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

Remote Sensing Crop Residue Cover

Guy Serbin, E. Raymond Hunt Jr., and Craig S. T. Daughtry

USDA/ARS Hydrology and Remote Sensing Lab, Beltsville, MD

What are crop residues?

- Crop residues are stalks, cobs, and other plant parts left behind after a harvest.
- They are also referred to as non-photosynthetic vegetation.

Why are crop residues important?

- When left on the soil surface, they:
  - Protect the soil from wind and water erosion.
  - Reduce evaporation by acting as a mulch.
  - Their breakdown helps sequester carbon to the soil.
    - This also recycles nutrients.
  - Improve soil structure and water retention.
- When removed from the soil:
  - They do not benefit the soil.
  - But, they can be used for cellulosic ethanol biofuels.

Tillage systems and residues

A. Intensively tilled field

B. No-tilled field

- Intensive tillage removes residue, exposes soil to erosion.
- Conservation tillage (e.g., no-till) leaves residue on fields.
- With conservation tillage, farmers save money on fuel, can sell carbon credits, and receive monetary benefits.

CTIC and USDA-NRCS tillage definitions

- Intensive tillage (< 15% residue cover)
- Reduced tillage (15 – 30% residue cover)
- Conservation tillage (> 30% residue cover)

Where else is non-photosynthetic vegetation important?

Prescribed rangeland burn, image courtesy Wyoming Wildlife and Natural Resource Trust

Simi Valley, CA, Oct. 14, 2008. (Associated Press)

- Dry vegetation is an important indicator of rangeland quality and soil health.
- Dry plant material easily catches fire:
  - Prescribed burning is an important management practice in Western US.
  - In Oct. 2007, California wildfires caused over $1 billion in damage.
  - Wildfires also occurring this year.

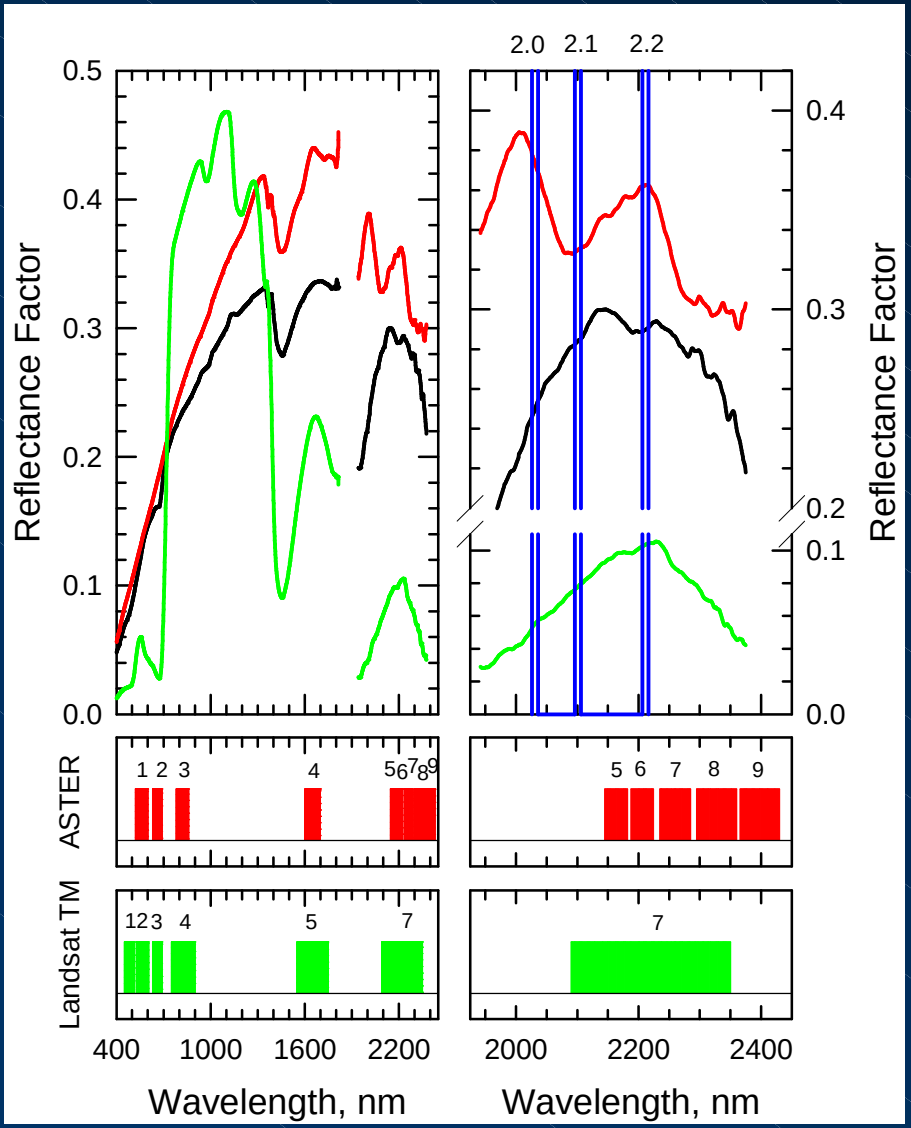
Verification of residue cover

A. Line-point transect.

B. Photographic.

C. Photo comparison.

Remote sensing of crop residue cover



Landsat TM-based indices:

