Sensor Needs for Agricultural and Carbon Management

E. Raymond Hunt, Jr.,
Craig S. T. Daughtry,
Paul C. Doraiswamy, &
Guy Serbin

USDA-Agricultural Research Service
Hydrology & Remote Sensing Laboratory
Beltsville, Maryland

USDA
Agricultural Research Service

USDA-ARS HRSL
Hydrology & Remote Sensing Lab
Beltsville, Maryland, USA

HRSL has about 65% of the total effort of ARS in Remote Sensing

Currently, we are doing research in three major areas:

- Microwaves and soil moisture
- Thermal infrared and fluxes
- Agricultural and carbon management

Special issue on ARS remote sensing

Agricultural Management – Nitrogen Fertilizer

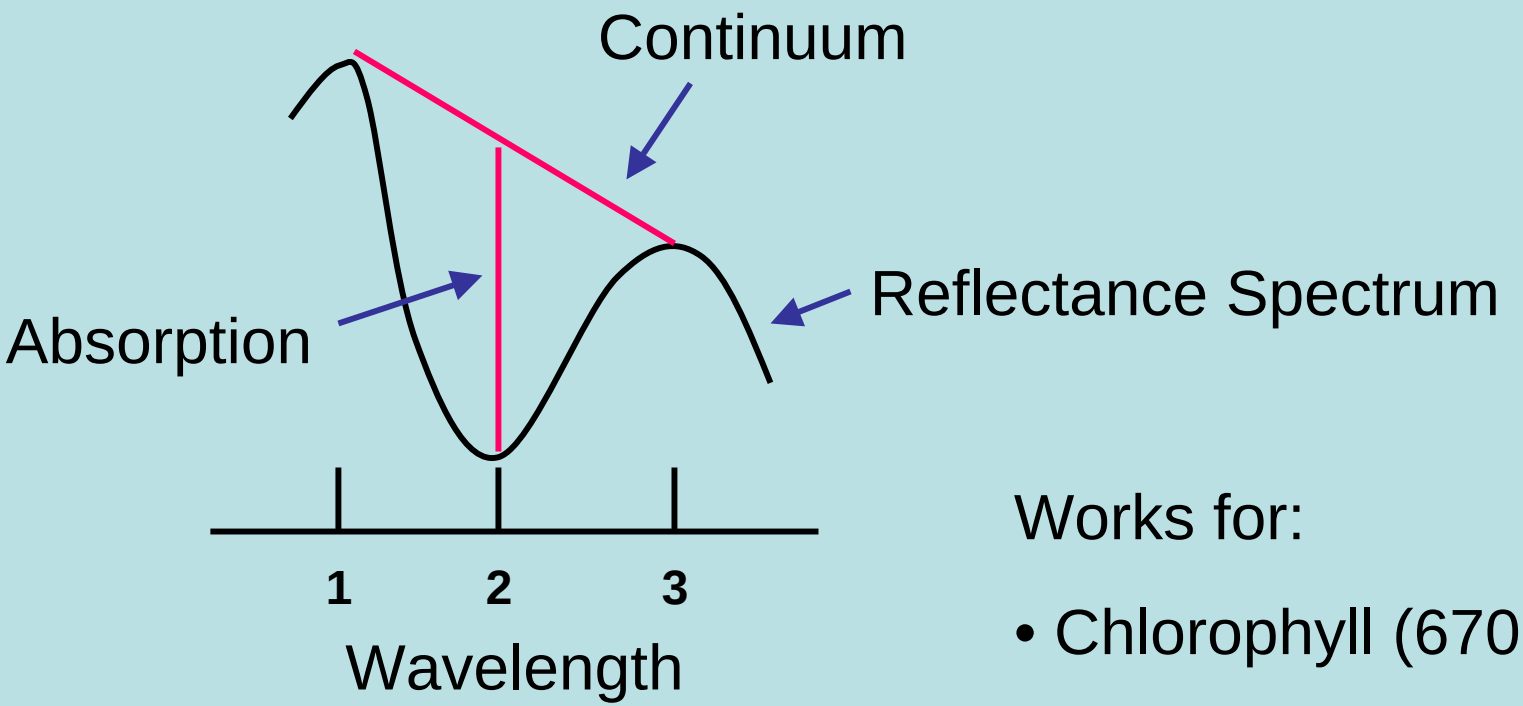
- Chlorophyll content
- Non-point-source pollution
- Cover crops

Carbon Management - Crop Residue

- Protects soil from erosion
- Increases soil fertility
- Carbon dioxide sequestration
- Potential biofuel (cellulosic ethanol)

New narrow bands will allow estimation of chlorophyll content and residue cover

Spectral Continuum Analysis



Works for:

- Chlorophyll (670 nm)
- Cellulose (2100 nm)

Index = weighted (1 + 3) - 2

Soil Tillage Intensity

Conservation tillage:
>30% residue cover

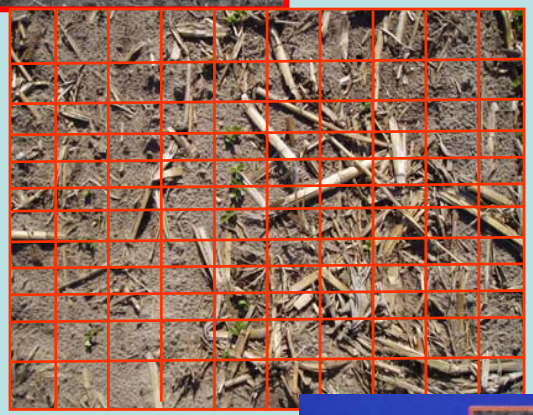
Reduced-tillage:
15-30% residue cover

Intensive tillage:
< 15% residue cover

Methods to Assess Crop Residue Cover

Line-point Transect Method

- Accuracy depends on length of line and number of points.
- Standard used by USDA NRCS.

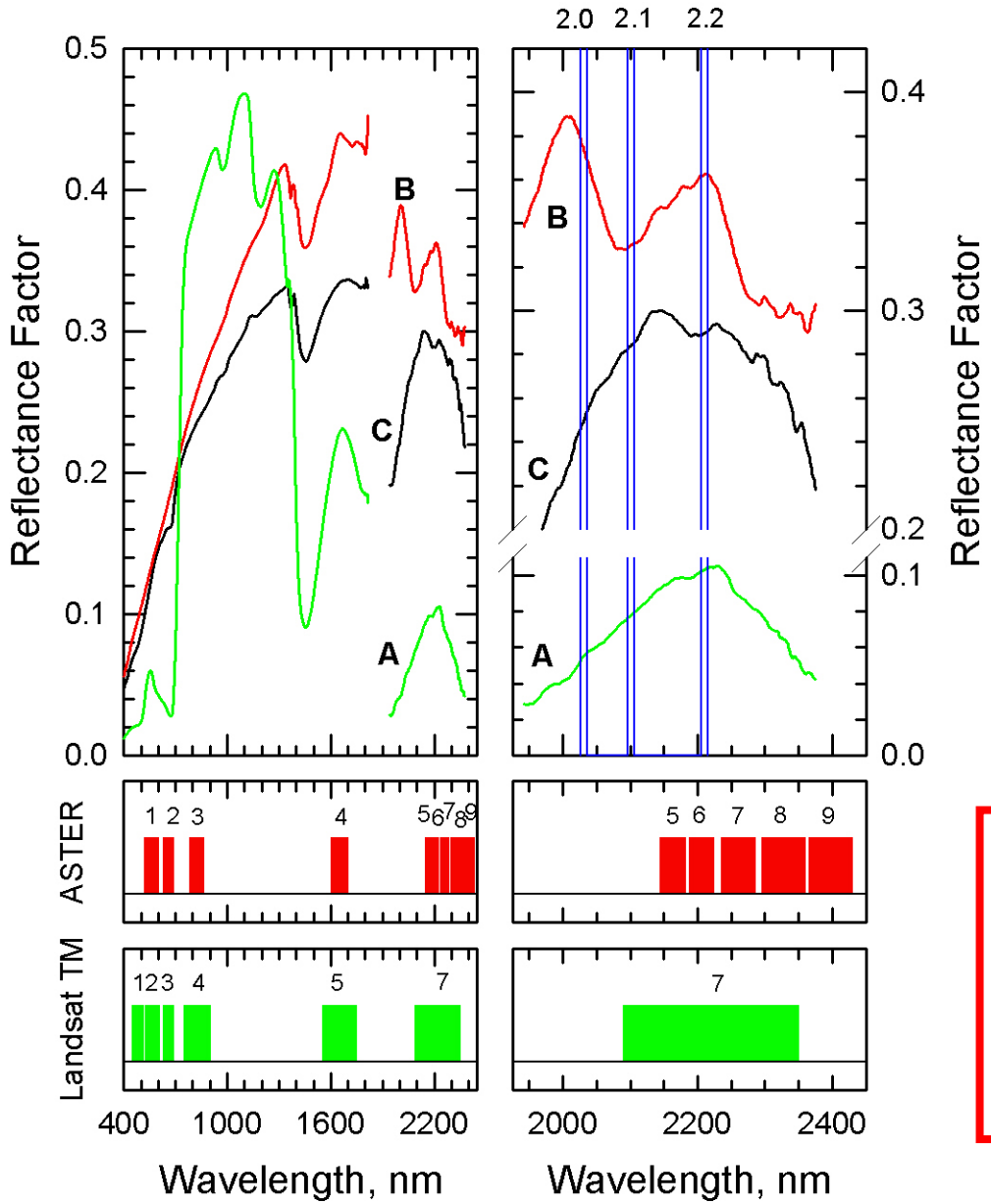


Photographic Method

- Accuracy depends on
  - number of points (manual).
  - contrast between residue and soil (automated).

