Assessment of TM & AWiFS imagery for cropland classification: three case studies

Rick Mueller, Section Head, Spatial Analysis Research Section

- Crop Acreage Estimation: Landsat TM and AWiFS Initial Assessments 2004-2005, **Claire Boryan**
- Crop Acreage Estimation, Landsat TM and AWiFS for Nebraska 2005, **Bob Seffrin**
- TM vs. AWiFS: A comparison of coincident imagery for classifying croplands, **Dave Johnson**

United States Department of Agriculture
National Agricultural Statistics Service
Research and Development Division

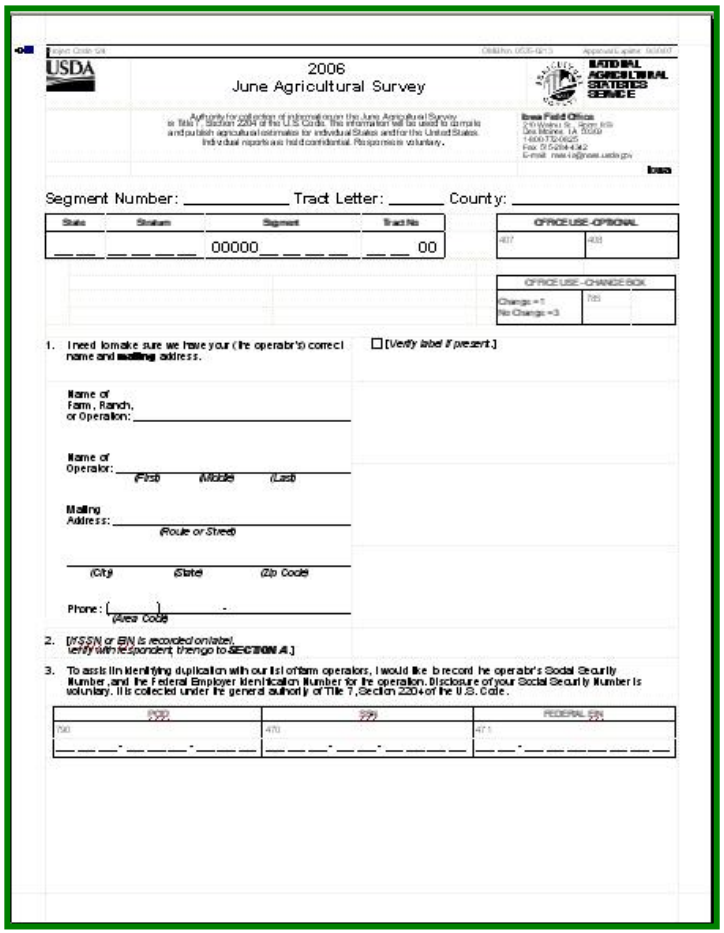
NASS
FACT FINDERS FOR AGRICULTURE
UNITED STATES DEPARTMENT OF AGRICULTURE

NASS
FACT FINDERS FOR AGRICULTURE
UNITED STATES DEPARTMENT OF AGRICULTURE

"Responsible for providing statistical data on US agriculture"

- **Produce acreage estimates with reduced error rates over the June Agricultural Survey.**
- **Create and distribute the Cropland Data Layer Product.**

June Agricultural Survey



2006
June Agricultural Survey

USDA

NATIONAL AGRICULTURAL STATISTICS SERVICE

Segment Number: _____ Tract Letter: _____ County: _____

1. I need to make sure we have your (the operator's) correct name and **mailing** address. ☐ *[Verify label if present.]*

Name of Farm, Ranch, or Operation: _____

Name of Operator: _____ *(First) (Middle) (Last)*

Mailing Address: _____ *(Route or Street)*

_____ *(City) (State) (Zip Code)*

Phone: (___) _____ *(Area Code)*

2. *[If SSN or EIN is recorded on label, verify with respondent, then go to* ***SECTION A****.]*

3. To assist in identifying duplication with our list of farm operators, I would like to record the operator's Social Security Number, and the Federal Employer Identification Number for the operation. Disclosure of your Social Security Number is voluntary. It is collected under the general authority of Title 7, Section 2204 of the U.S. Code.

