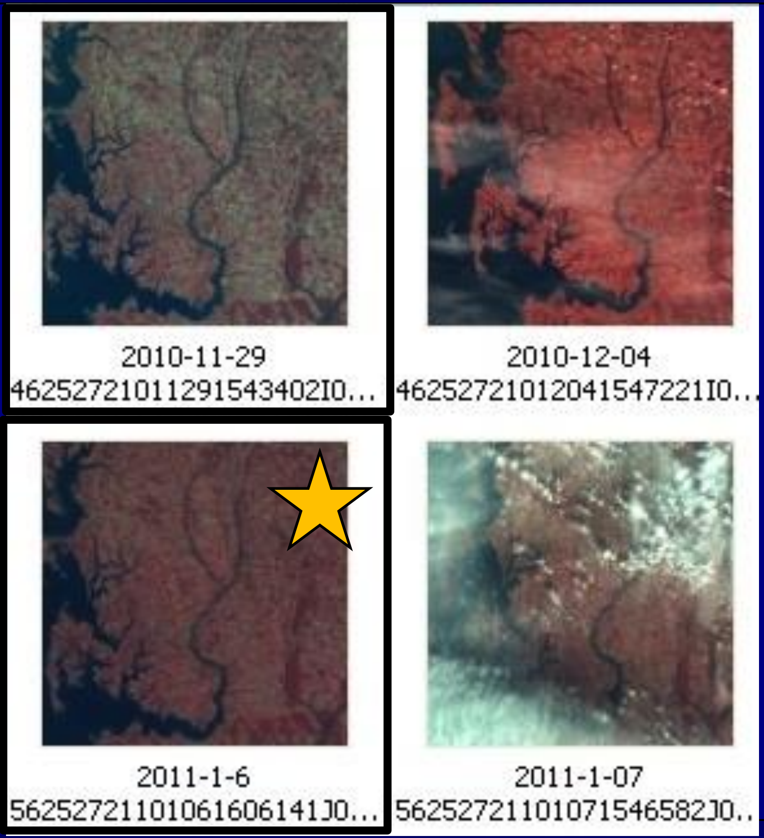


Satellite Imagery

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

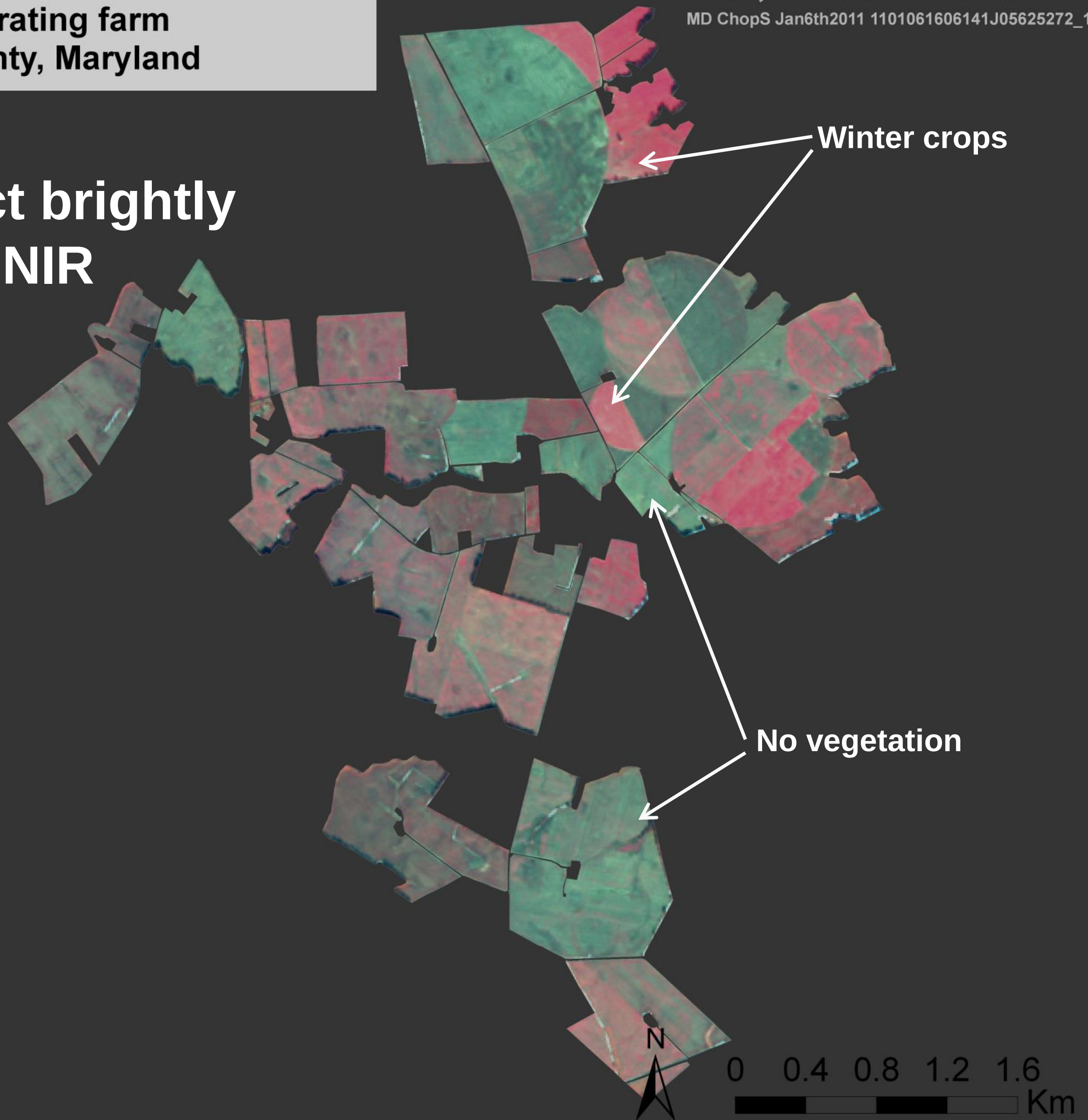
D. Hively, USGS EGSC, USDA-ARS Choptank CEAP, 12-13-2012