Photo Comparison

- Accuracy depends on good examples and experience.



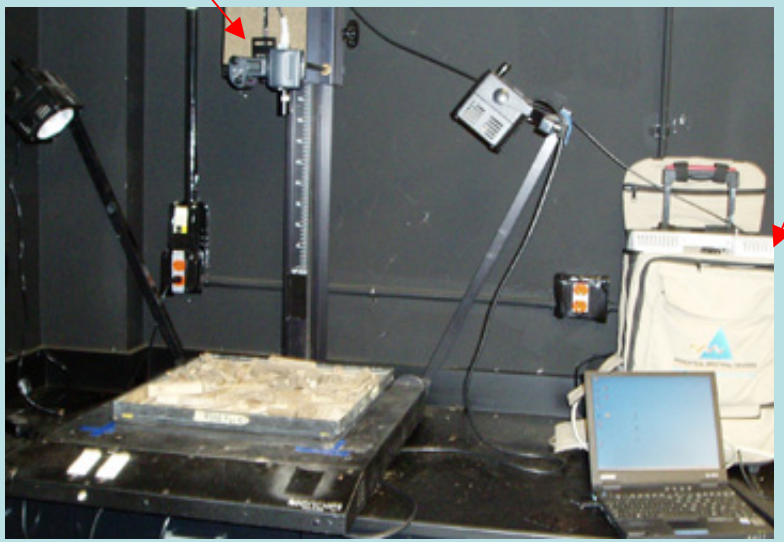
Reflectance Spectra

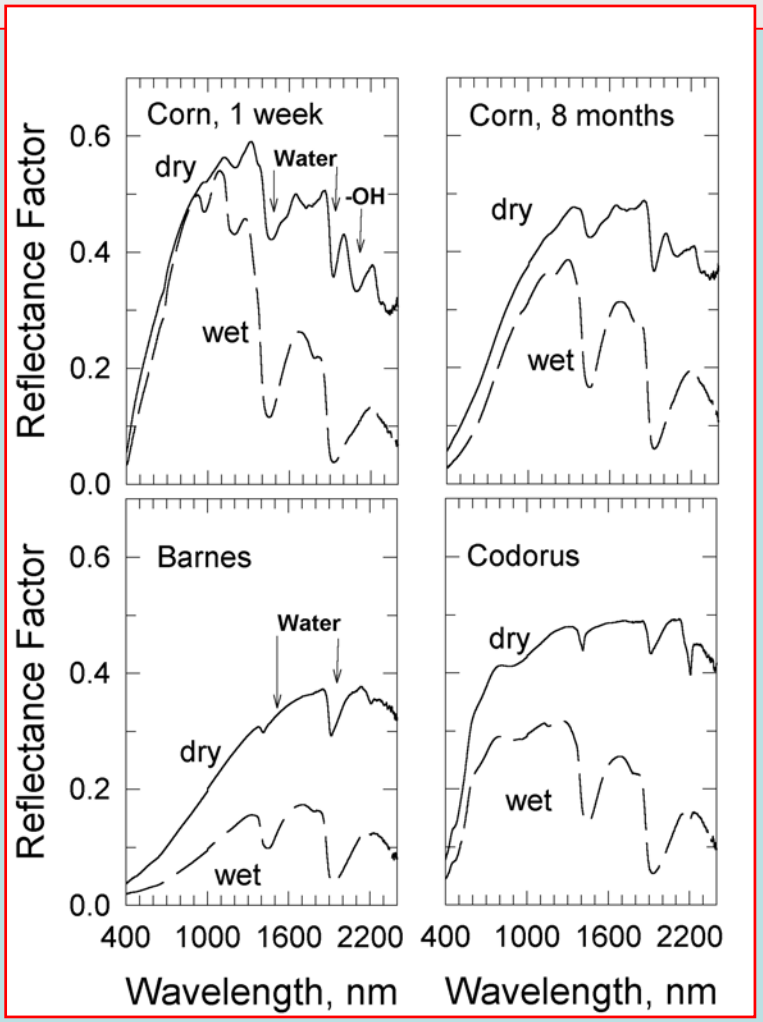
A. Plant (Green)
B. Residue (Red)
C. Soil (Black)

- Soil and crop residue spectra have similar shape in 400-1200 nm region.
- Crop residue spectra have a unique cellulose absorption feature near 2100 nm.

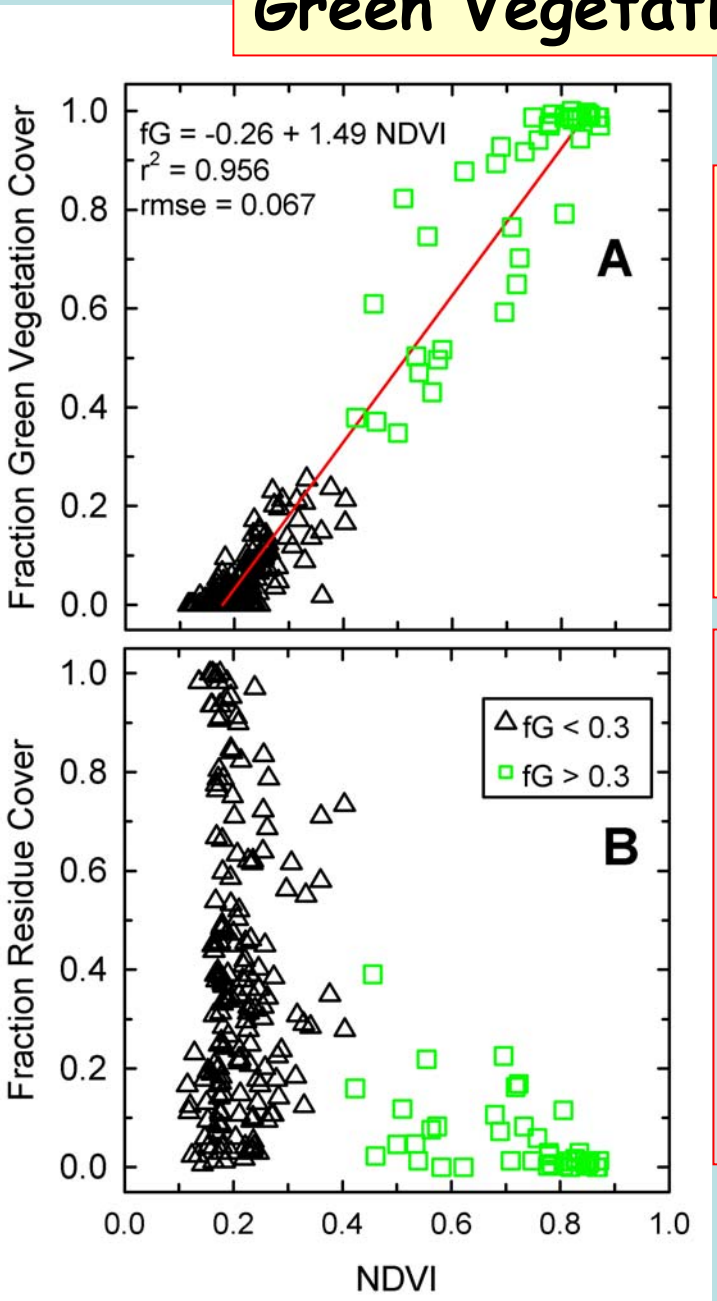
Spectral reflectance of crop residues is determined by

- Moisture content
- Age (weathering and decomposition)
- Crop type (C:N ratio; cellulose & lignin contents)
- Soil type and mineralogy