SSN _____-_____-_____

FEDERAL EIN _____-_____

June Agricultural Survey (JAS) – National in Scope

- **41,000 farms visited**
- **11,000 one-square mile sample area segments visited**
- **Most states contain between 150 – 400 segments**
- **Planted acreage estimate**

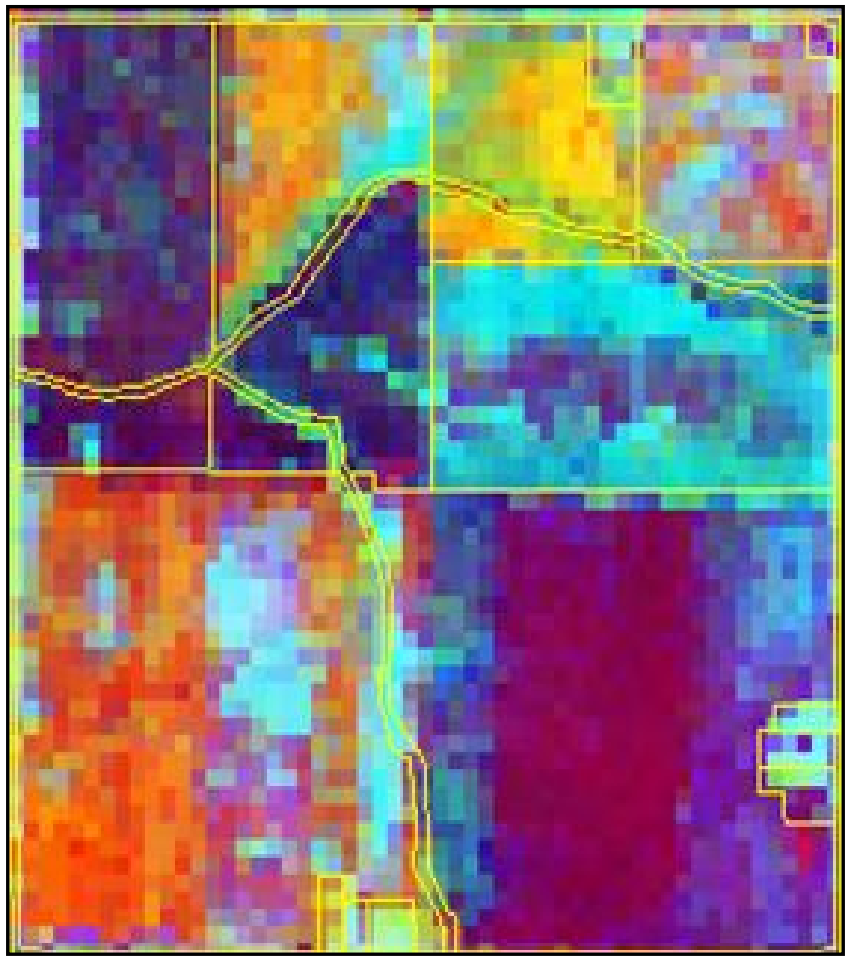
Cropland Data Layer depends on the JAS data

- Unbiased statistical estimator of crop area
  - **State and county level estimates**