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

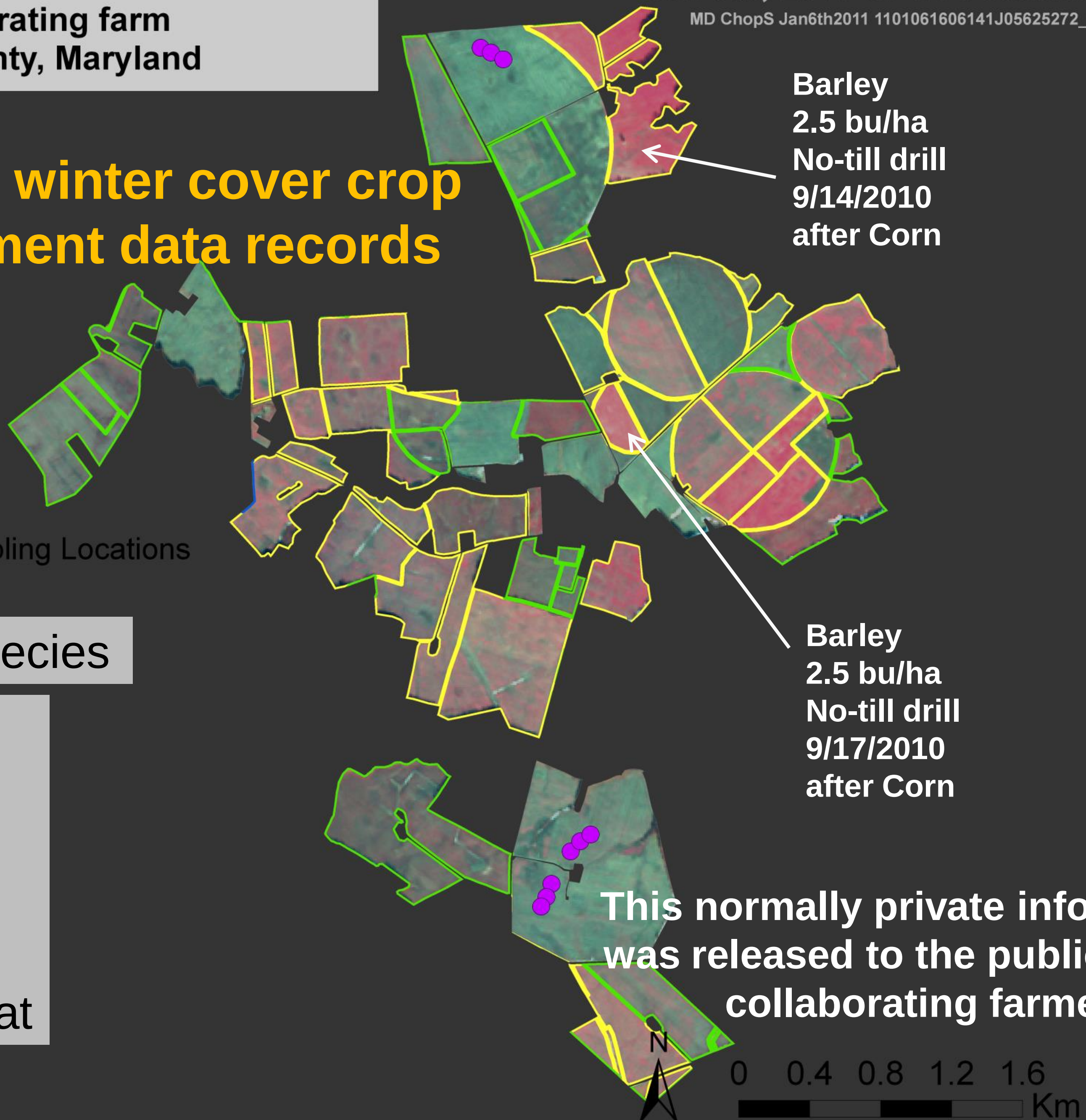


USGS

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

A collaborating farm
Talbot County, Maryland