- NDI5 (McNairn and Protz, 1993)*

$$NDI5 = \frac{TM4 - TM5}{TM4 + TM5}$$

- NDI7 (McNairn and Protz, 1993)

$$NDI7 = \frac{TM4 - TM7}{TM4 + TM7}$$

- NDSVI (Qi et al., 2003)*

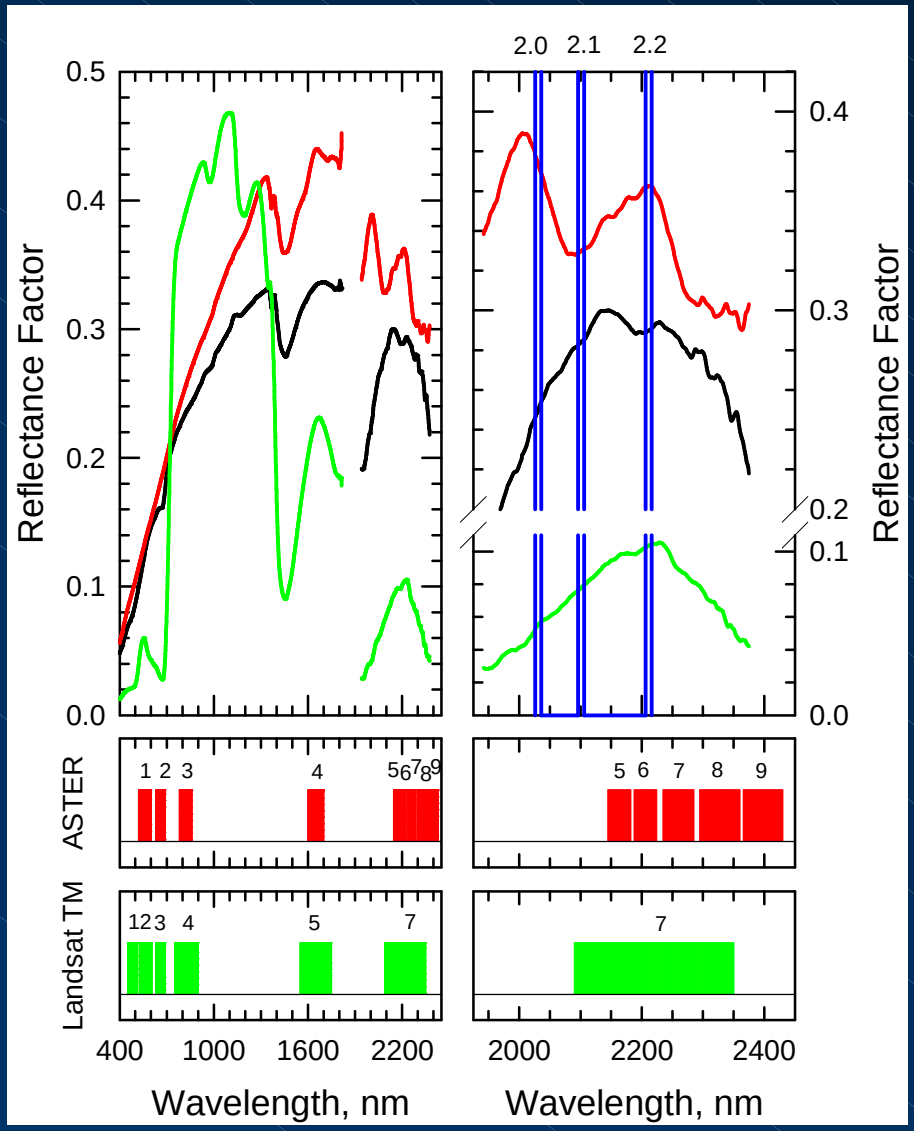
$$NDSVI = \frac{TM5 - TM3}{TM5 + TM3}$$

- NDTI (van Deventer et al., 1997)