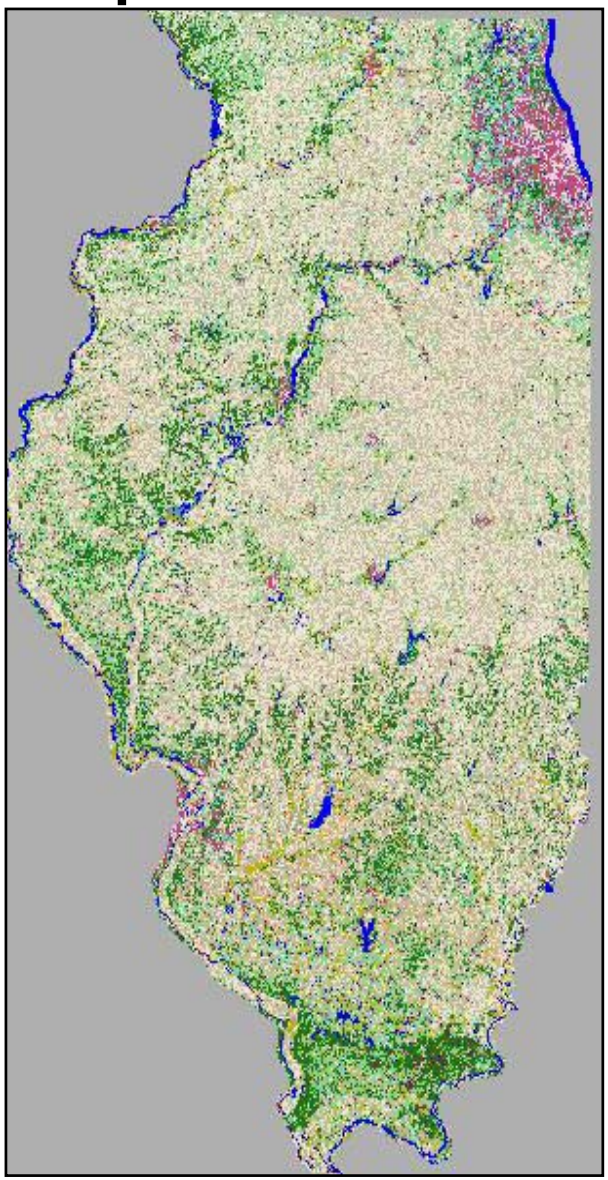
Segments

Enumerated

Digitized

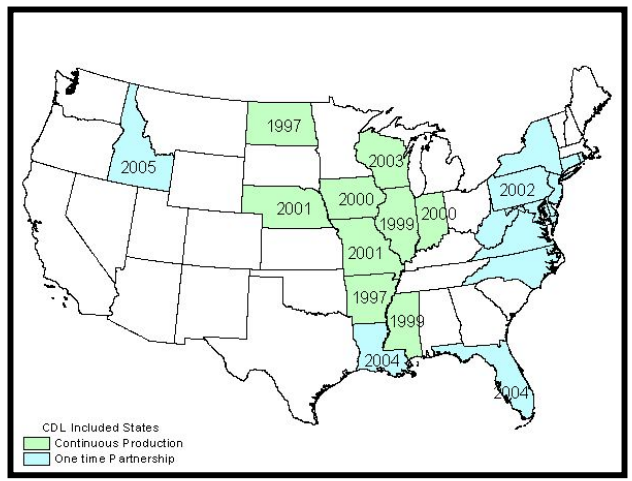


Purpose of the Cropland Data Layer



1. Combine remote sensing imagery and NASS survey data to produce *supplemental* acreage estimates for the state's major commodities

2. Production of a crop-specific digital land cover data layer for distribution in industry standard GeoTiff format



The Landsat Data Gap

Landsat 7 ETM+

Landsat 5 TM

USGS
science for a changing world

News Release

November 30, 2005 Ron Beck

Landsat 5 Experiencing Technical Difficulties

On November 26, 2005, the back-up solar array drive on Landsat 5 began exhibiting unusual behavior. The solar array drive maintains the proper pointing angle between the solar array and the sun. The rotation of the solar array drive became sporadic and the solar array was not able to provide the power needed to charge the batteries. Maintaining power to the batteries is critical to sustain proper operation of the spacecraft. The primary solar array drive failed under similar circumstances last January. As a result of this current situation, imaging operations will be suspended for at least the next two weeks or until attempts to solve the problem have been resolved.