Green Vegetation and Residue vs NDVI



Normalized Difference Vegetation Index

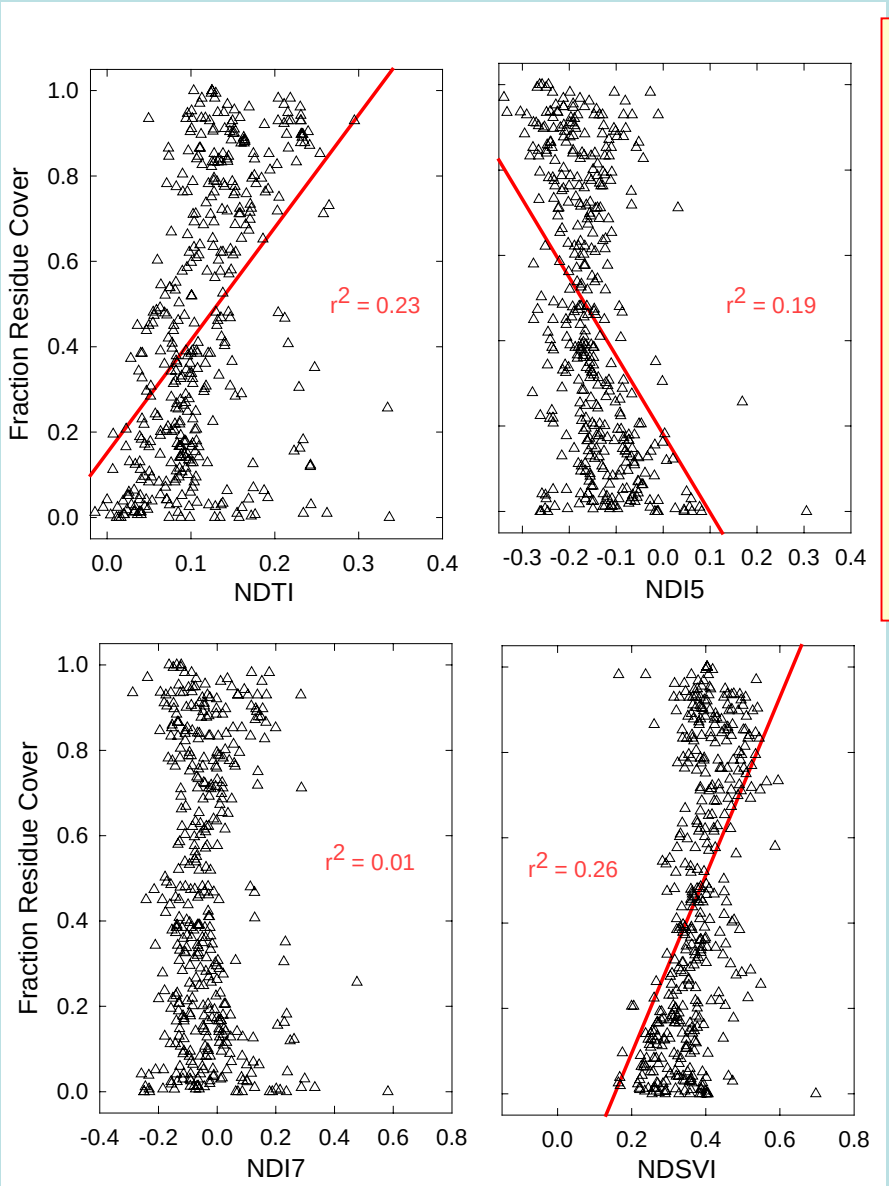
$$NDVI = (TM4 - TM3)/(TM4 + TM3)$$

where TM3 and TM4 are reflectances of the Landsat Thematic Mapper bands.

➢ Squares indicate scenes with more than 30% green vegetation cover.

- Green vegetation cover is linearly related to NDVI.
- Crop residue cover is not related to green vegetation indices including:
  - NDVI
  - NIR/Red
  - VI(green)
  - SAVI, OSAVI
  - VARI
  - MCARI

Crop Residue Cover vs Landsat TM Indices



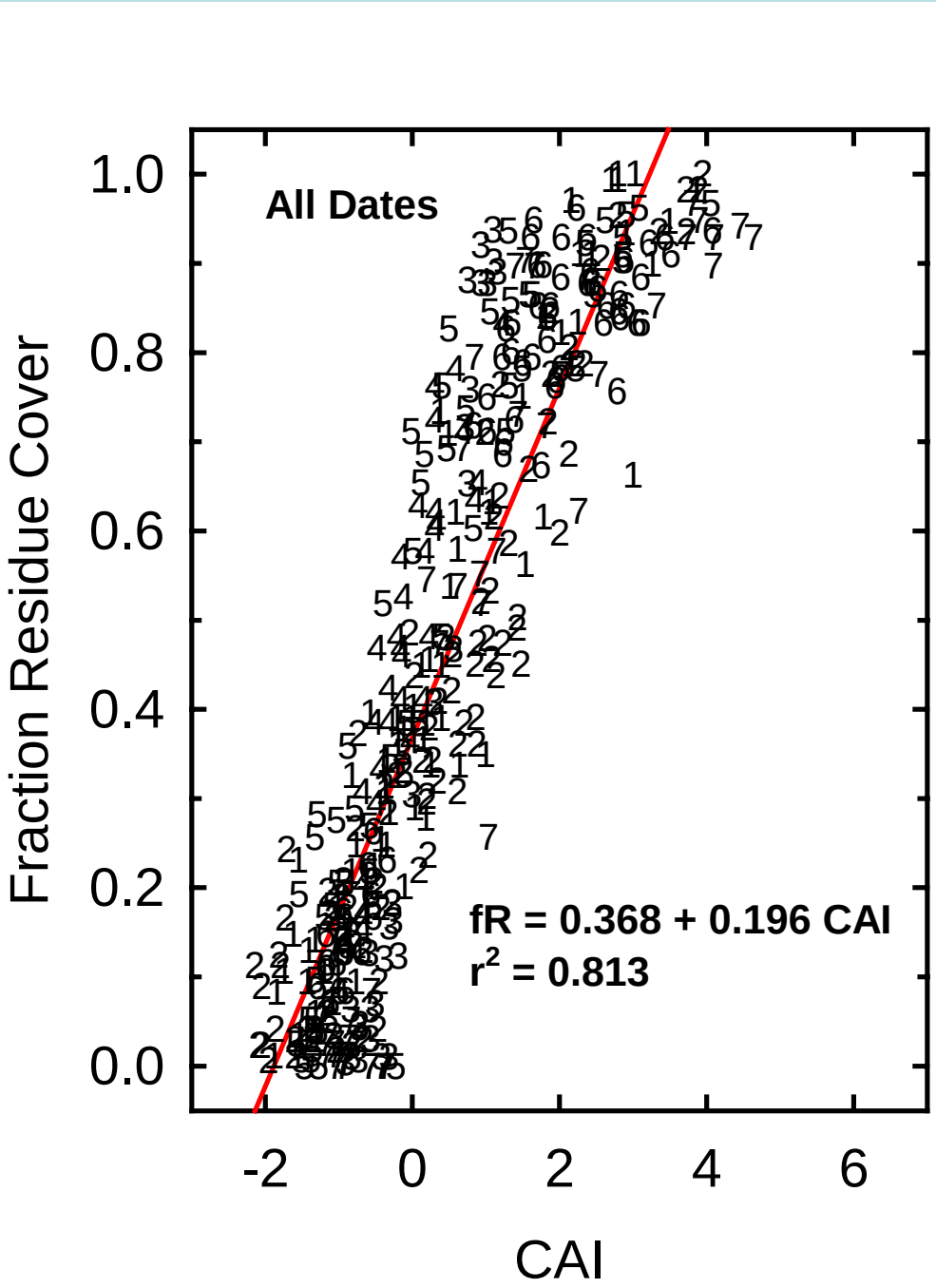
- Normalized Difference Tillage Index
  NDTI = (TM5 - TM7)/(TM5 + TM7)

- Normalized Difference Index
  NDI5 = (TM4 - TM5)/(TM4 + TM5)
  NDI7 = (TM4 - TM7)/(TM4 + TM7)

- Normalized Diff Senescent Vegetation Index
  NDSVI = (TM5 - TM3)/(TM5 + TM3)

where TM3, TM4, TM5, and TM7 correspond to reflectance in the Landsat Thematic Mapper bands.

- Crop residue cover is only weakly related to Landsat spectral indices.
- The broad spectral bands of Landsat are not well suited for discriminating crop residues from soils.