$$NDTI = \frac{TM5 - TM7}{TM5 + TM7}$$

*Only NDI5, NDSVI appropriate for AWiFS/ LISS III

Remote sensing of crop residue cover



- ASTER: Lignin-Cellulose Absorption (LCA) Index

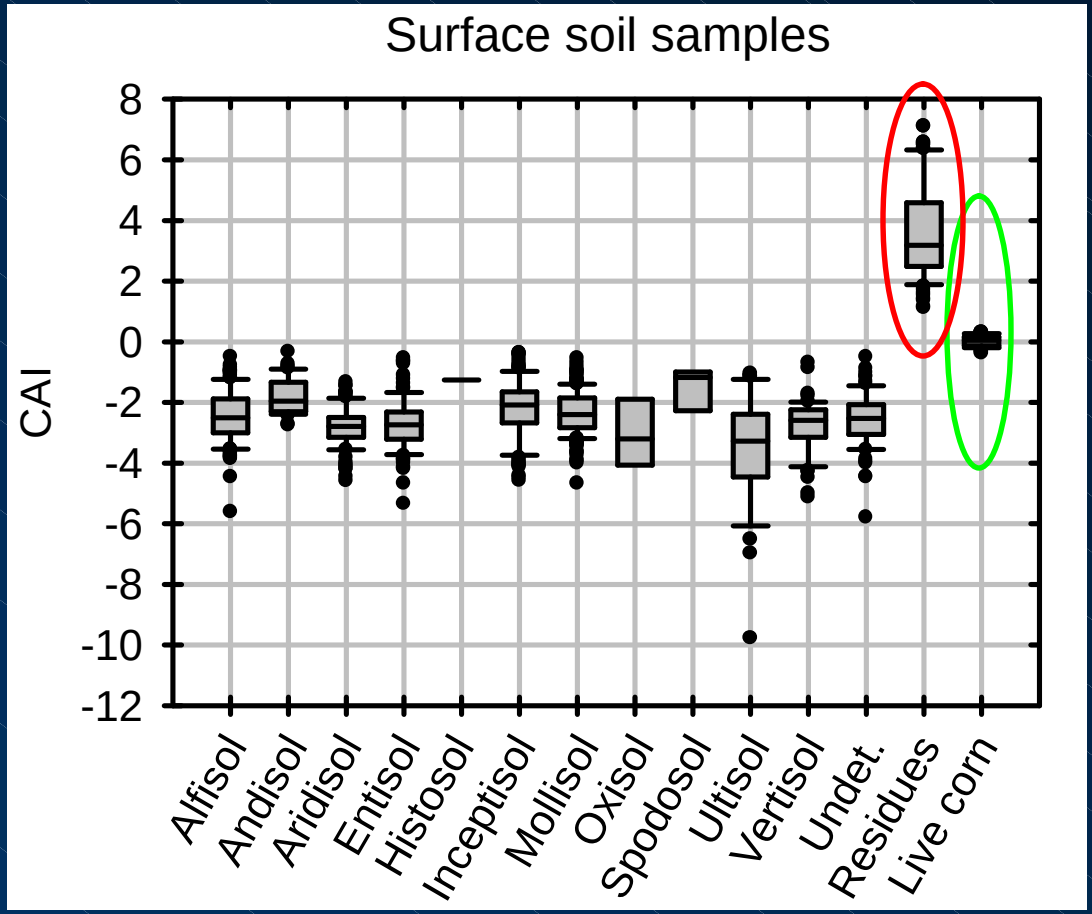
$$LCA = 100\left[2\,ASTER6 - \left(ASTER5 + ASTER8\right)\right]$$

- Hyperspectral SWIR: Cellulose Absorption Index (CAI)

$$CAI = 100\left[\left(R_{2031} + R_{2211}\right)/2 - R_{2101}\right]$$

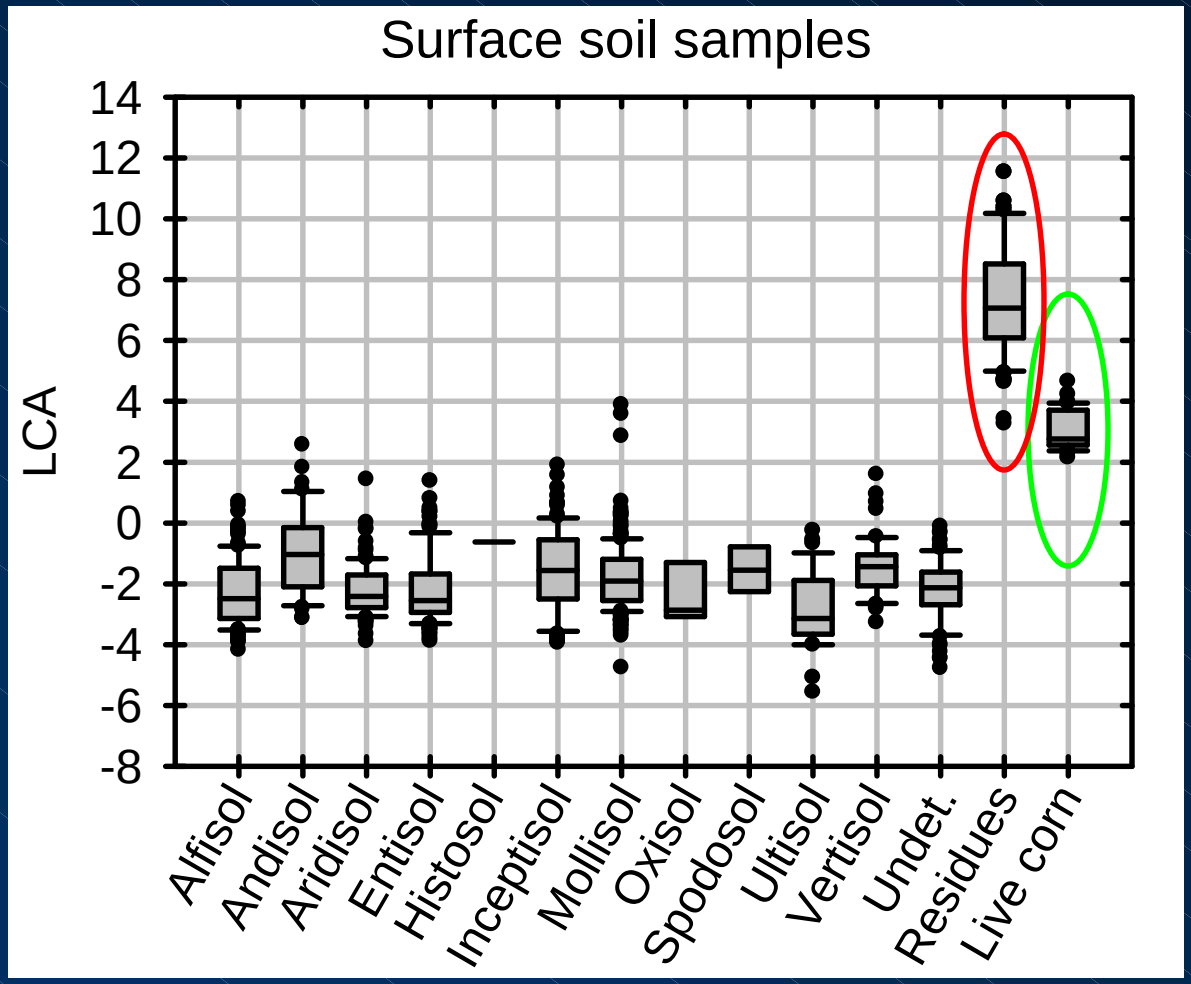
  - CAI most effective in measuring residue cover:
    - Shortwave infrared
    - Narrowband