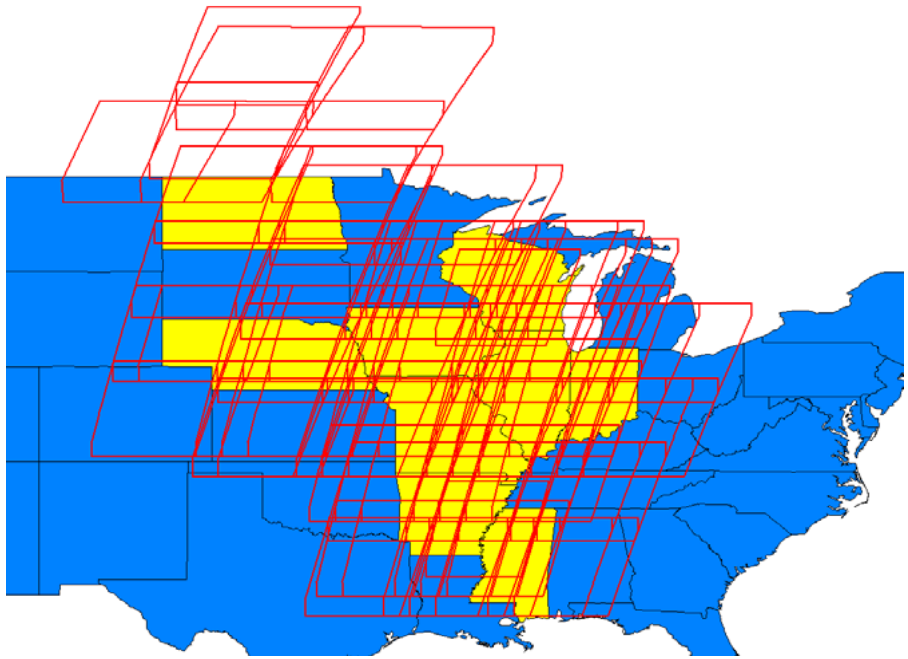
Source: USGS, Landsat Project:
http://landsat.usgs.gov/slc_enhancements/slc_off_level1_standard.php

Indian Remote Sensing Satellite: RESOURCESAT-1

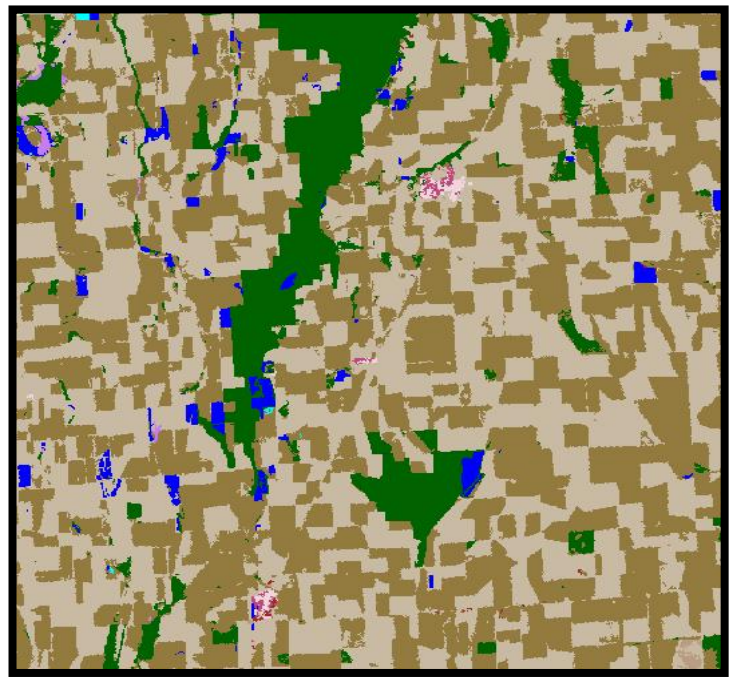
Advanced Wide Field Sensor (AWiFS)

States Targeted for Data Collection in August 2004

- AWiFS: Swath: 370 km each head, 740 km combined, 56 m resolution at nadir, 70 m resolution at field edges.
- **Spectral Bands**
- **B2: 0.52-0.59 (Visible Green)**
- **B3: 0.62-0.68 (Visible Red)**
- **B4: 0.77-0.86 (Near Infrared**
- **B5: 1.55-1.70 (Middle infrared)**