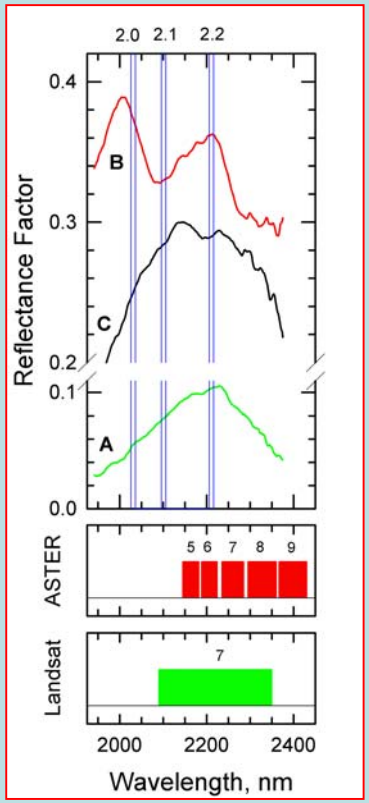
Cellulose Absorption Index

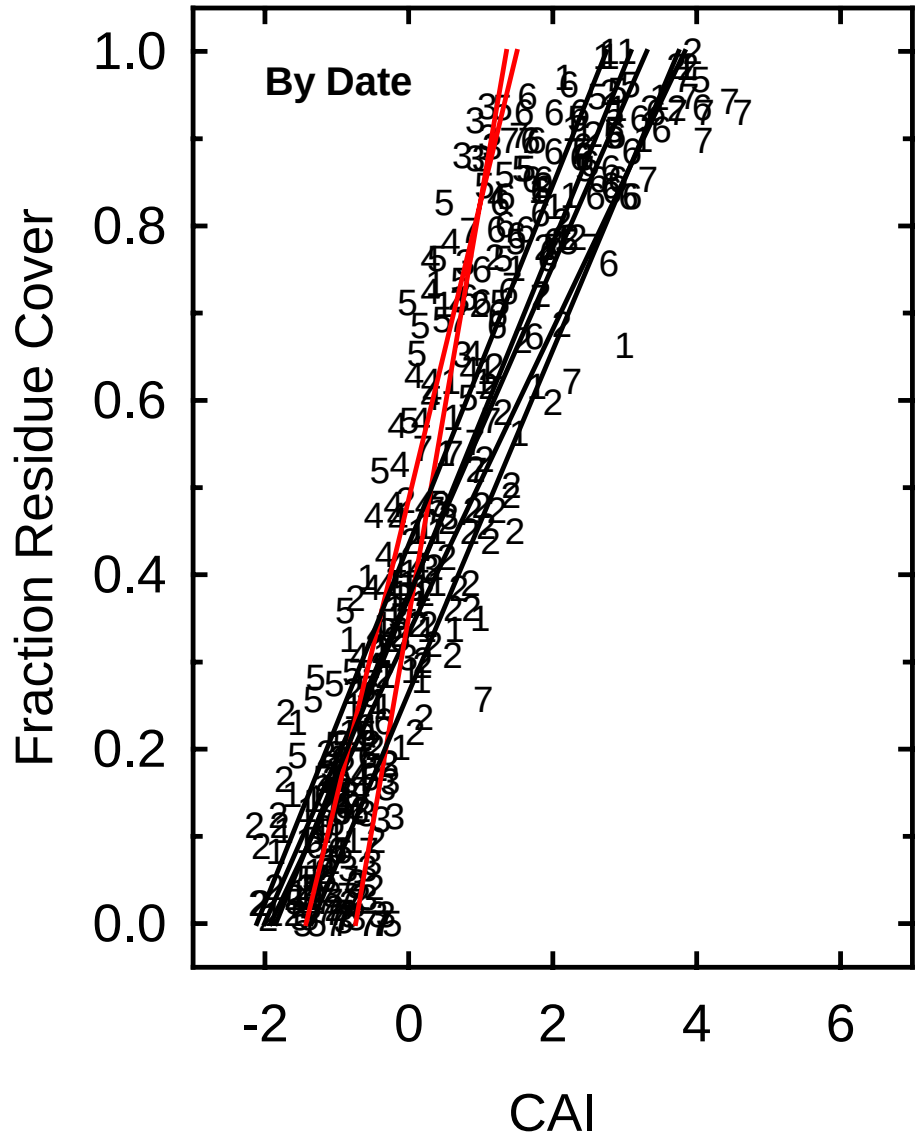
$CAI = 100\,[0.5\,(R_{2.0}+R_{2.2})-R_{2.1}]$

$R_{2.0}$ is band at 2030 nm,

$R_{2.1}$ is band at 2100 nm,

$R_{2.2}$ is band at 2210 nm.

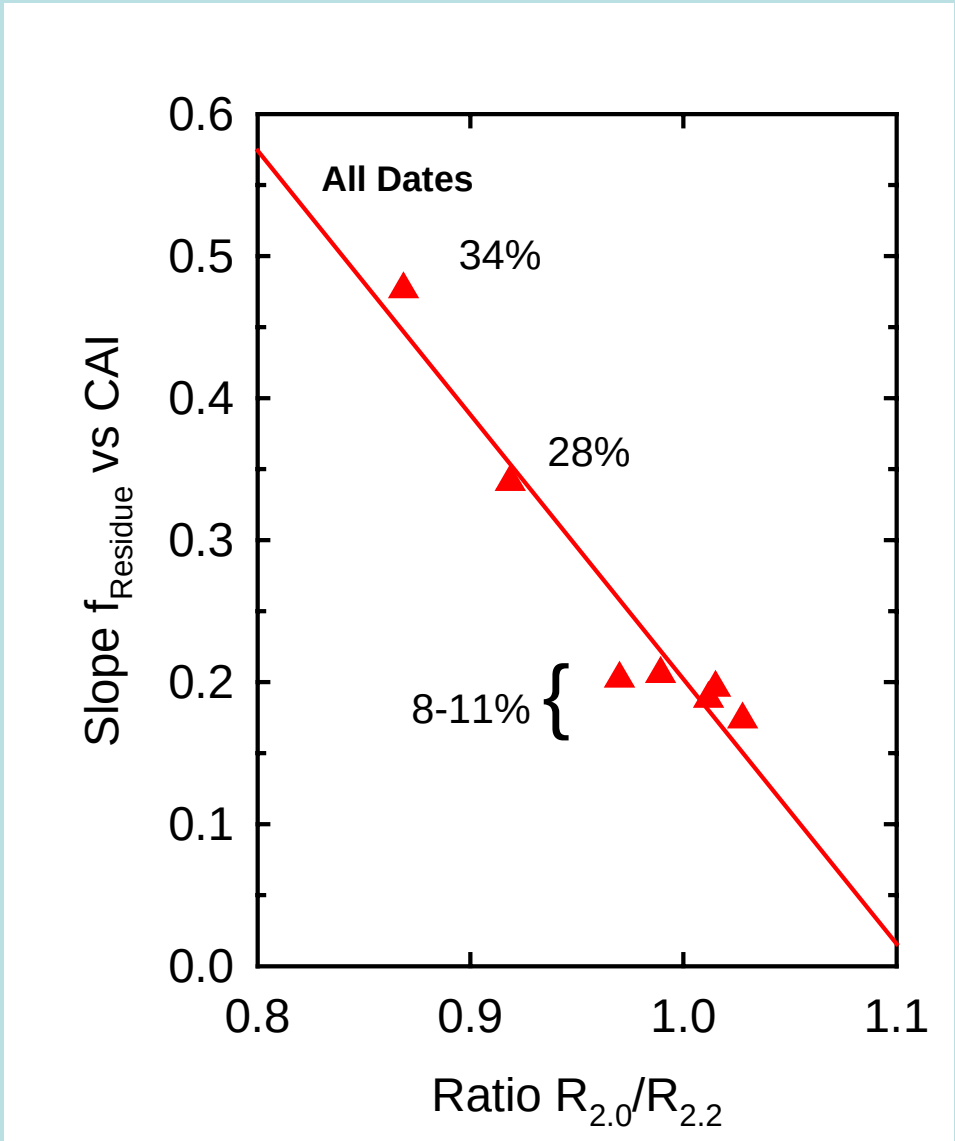


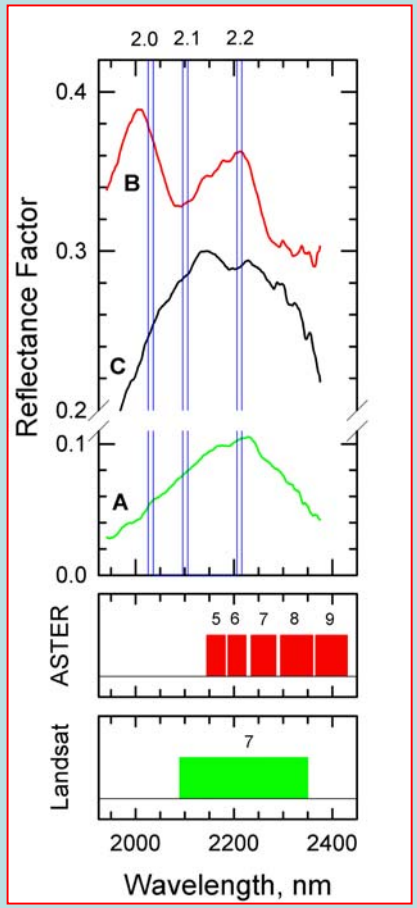


Crop Residue Cover vs CAI

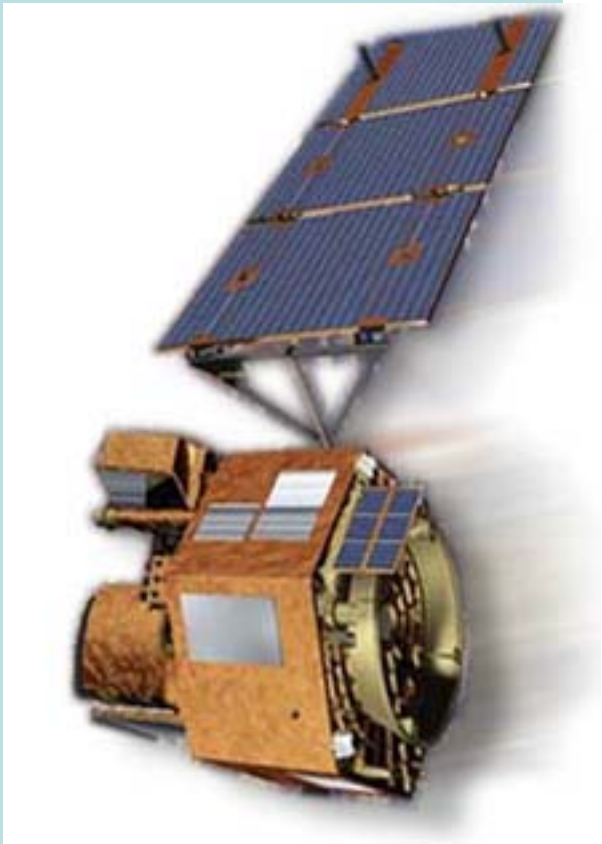
Date	Slope	rmse	r^2	% water
1	0.188	0.099	0.896	9
2	0.174	0.093	0.888	8
3	0.477	0.091	0.933	34
4	0.341	0.089	0.813	28
5	0.206	0.140	0.834	10
6	0.203	0.113	0.888	11
7	0.196	0.165	0.825	9
All	**0.196**	**0.144**	**0.813**	

