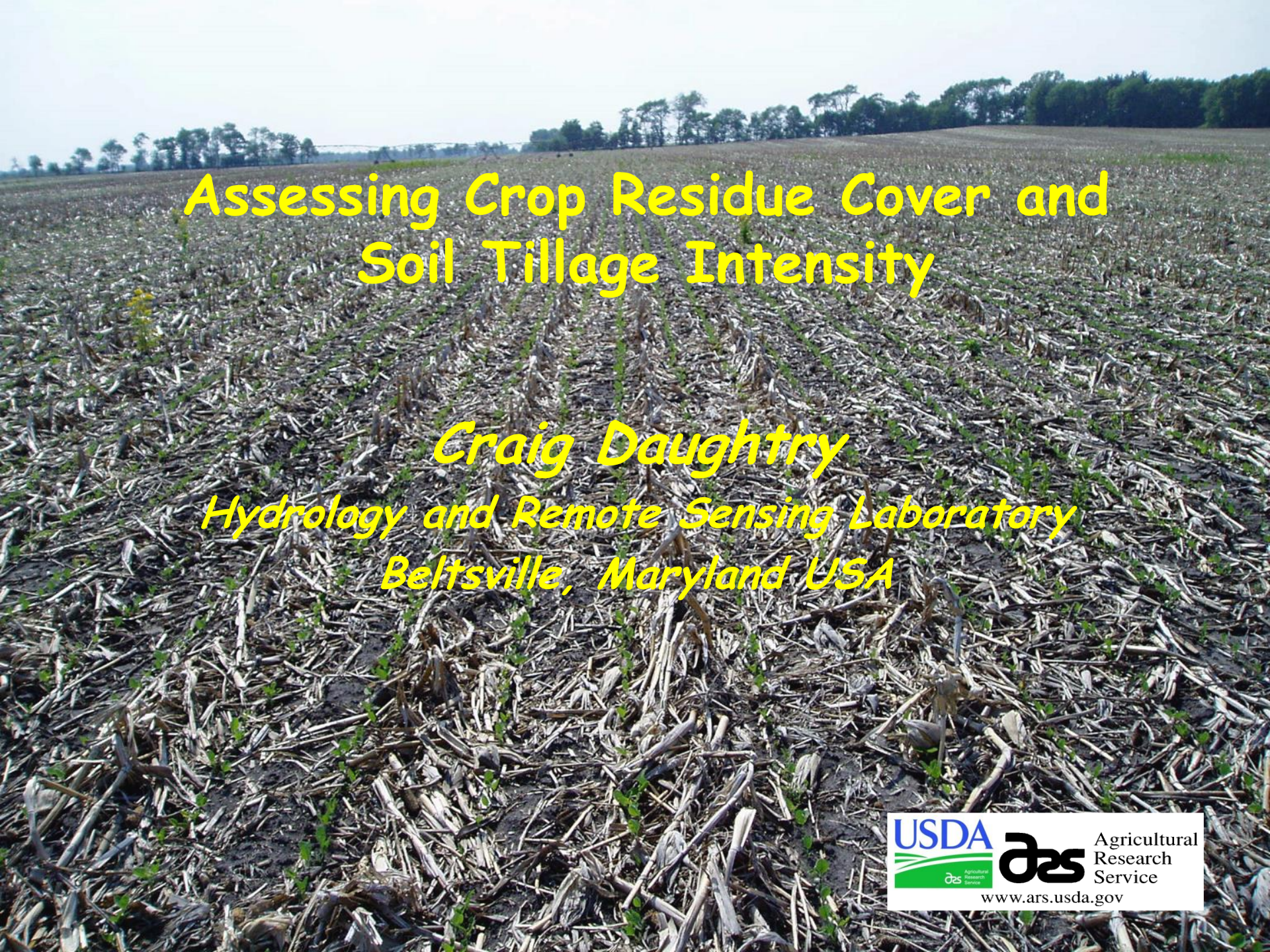

Assessing Crop Residue Cover and Soil Tillage Intensity

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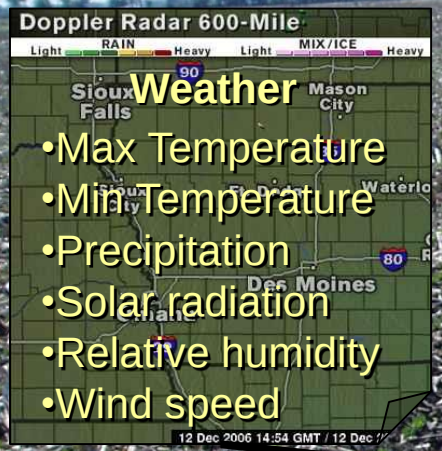
Impacts of management practices on crop yields, soil organic carbon, and water quality



Weather
- Max Temperature
- Min Temperature
- Precipitation
- Solar radiation
- Relative humidity
- Wind speed

Soil (by layer)
- Carbon content
- Texture
- Bulk density
- pH
- Water content
- Sum of bases
- ... etc

Topography
- Slope length
- Slope steepness
- Elevation
- Field size
- Lat and Long

Management
- Tillage operations
- Crops
- Inputs
- ... etc

Process Models: EPIC, APEX, SWAT, etc

Crop biomass and yield

Soil Organic Carbon