CAI, surface soils



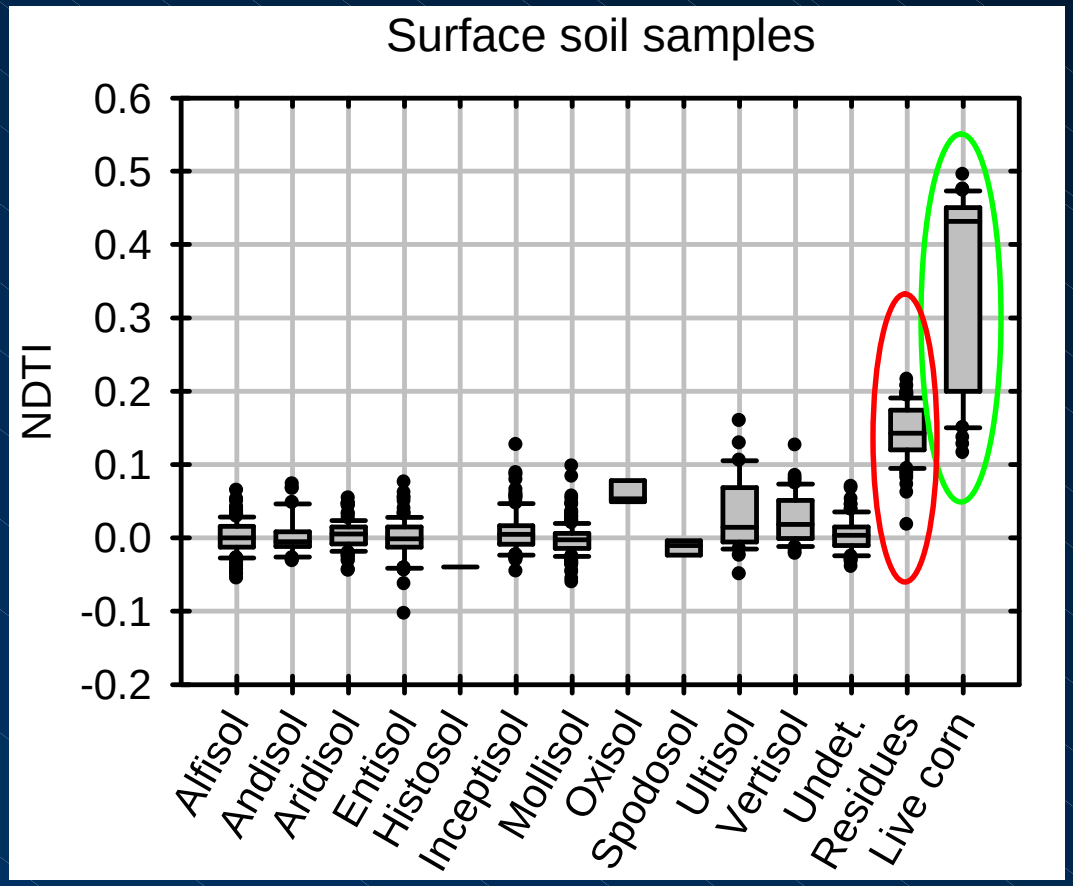
- Crop residues contrast well with all soils, green vegetation.
- N = 893 surface soils from Brown et al. 2006.