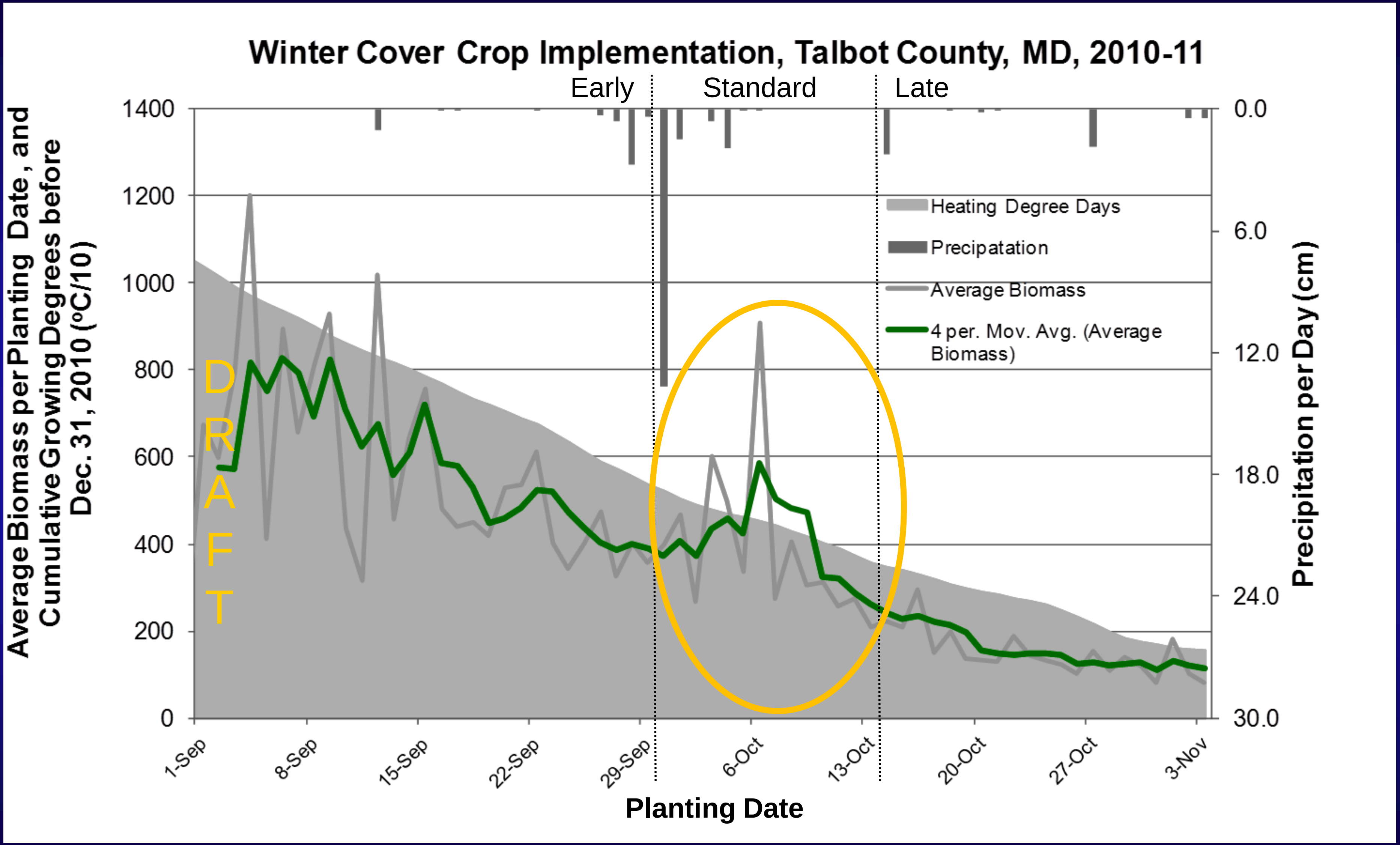
Overlap with winter cover crop farm enrollment data records



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

What factors affect cover crop success?