Water Quality

Tillage intensity is defined by crop residue cover.

Crop residue = Portion of a crop that is left in the field after harvest.

Conservation till
>30% cover

Reduced till
15-30% cover

Intensive till
<15% cover

- Crop residues on the soil surface:
  - first line of defense against soil erosion
  - increase soil organic carbon
  - improve soil and water quality
- Management of crop residue cover is an integral part of conservation tillage.
- Soil tillage and biomass harvesting reduce crop residue cover.

Current Methods of Measuring Crop Residue Cover

Line Point Transect

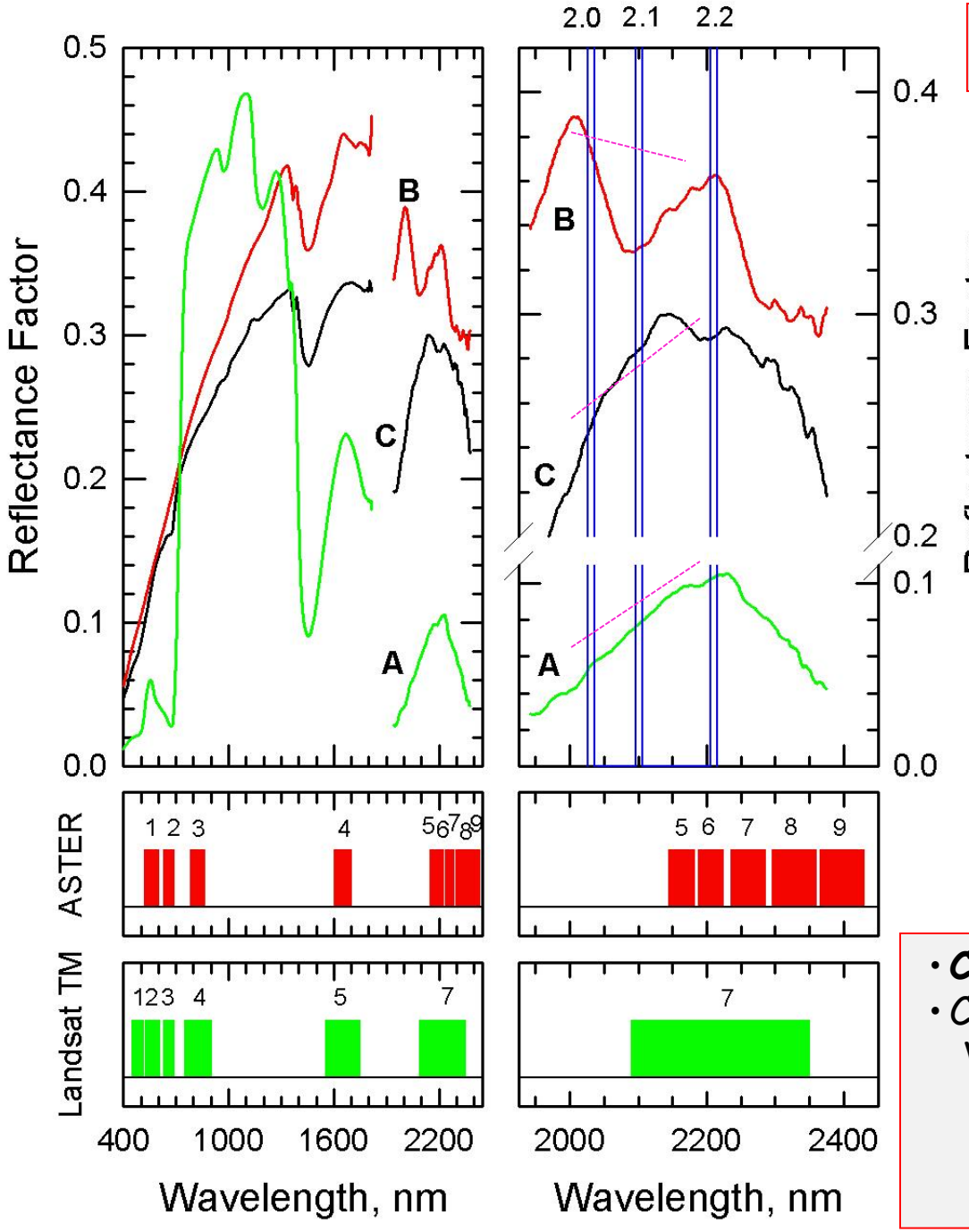
- Stretch Line-Point Transect across rows and count the number of markers that intersect residue.