LCA, surface soils



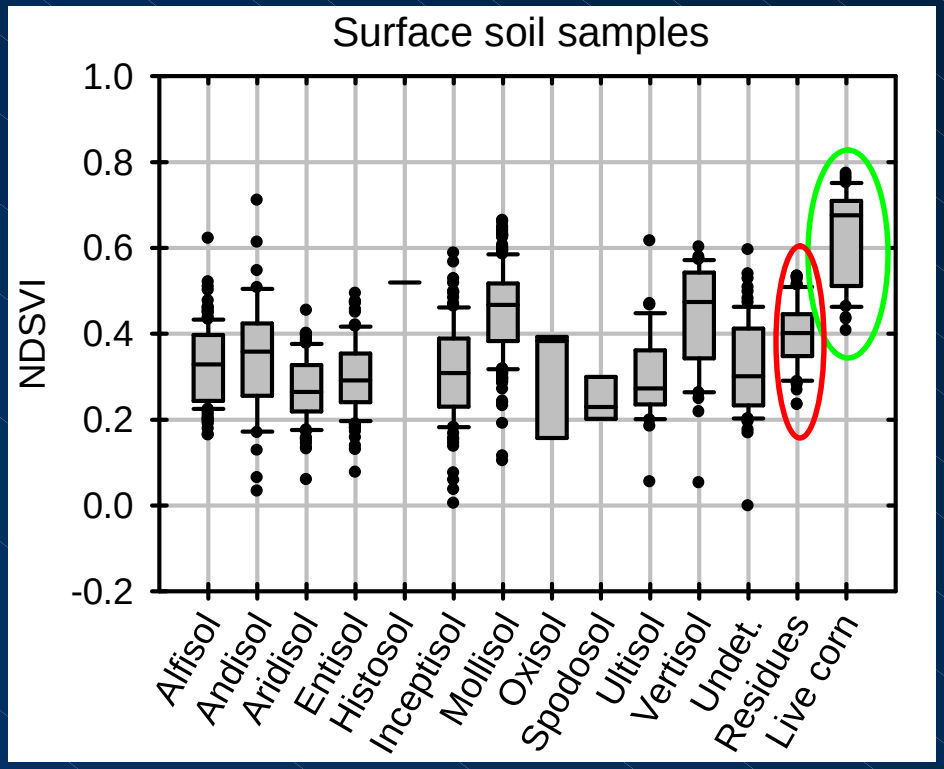
- Some overlap seen between crop residues, soils, and green vegetation.

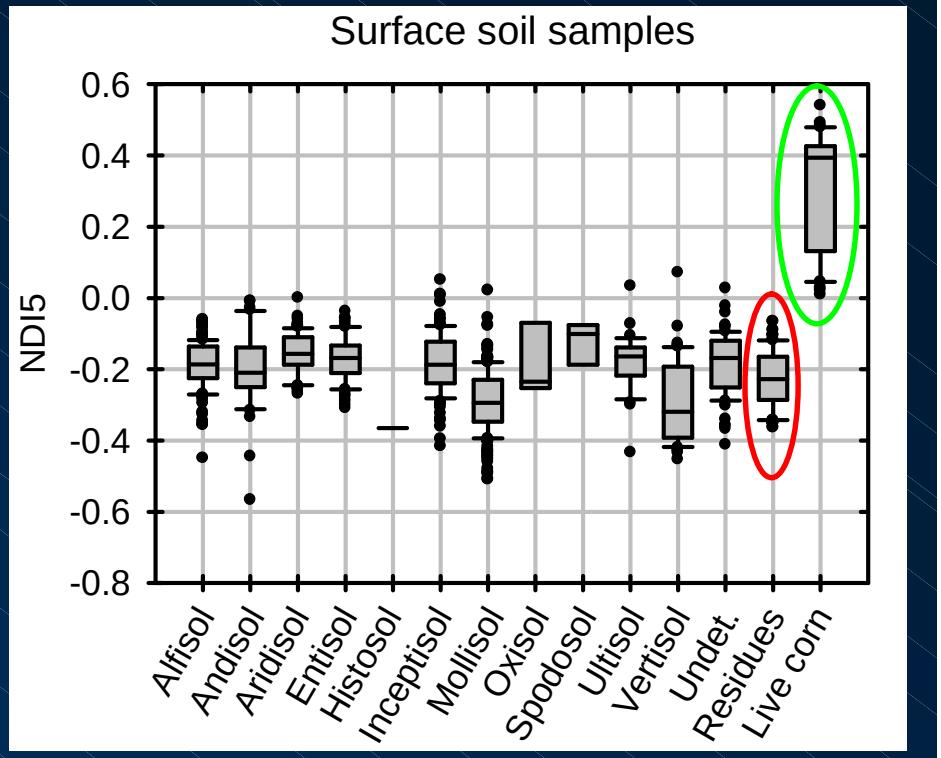
NDTI, surface soils



- Green vegetation has strongest response.
- Crop residues overlap some soils and green vegetation.