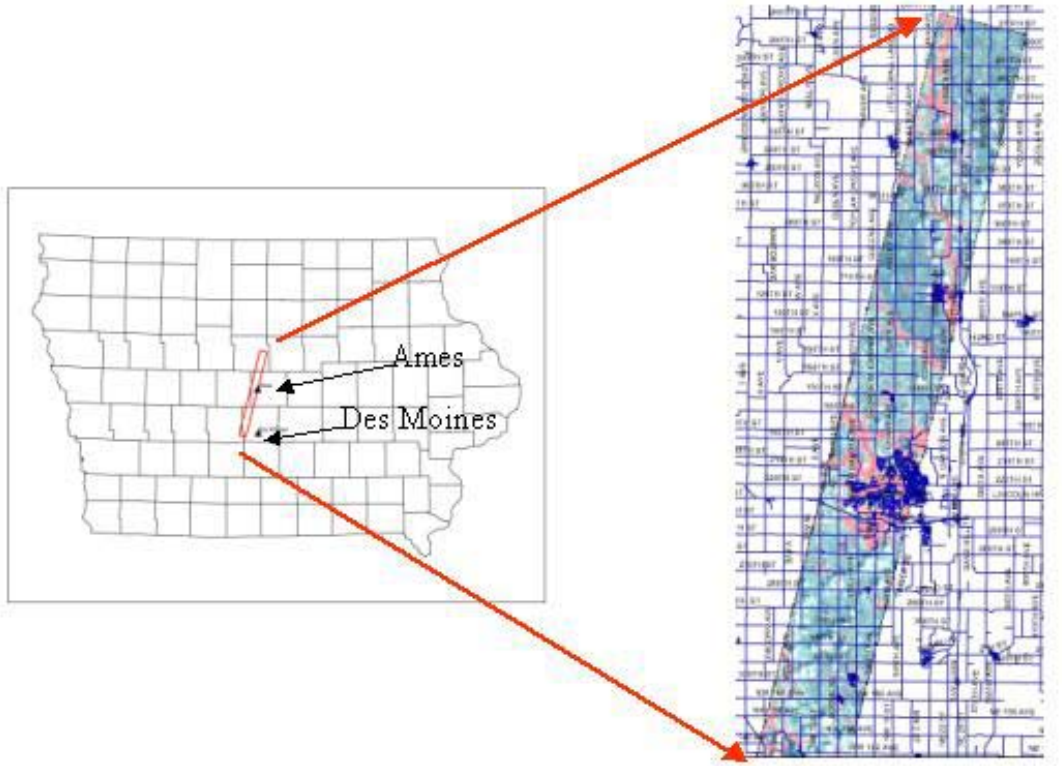
Changes in Slope as a function of Ratio of CAI bands





Scaling up: Hyperion Reflectance Spectra

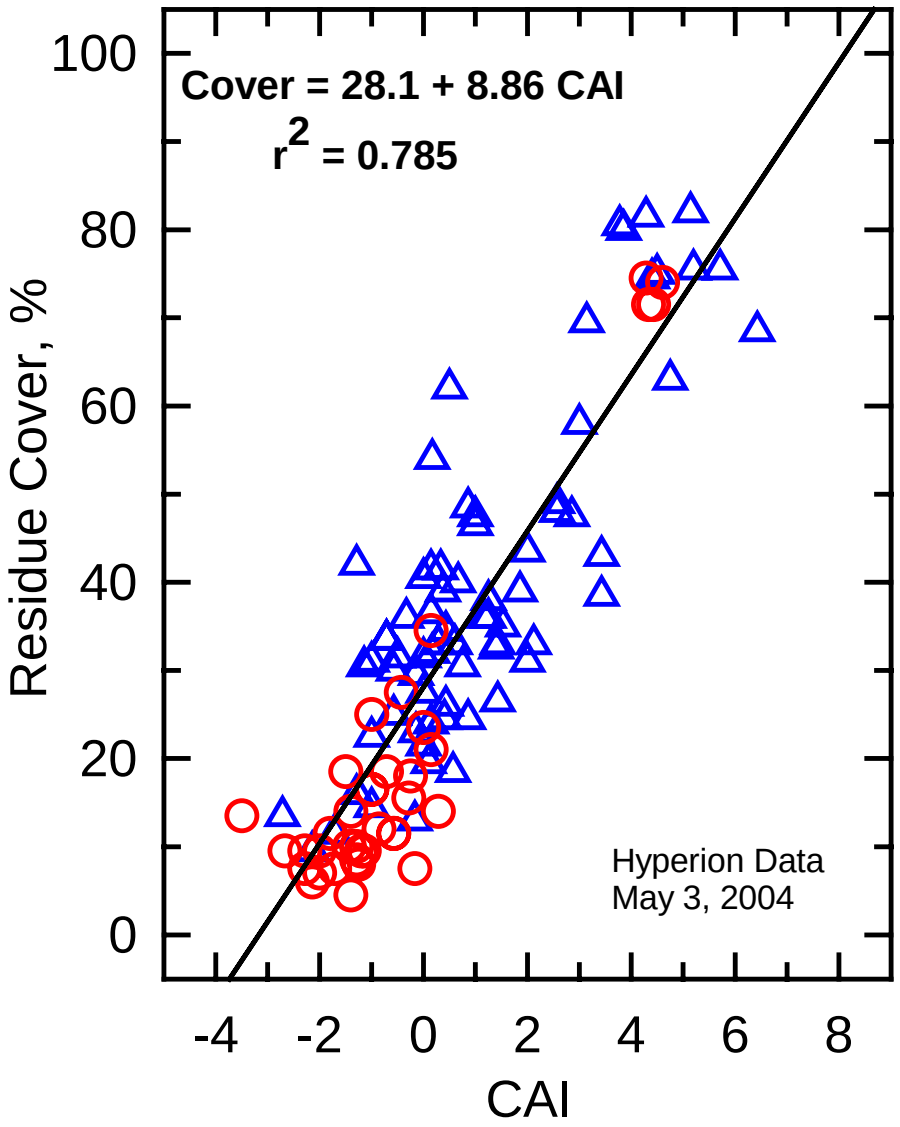




Hyperion hyperspectral imager on EO-1 satellite

- 220 bands over 400-2500 nm wavelength range.
- 30 m pixels; 7.5 km x 100 km scene

Crop Residue Cover vs CAI for Hyperion Image Iowa – May 3, 2004



Crop residue cover was measured on May 10-12.

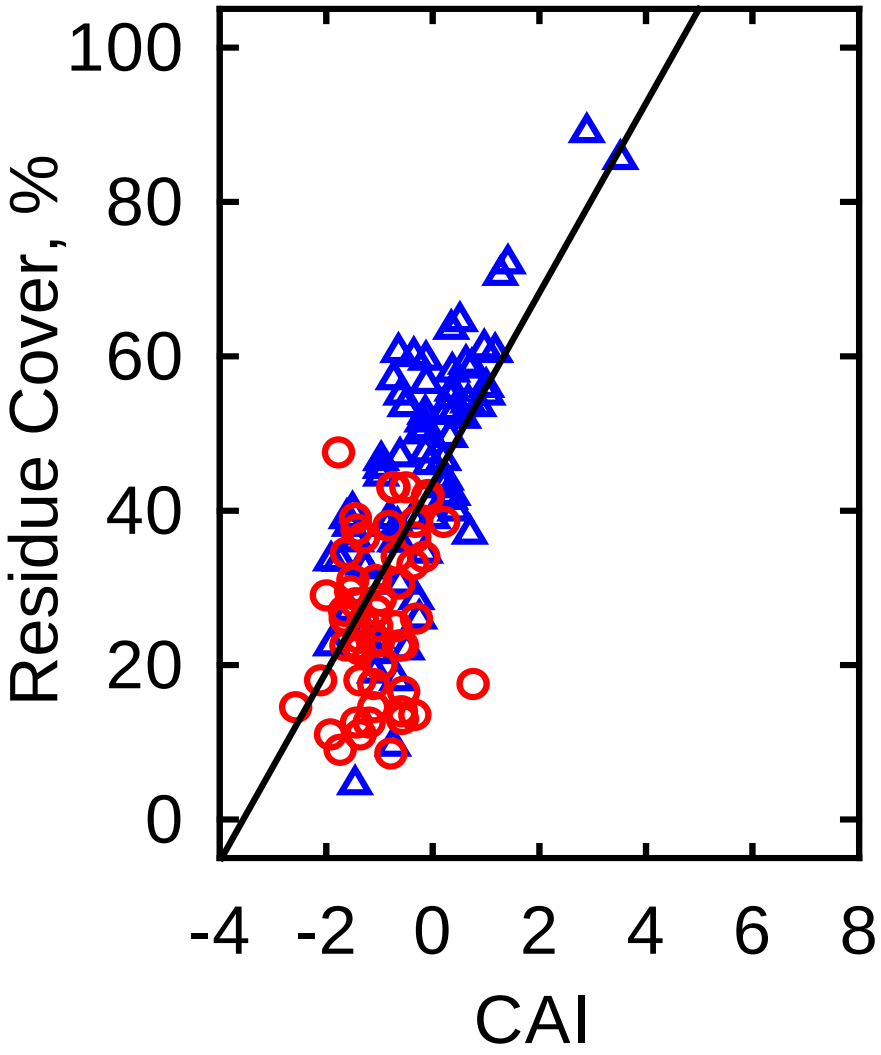
Planting progress for May 9
(Iowa Crop & Weather, 2004)