Windshield Survey

- Trained observers stop at intervals along a fixed route and assess fields on both sides of road.

Traditional methods of measuring crop residue cover are inadequate for many fields and large areas.

Reflectance Spectra



Reflectance Factor

Corn residue

Bare soil

Green vegetation

- **Cellulose Absorption Index**
- $CAI = 100\ [0.5\ (R_{2.0} + R_{2.2}) - R_{2.1}]$

  Where:

  $R_{2.0}$ = reflectance at 2030 nm

  $R_{2.1}$ = reflectance at 2100 nm

  $R_{2.0}$ = reflectance at 2210 nm

Scaling-up: Field Reflectance Spectra

Reflectance spectra

- **ASD Spectroradiometer**
  - 18-degree fore optics
  - 350-2500 nm wavelength range
  - Referenced to Spectralon panel
- **Digital Camera**
  - Aligned with FOV
  - Cover fractions determined using dot grid overlay.

Scaling-up: Airborne & Satellite Imaging Spectrometers

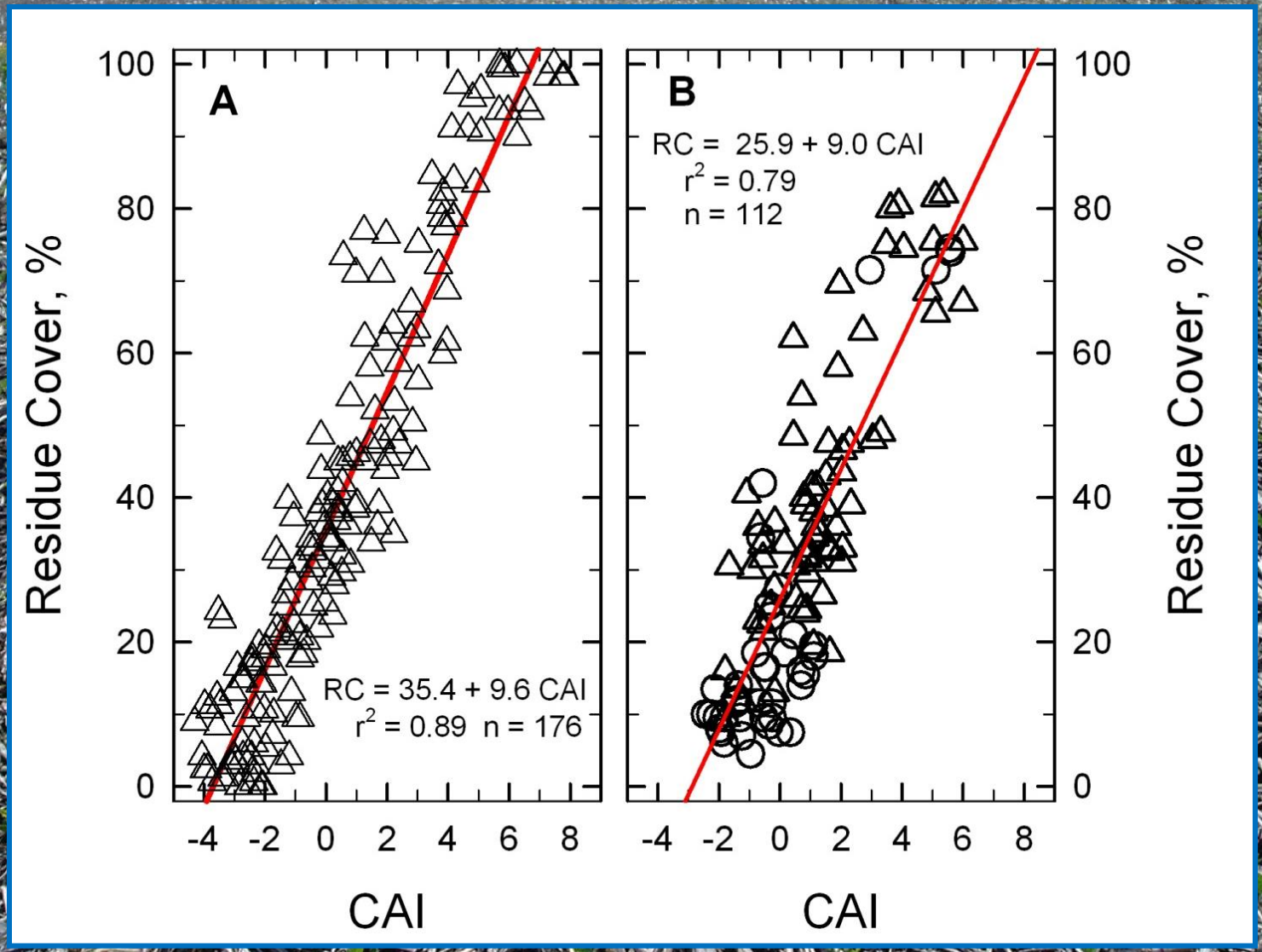
EO-1 Hyperion
- 400-2500 nm
- ~10 nm bands
- 30 m pixels;

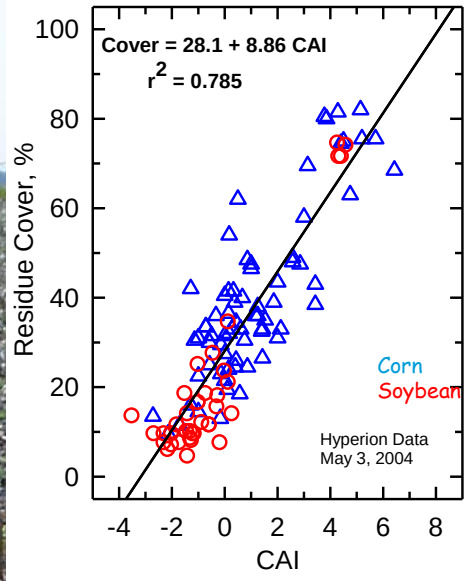
AVIRIS (NASA)
- 400-2450 nm
- ~10 nm bands
- 20 m pixels;

AISA Sensor (SpecTIR)
- 400-2450 nm
- ~5-10 nm bands
- 0.5 to 4 m pixels

Crop Residue Cover vs. Cellulose Absorption Index

Ground-based Satellite-based





Slope of line is similar to ground-based (ASD) and aircraft (AVIRIS & AISA) data in MD, IN, and IA.