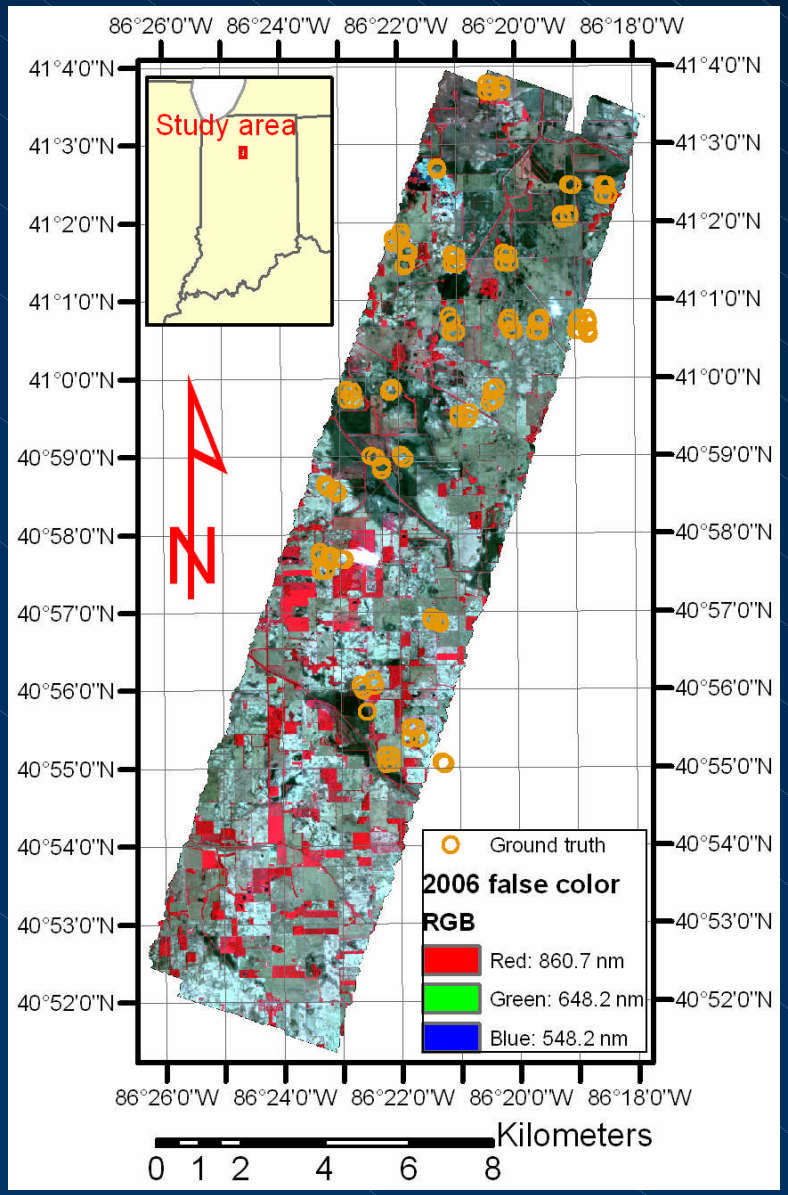
NDSVI, NDI5, surface soils





- Green vegetation has strongest response.
- Crop residues overlap most soils.
- These indices only usable in limited areas.

2006-2007 study areas



- Airborne hyperspectral SpecTIR imagery were acquired in north-central Indiana.
- Imagery acquired shortly after planting (May/June).
- Most fields were soybean or corn.
- Ground truth of residue cover acquired at > 50 fields using line-point transects, 2 locations measured per field.
- Soil and residue samples also acquired at select locations.
- Hyperspectral bands convolved to equivalent ASTER VNIR and SWIR, and Landsat TM bands.

2006-2007 field analysis methods

- Pixels within 30 m of sampling locations analyzed for:
  - NDVI for live green vegetation cover.
  - Indices residue cover.
    1. Compared with line-point transect f_R using linear regression.
    2. Inversion to determine f_R for CAI:

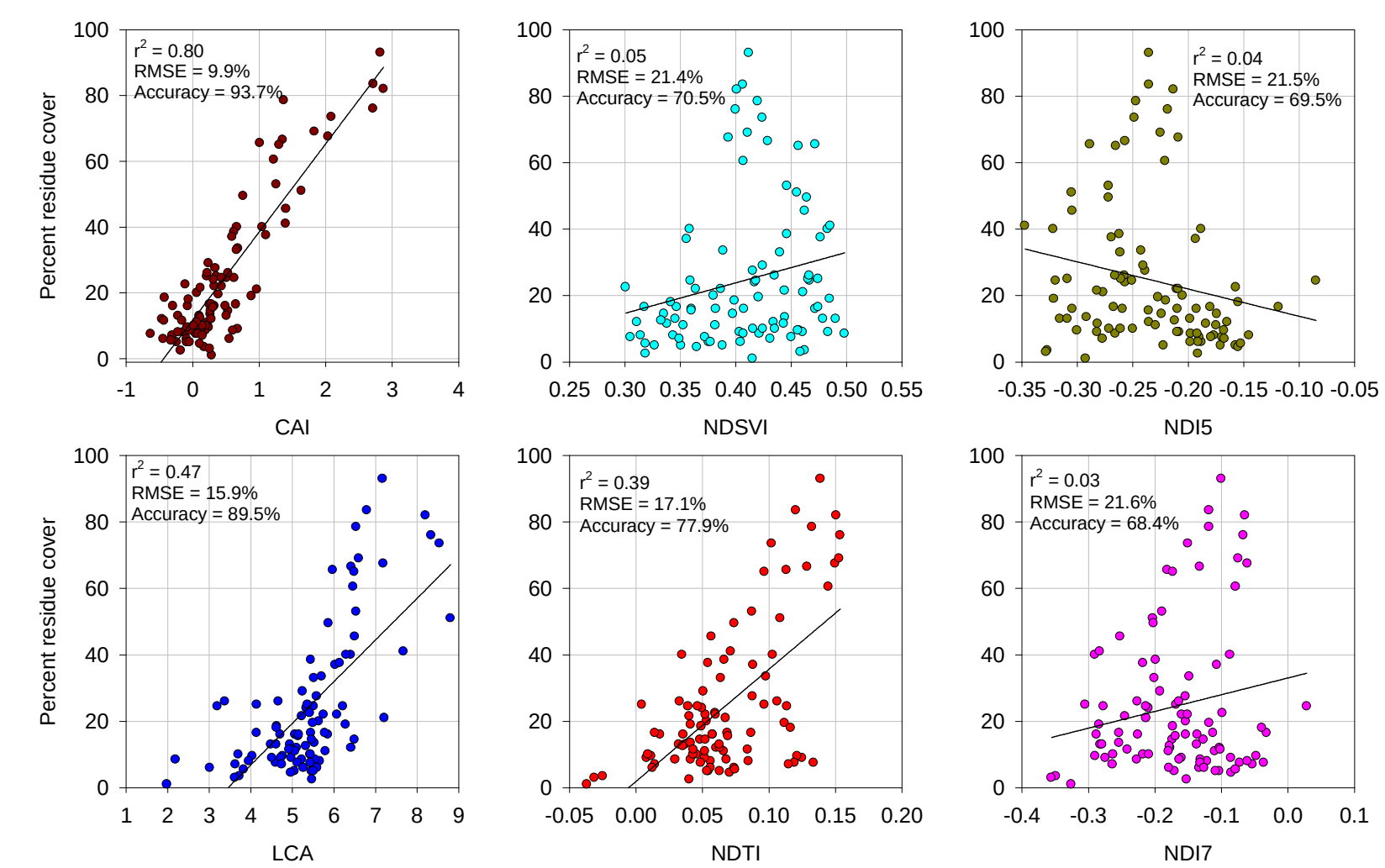
$$f_R = (CAI_{pixel} - CAI_{soil})/(CAI_{residue} - CAI_{soil})$$

    - Two CAI_{soil} endmembers: low- and high-soil organic carbon (SOC).
    - Two $CAI_{residue}$ endmembers: Corn and soybean.

2006-2007 field analysis methods

- Linear regression and inversion f_R compared against line-point transect f_R estimates using:
  - Correlation coefficients (r^2).
  - Root-mean-square errors (RMSE).
- Data points aggregated into two residue cover classes:
  - $f_R < 0.30$ (Intensive and reduced till)
  - $0.30 \leq f_R$ (Conservation till)
- Classifications were assessed for accuracy.