Corn:
93% planted;39% emerged

Soybeans:
54% planted; 4% emerged

Slope of line is similar to ground-based and aircraft data in Maryland.

Crop Residue Cover vs CAI for Hyperion Image
Iowa – May 22, 2005

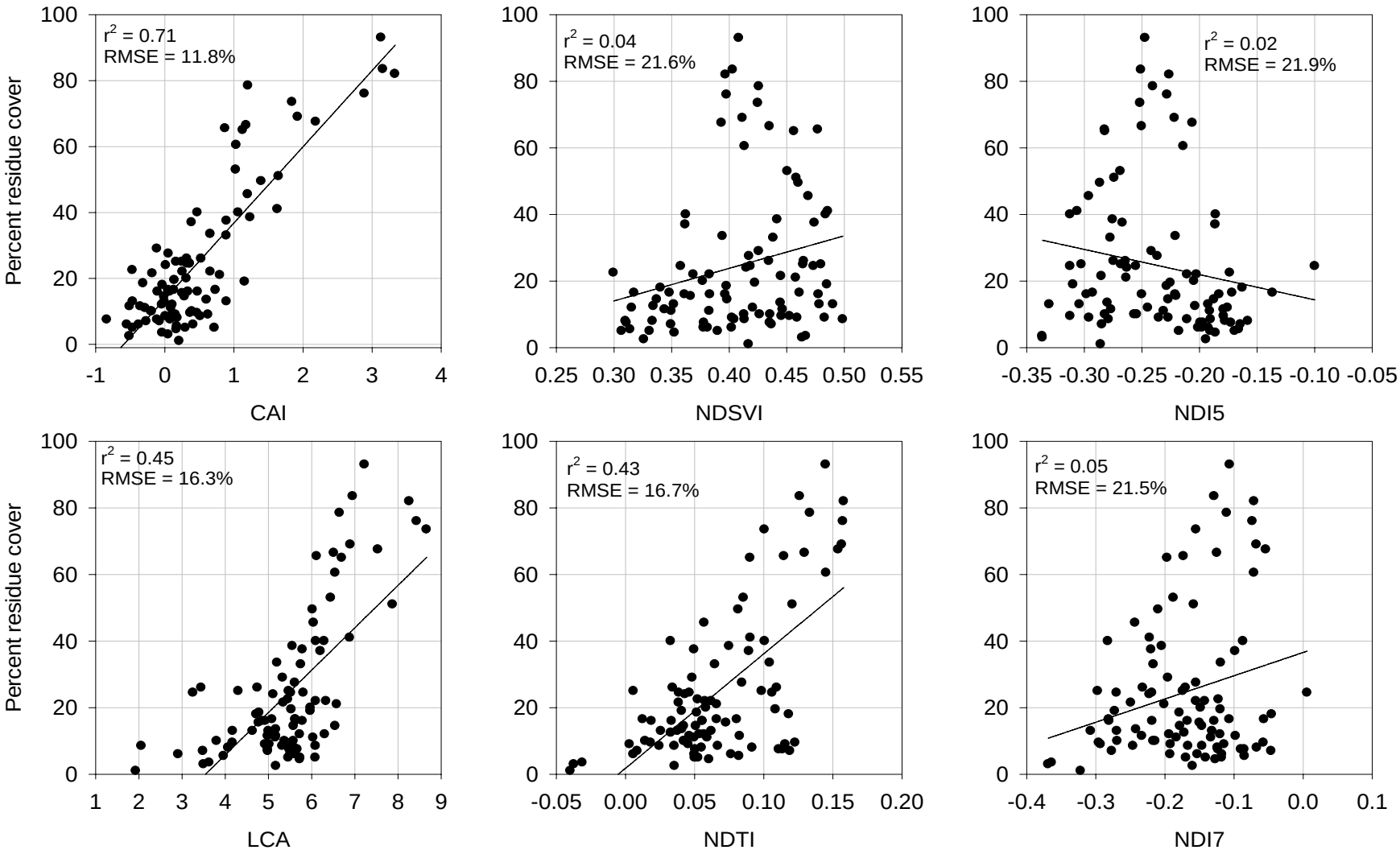


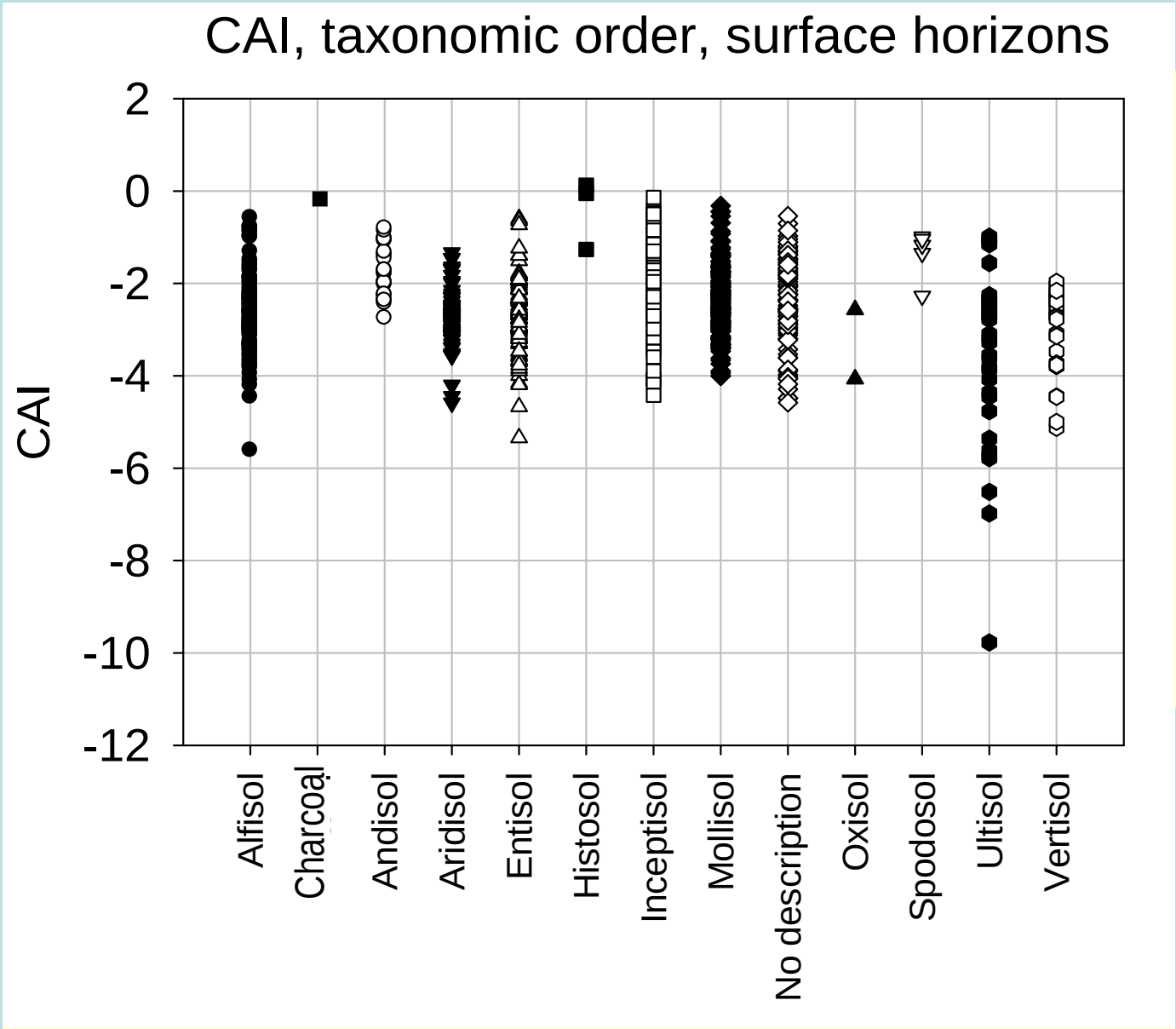
Crop residue cover was measured on May 19-22.