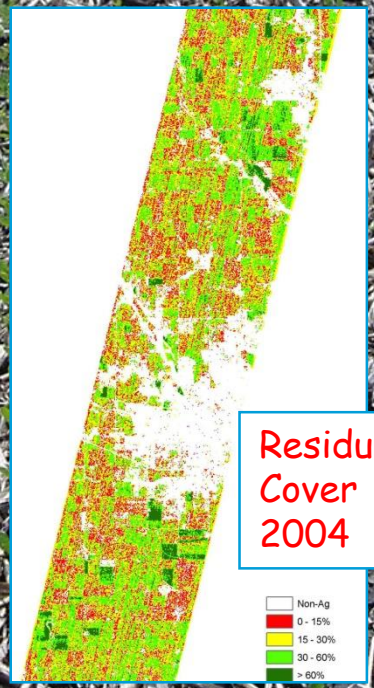
Planting progress for May 9
(Iowa Crop & Weather, 2004)

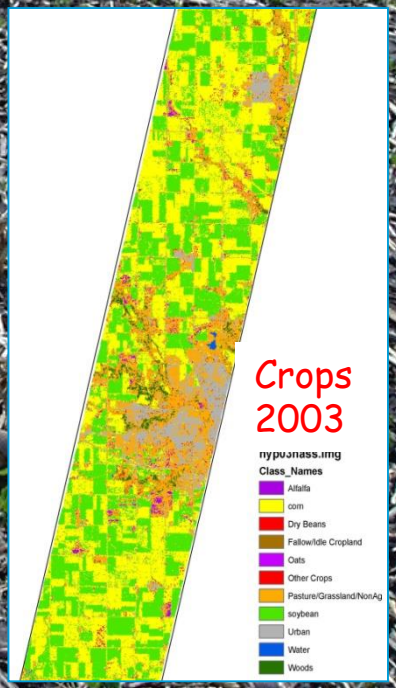
Corn: 93% planted;39% emerged
Soybeans: 54% planted; 4% emerged