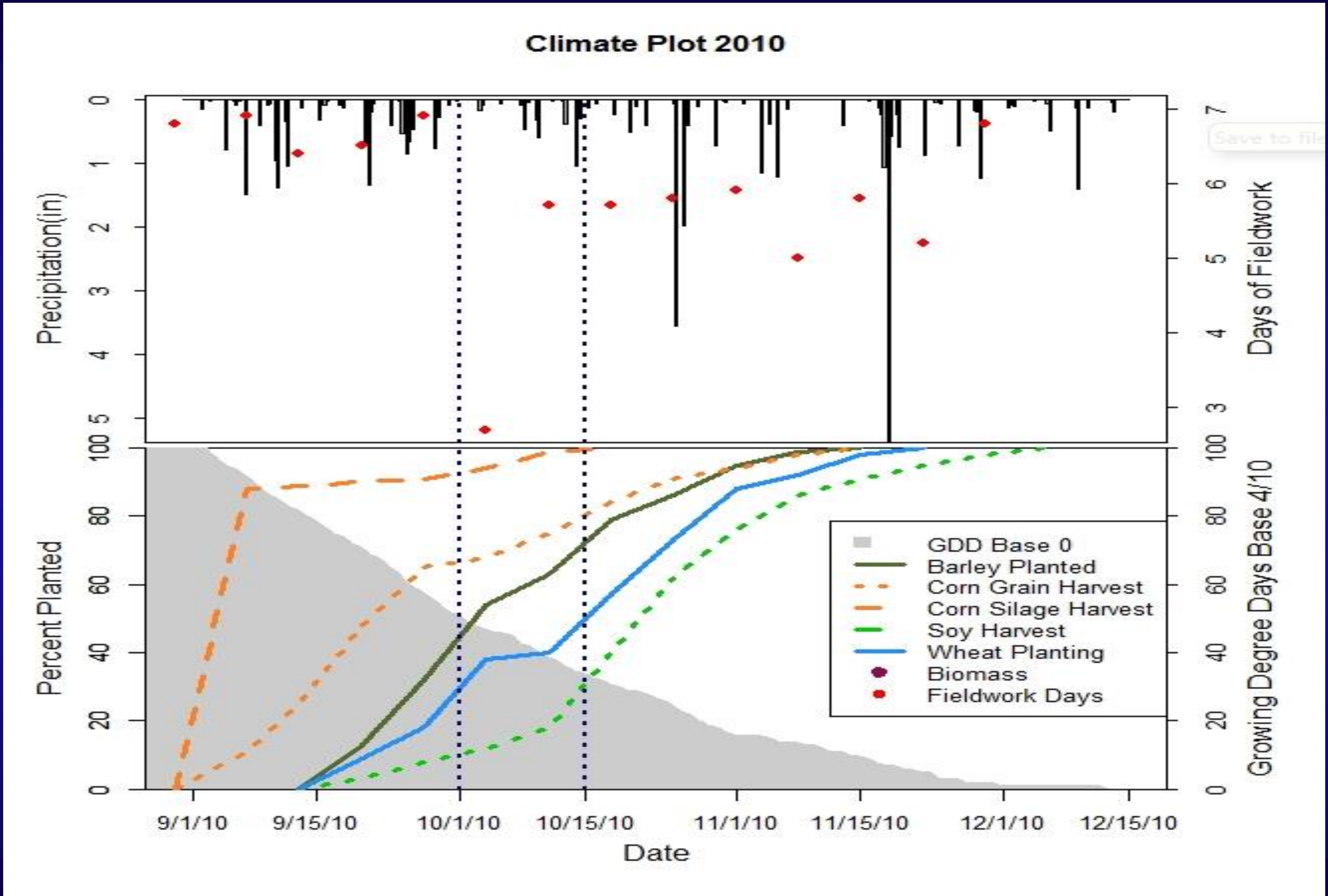
Linking performance to climate



These data are preliminary and are subject to revision. They are being provided to meet the need for timely 'best science' information.