Planting progress for May 22
(Iowa Crop & Weather, 2005)
- **Corn:**
  99% planted; 83% emerged
- **Soybeans:**
  75% planted; 19% emerged

For both corn and soybean fields, crop residue cover is linearly related to CAI.

2006 SpecTIR Airborne Hyperspectral Imagery in Indiana
CAI does best





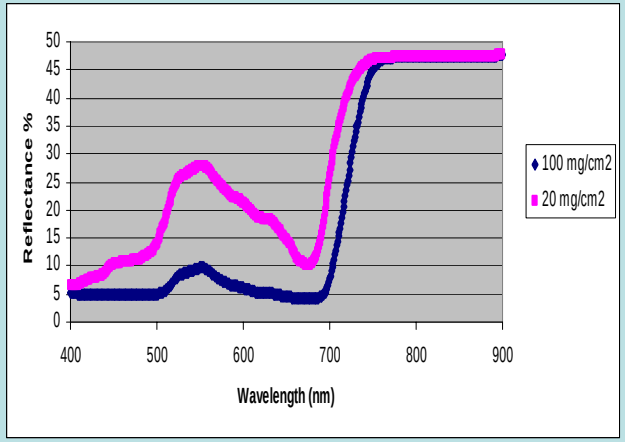
Soils can have strong differences in CAI, based on mineralogy.

Corrections for soil type increase R^2

Mid-season Nitrogen Fertilizer Application in Winter Wheat

Maximize protein content (grain quality)

Minimize nutrient run-off into the watershed



At the leaf level, chlorophyll content is easily measured by spectral reflectances. However, at the canopy level, there are strong interactions with leaf area index and plant cover.

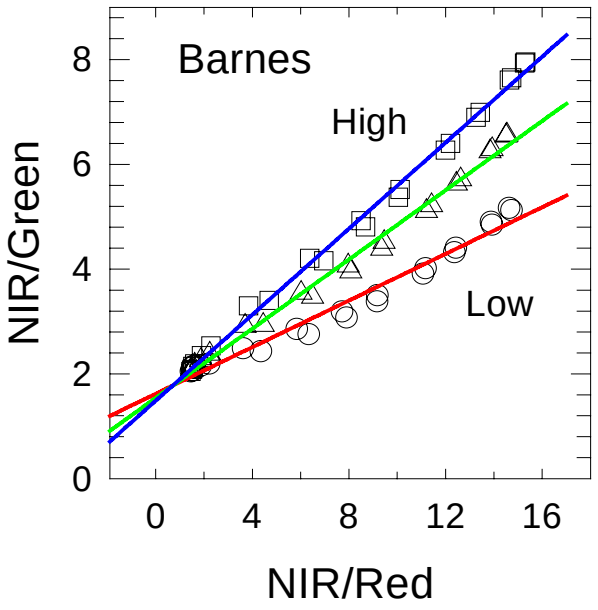
Chlorophyll Absorption in Reflectance Index (CARI)

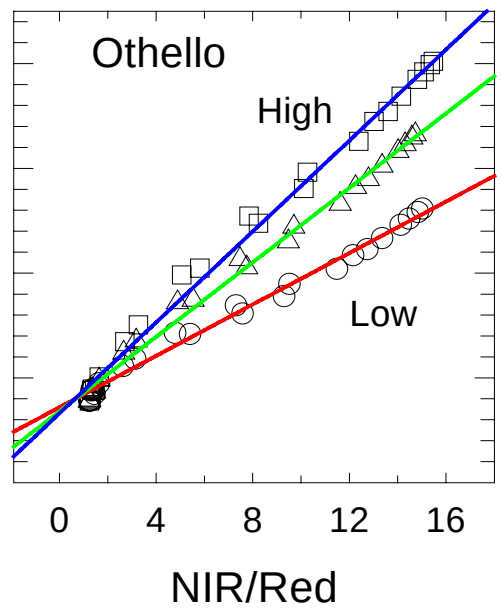
$$CARI = (0.8\ R_{700} + 0.2\ R_{550}) - R_{670}$$

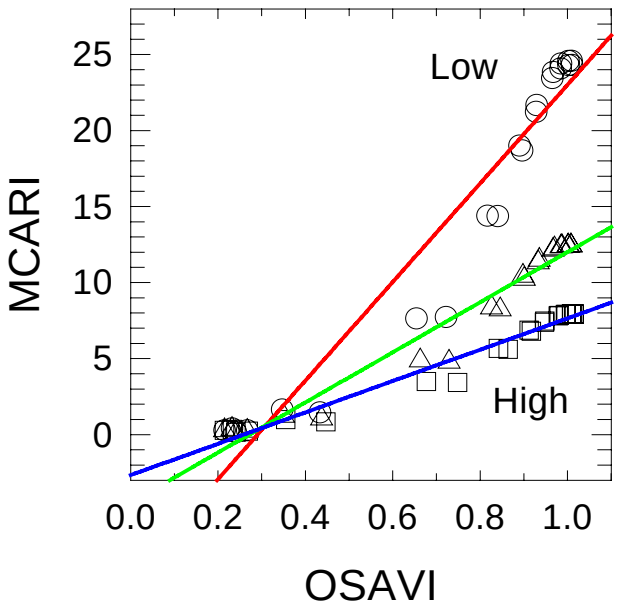
Modified CARI (MCARI)

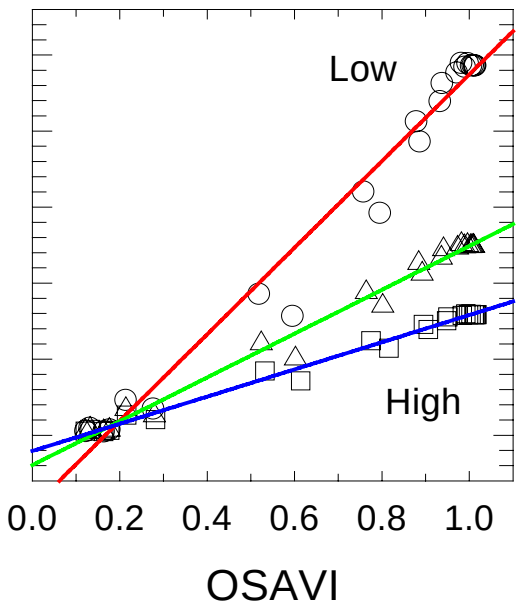
$$MCARI = [(0.8\ R_{700} + 0.2\ R_{550}) - R_{670}]\ R_{700}/R_{670}$$

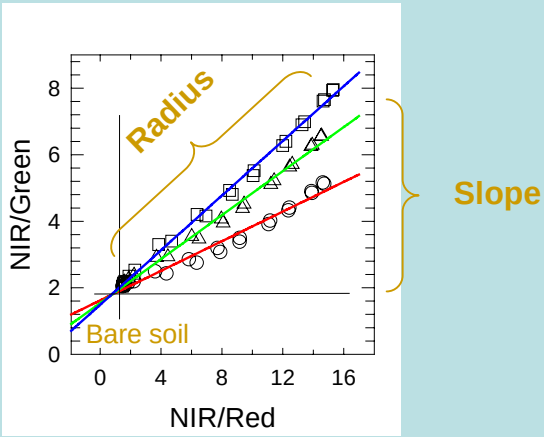
All VIS-NIR indices are sensitive to both chlorophyll content and cover/LAI