Residue cover was measured: May 10-12

Hyperion Imagery was acquired: May 3

Daughtry et al. 2006.
Soil Tillage Research 91:101-108

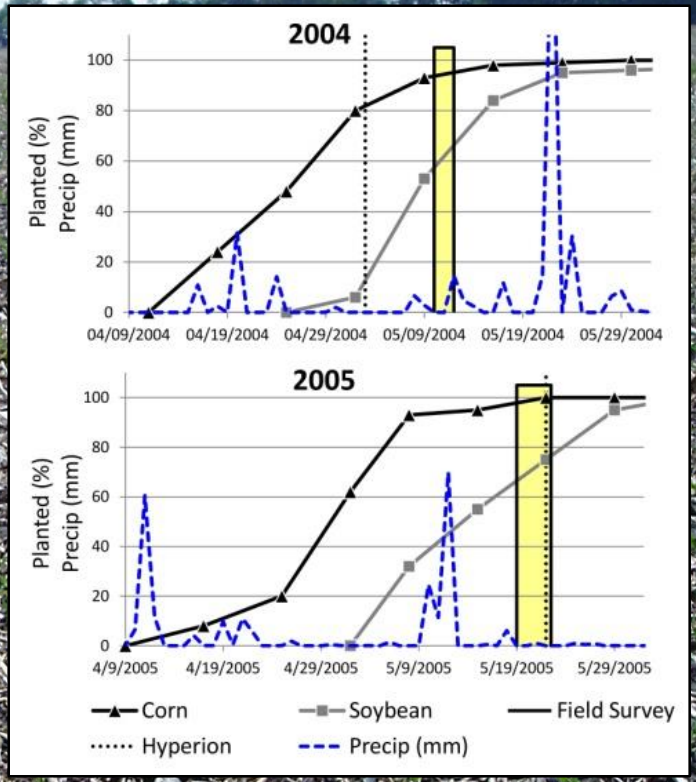




Residue Cover Category			
Tillage Class =	Intensive	Reduced	Conservation

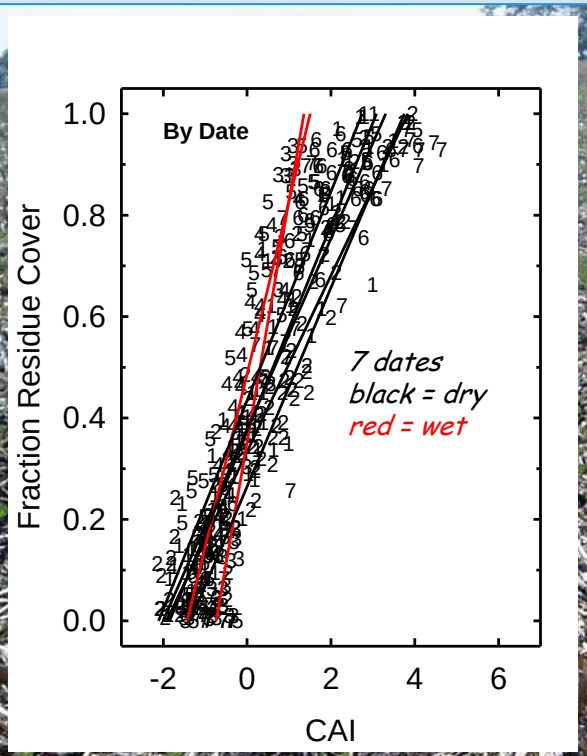
3 May 2004	<15%	15-30%	>30%
2003 Crop	%	%	%
Corn	18	36	46
Soybean	35	40	25
Overall	25	38	37

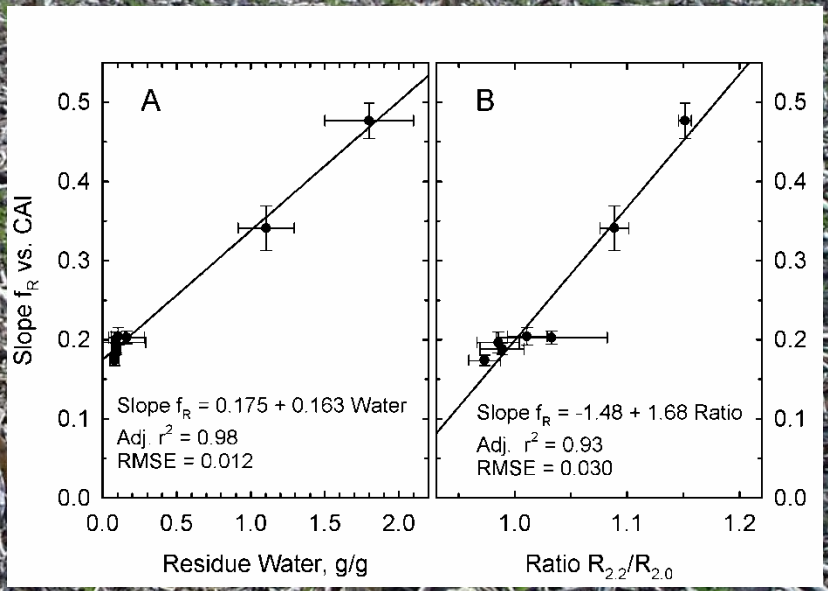
22 May 2005	<15%	15-30%	>30%
2004 Crop	%	%	%
Corn	7	38	55
Soybean	3	21	76
Overall	5	31	64



- Weather at planting influences tillage intensity.
  - 2004: warm, dry = more intense tillage
  - 2005: cool, wet = less intense tillage
- Timing of images relative to planting progress.