USGS

Link performance to climate



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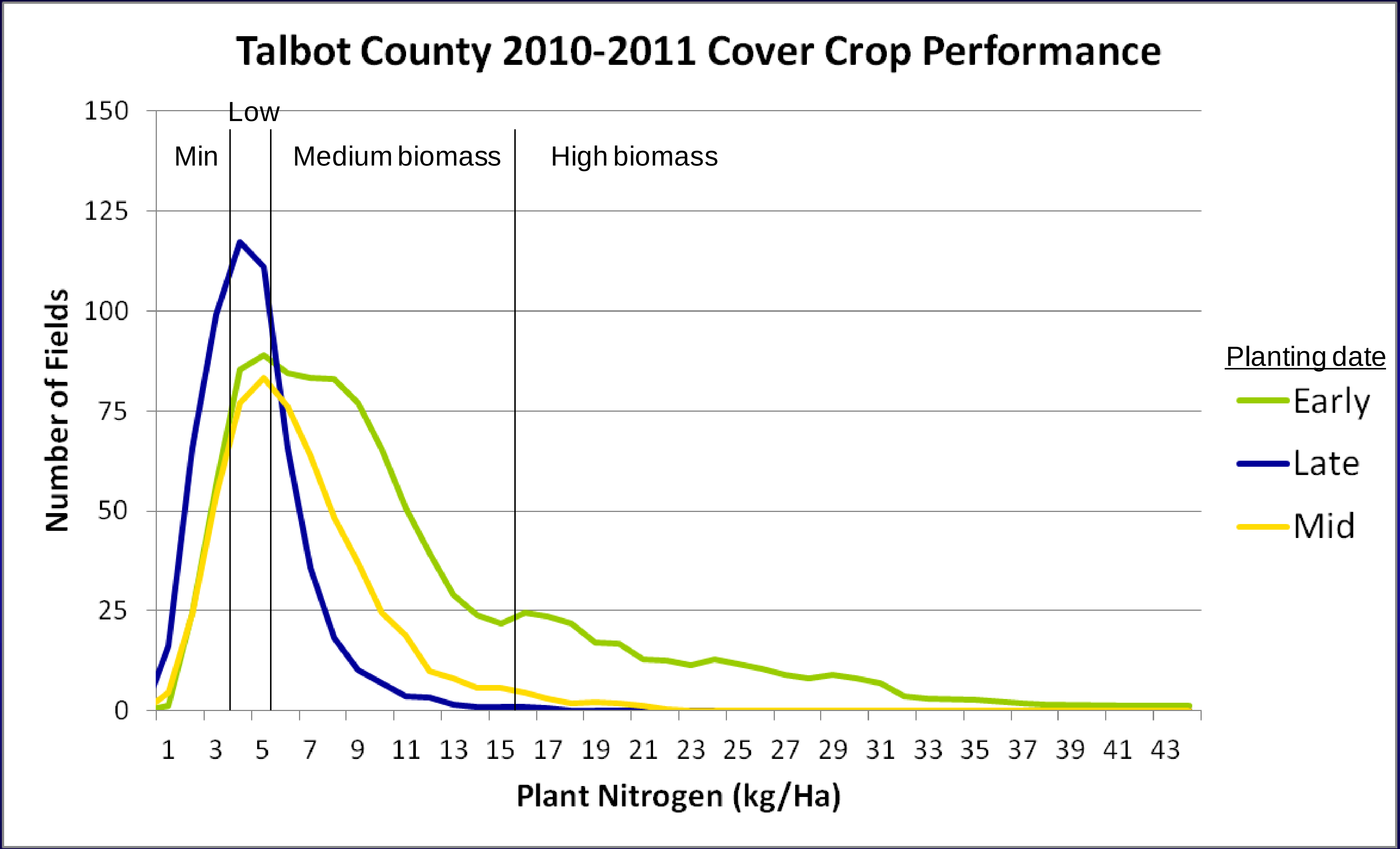