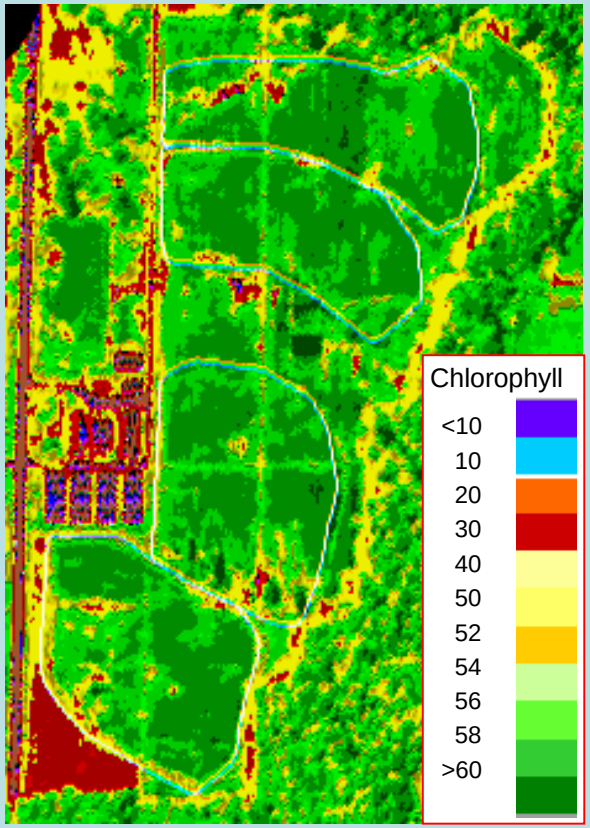


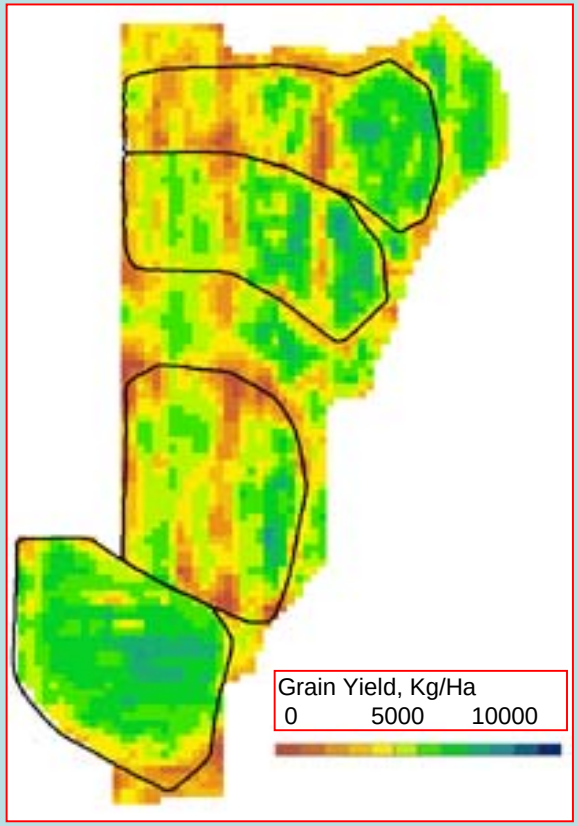
Slope is related to chlorophyll content, approximately equal to the ratio of indices

Optimizing Production for Economic and Environmental Enhancement (OPE3) at Beltsville Agricultural Research Center

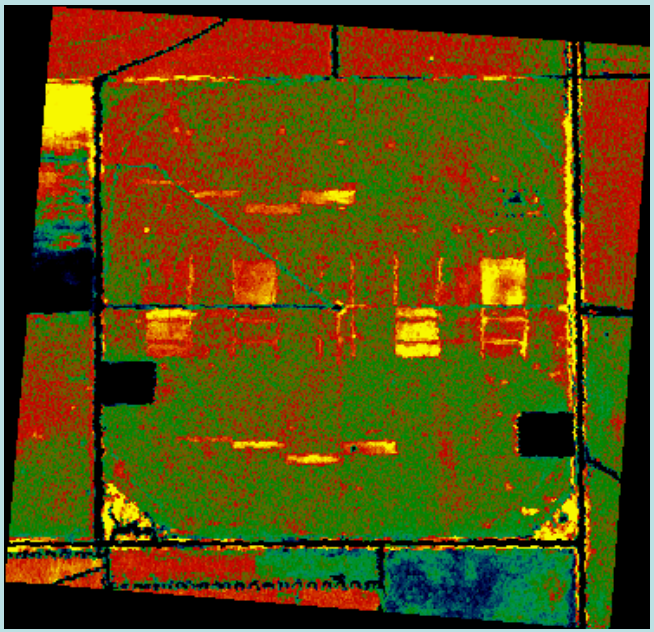
Management treatments on OPE3 since 2000

A = Dairy manure, Uniform application
B = Fertilizer, Split, Uniform N rate
C = Fertilizer, Split, Uniform N rate
D = Fertilizer, Split, Variable N rate (***Increases NUE and maintains yields***!)



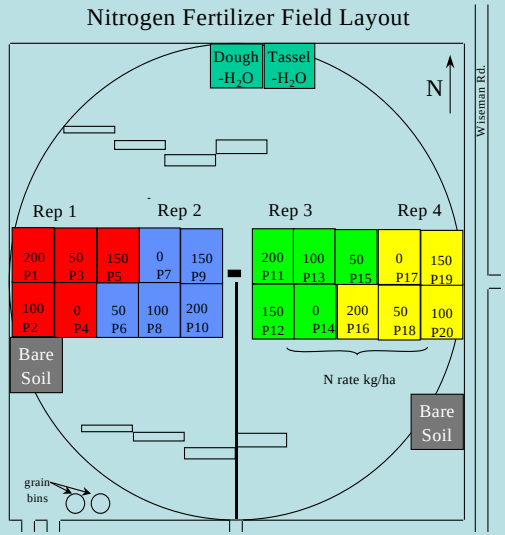


Index to Detect Changes in Chlorophyll in Nebraska: MCARI/OSAVI

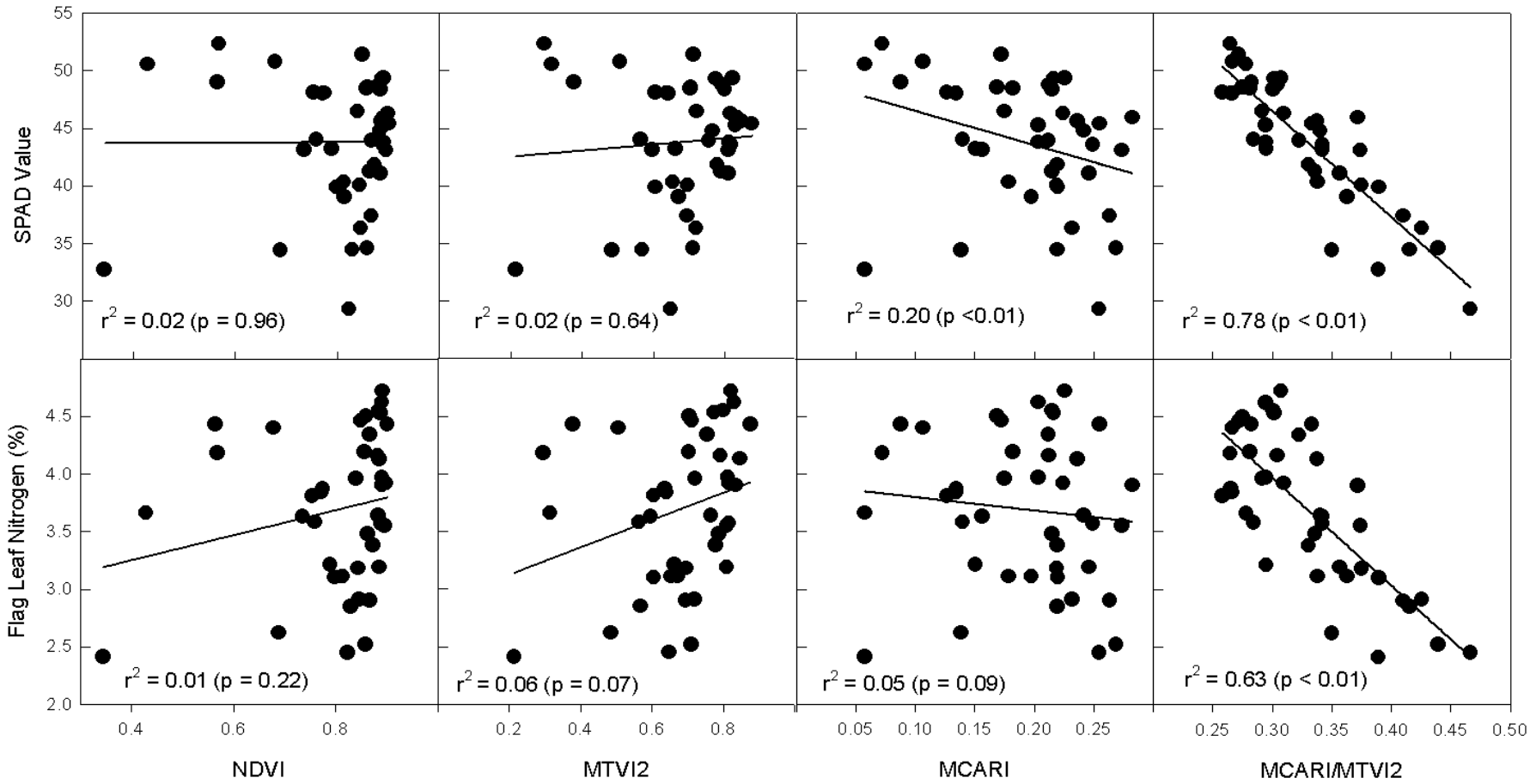


Pixel Values

- **Apply No N (Control Area)**
- **Index Indicates "More N Needed"**
- **Recommended N Needed**
- **Less N Needed**
- **Apply No N (Control Area) (Bare Soil)**



Leaf Chlorophyll and Nitrogen in Winter Wheat



Narrow-bands allow estimation of absorption features in atmospherically-corrected imagery.

Two important compounds are chlorophyll and cellulose.

Important bands:

550 (green), 670 (red), 710 (red-edge)*, 850 (NIR), 1650 (SWIR)

2030, 2100, 2210 (SWIR)*

* NEW BANDS