Basic Research: Field Reflectance Spectra



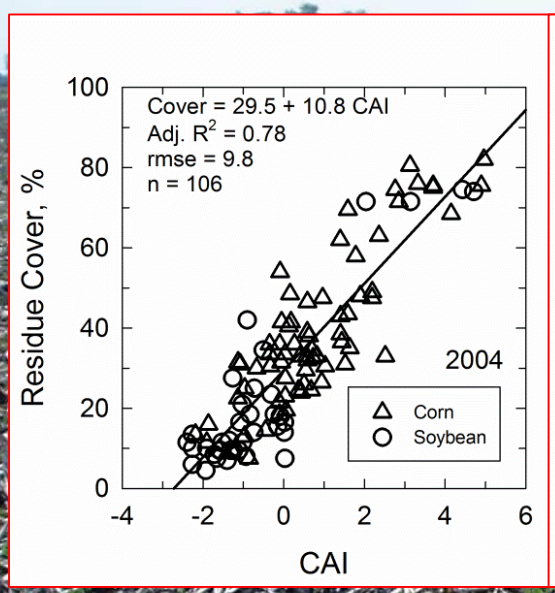


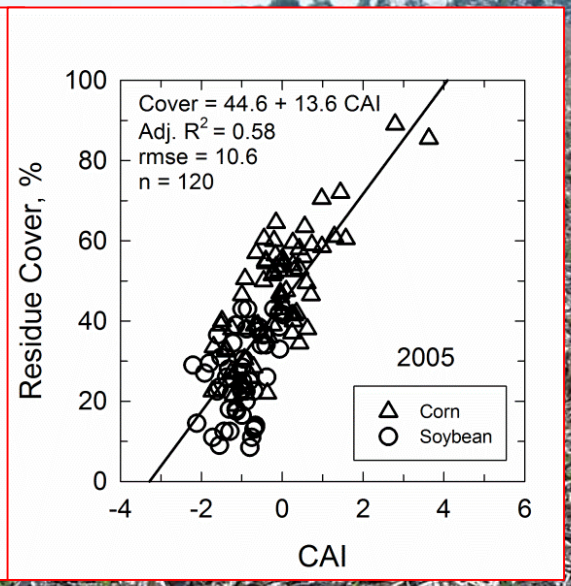
Cellulose Absorption Index

- CAI measures the relative intensity of the absorption feature at 2100 nm.
- Crop residue cover is linearly related to CAI, but water in the scene attenuates the reflectance signal and changes the slope of relationship.
- A ratio index measured relative scene moisture and improved estimates of crop residue cover.

Daughtry and Hunt 2008 Remote Sensing Environment 112:1647-1657

Hyperion Data

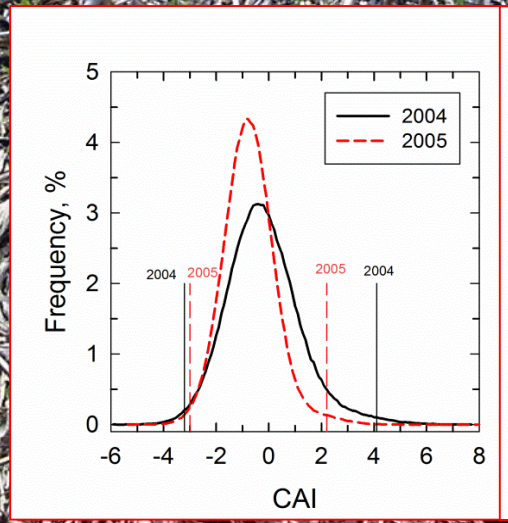


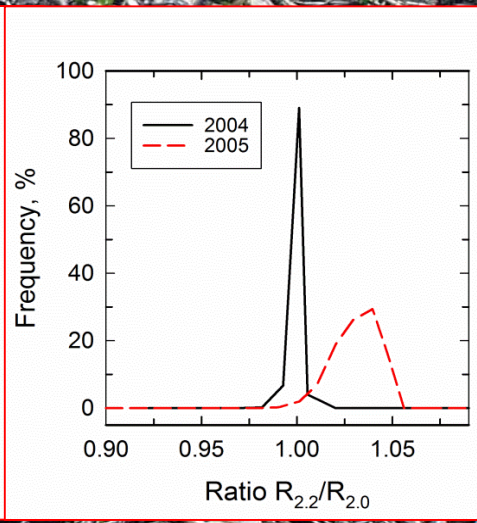


- Crop residue cover is linearly related to CAI.
- Differences in slope are related to scene moisture.