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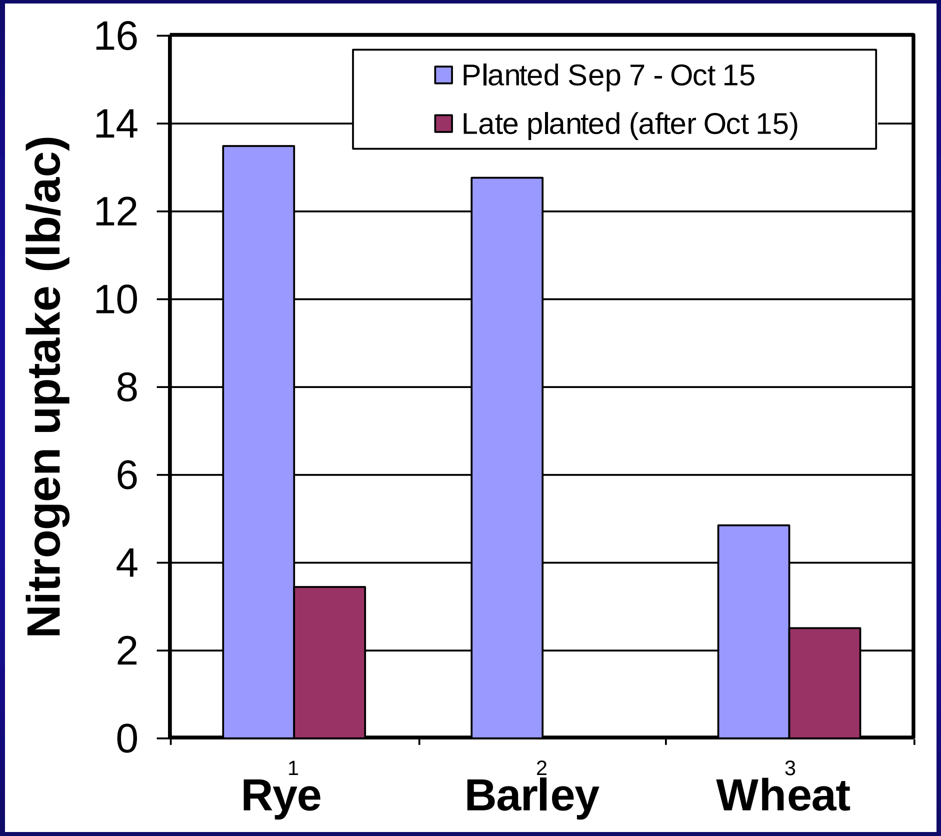
Summarize cover crop performance