Indiana 2006 results

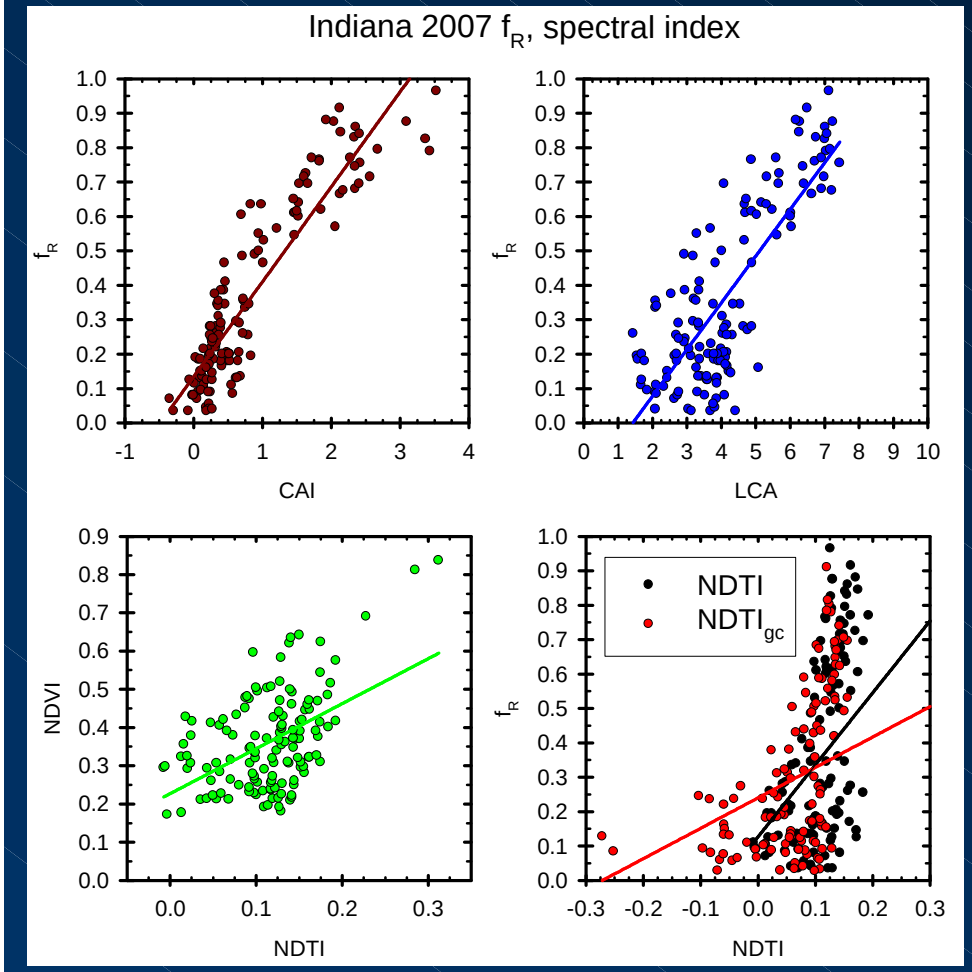


- NDVI showed that live green vegetation was minimal, ranged from 0.10 to 0.29, mean of 0.16.

Indiana 2006 statistical data

Index	CAI reg.	CAI cal.	LCA	NDTI	NDSVI	NDI5	NDI7
r^2	0.80	0.82	0.47	0.39	0.04	0.02	0.05
RMSE	0.099	0.099	0.159	0.171	0.216	0.219	0.215
2-class accuracy	0.937	0.958	0.895	0.779	0.705	0.695	0.684
z-stat	12.24	16.31	9.40	4.66	0.51	0.38	-0.71

Indiana 2007 results

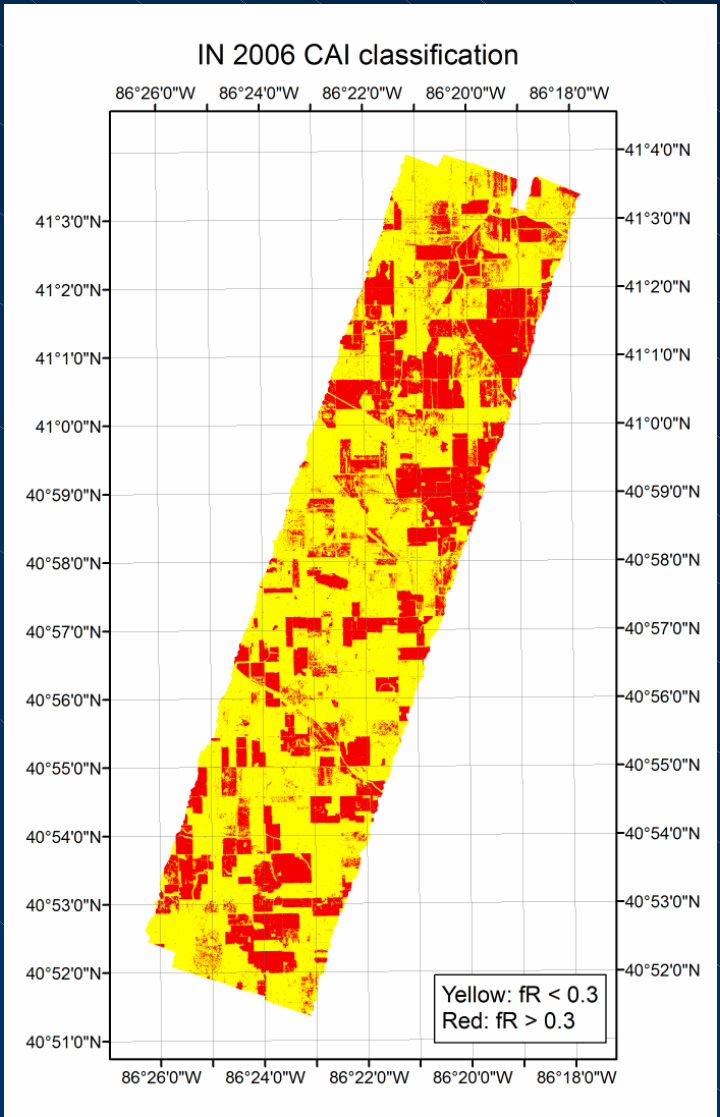


- In 2007 aircraft data acquired later than in 2006.
- Scene was significantly greener: NDVI range: 0.17 to 0.84, mean of 0.36.
- CAI, LCA gave acceptable results.
- NDTI showed improvement after removal of NDVI > 0.5 pixels, and subpixel green cover correction (NDTI$_{gc}$).

Indiana 2007 statistics

Index	CAI reg.	CAI 4-way	LCA	NDTI	$NDTI_{gc}$
r^2	0.83	0.83	0.64	0.18	0.09
RMSE	0.107	0.107	0.156	0.235	0.219
2-class accuracy	0.853	0.860	0.676	0.625	0.728
z-statistic	11.40	11.87	4.47	3.04	5.97

Spectral index results



- Spectral index performance (from best to worst):

1. CAI
2. LCA
3. NDTI
4. NDI5*, NDI7, NDSVI*

*Only NDI5, NDSVI appropriate for AWiFS/ LISS III

Conclusions

- CAI works best for crop residue cover estimation.
- CAI might also work well for fire risk assessment and rangeland quality research.
- Future Resourcesat sensors could include the three CAI bands.
- NDTI (TM bands 5 and 7) works well; may be corrected for vegetation.
- Current AWiFS/LISS bands may estimate crop residue cover only at a few locations.