Difference between years.

- Rainfall in 2 weeks prior to Hyperion overpass was 48 mm in 2004 and 114 mm in 2005.
- Scene was wetter in 2005 than in 2004.
- Mode of CAI for 2005 decreased.
- Mode of Ratio Water Index for 2005 increased.

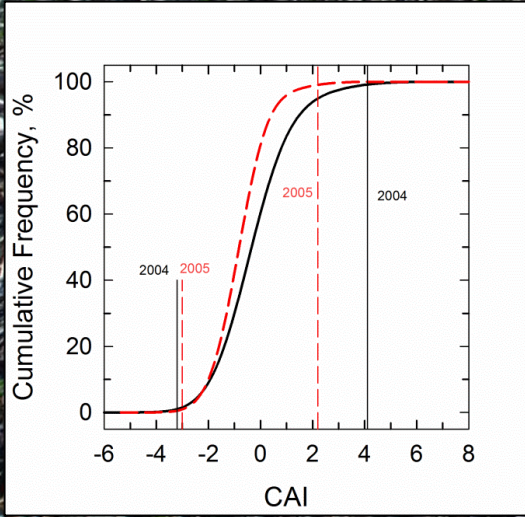




Surface Reference Data

	Sample Scheme	n
1	All (n=106 or 119) = all surface reference samples	106 or 119
2	5 Low + 5 High = samples regardless of crop type	10
3	Cum. Histogram, 1% = bare soil; 99%= 75% cover	2

Measured Cover	2004 n	2004 All Samples <30%	2004 All Samples ≥30%		2005 n	2005 All Samples <30%	2005 All Samples ≥30%	
0-30%	52	45	7		42	22	20	
>30%	54	12	42		77	10	67	
Correct				**82%**				**75%**
		5 Low + 5 High				**5 Low + 5 High**		
		<30%	≥30%			<30%	≥30%	
0-30%	52	**36**	16		42	**42**	0	
>30%	54	7	**47**		77	32	**45**	
Correct				**78%**				**73%**
		Histogram				**Histogram**		
		<30%	≥30%			<30%	≥30%	
0-30%	52	**35**	17		42	**28**	14	
>30%	54	7	**47**		77	15	**62**	
Correct				**77%**				**76%**



Reality Check

Imaging Spectrometers

- NASA Hyperion - launched in 2000.
- German EnMAP scheduled launch: 2018.
- *NASA HyspIRI anticipated launch: >2020.*

Advanced Multispectral Systems with SWIR bands

- Digital Globe – WorldView-3 (launched 2014)

Summary

- Spectral indices are robust and linearly related to crop residue cover.
- Relationships developed with ground-based sensors are extendable to airborne and space-borne sensors.
- Currently images are small – no wall-to-wall coverage.

Reality Check (part 2)

Multispectral Systems with Broad SWIR bands

- Landsat-7 (launched 1999); Landsat-8 (launched 2013)
- Sentinel-2 (scheduled launch 2015)

Summary

- Broad band residue indices are not robust.
- Only a few residue cover classes may be identified.
- Training statistics are not extendable in time or space.
- Soil type, crop type, residue age, and scene moisture affect classifications.
- Images are large and wall-to-wall coverage with both Landsat-8 and Sentinel-2.

Challenges

How to best use a few Advanced Multispectral and Hyperspectral images and many Landsat and Sentinel-2 to produce surveys of soil tillage intensity at watershed to national scales.

- Use spatial and temporal data fusion models to combine Advanced Multispectral and Broadband Multispectral images (e.g. STAR-FM).
- Use Advanced Multispectral images for a stratified sampling approach to provide reliable ground truth data for Broadband Multispectral data.