(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

USGS

These data are preliminary and are subject to revision. They are being provided to meet the need for timely 'best science' information.

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

DRAFT

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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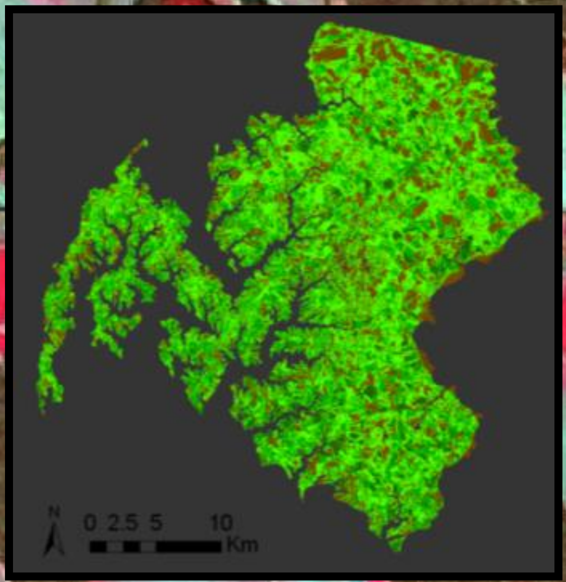
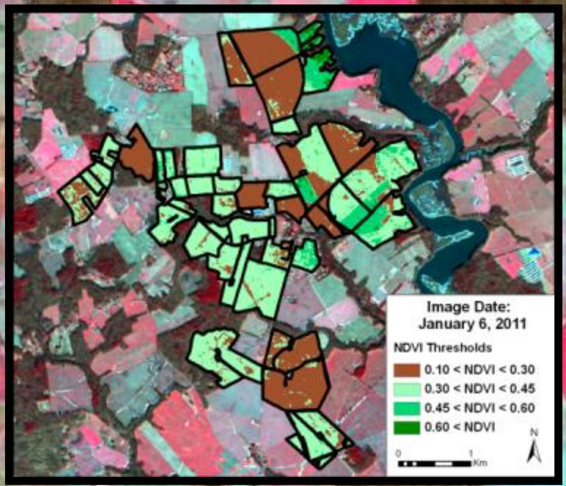
Adaptive Management of Winter Cover Crops



Produce county/watershed reports for local partners

Provide field-specific information to farmers

Target low-productivity fields for site visits



Green is good

But is greener always better? When/where are nutrients in excess? Where are the best cover crops?

Is there a lower threshold for cover crop success?

USGS

How do we define success?

- Successful strategies fit in with climate and farming systems
- Awareness of constraints and opportunities
- Experimentation and sustainability

Carrots, sticks, knowledge, and experience

Scientific challenges

- Inter-image variability in index threshold values and (in)stability of calibration equations: Is surface reflectance consistent? Are some indices more stable?
- How much collection of calibration data is necessary and how can we supply it?
- How does small grain phenology and reflectance change over the wintertime and into the spring?
- What is the best time of year for analysis, and can we consistently obtain good imagery at that time?

Scientific challenges

- **Communicate results to farmers/stakeholders**
- **Provide timely information to influence crop management and supporting adaptive management**
- **Link mapped outcomes to successful management practices (use of robust cover crops within diverse crop rotations)**
- **Support the growth of cover crops, soil health, and sustainable agriculture**

Your suggestions are welcome!

Thank you! ~ Questions?

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