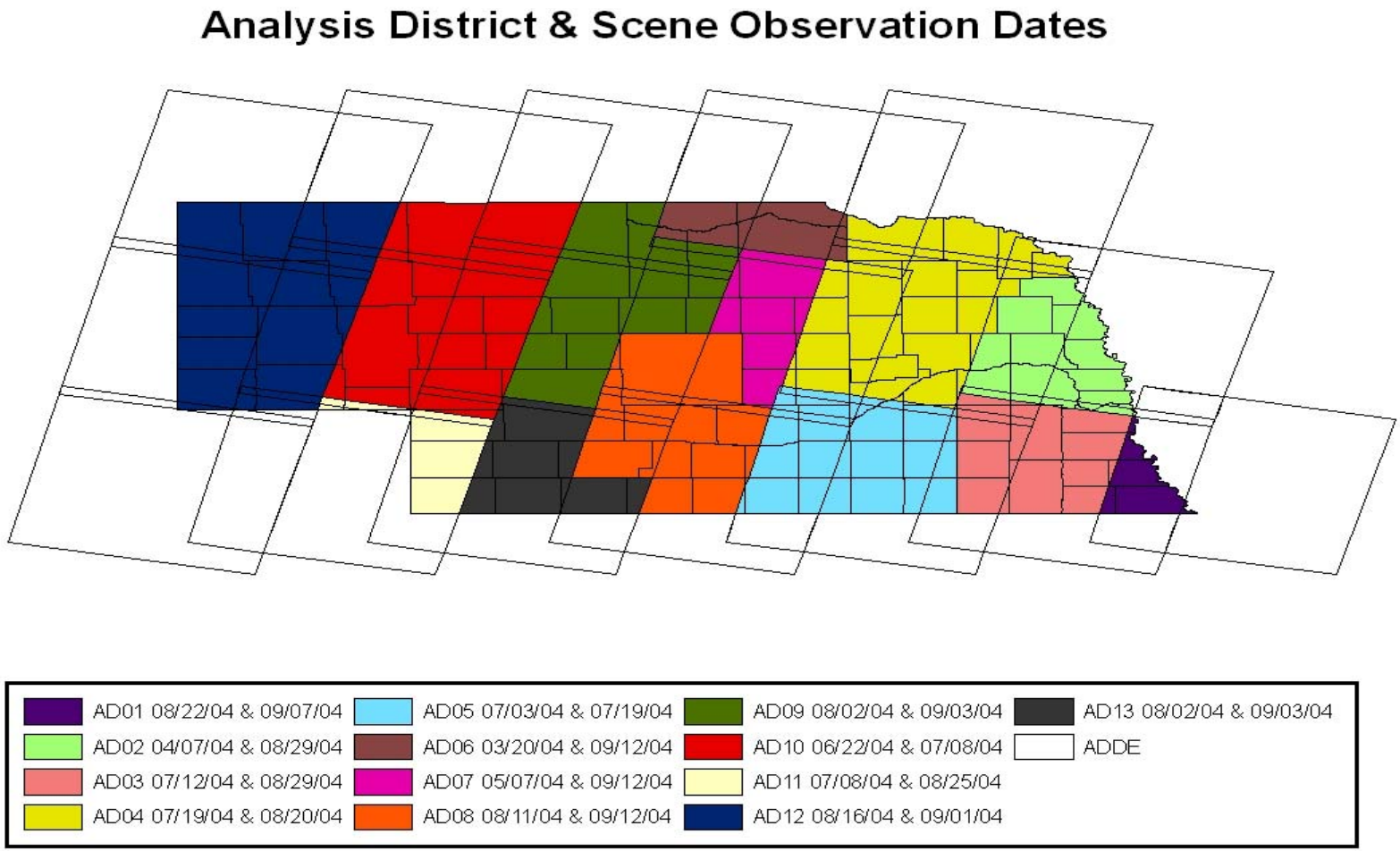


Crop Acreage Estimation: Landsat TM and AWiFS Initial Assessments 2004-2005



Claire G. Boryan, Geographer
USDA/NASS/Research and Development Division
claire_boryan@nass.usda.gov

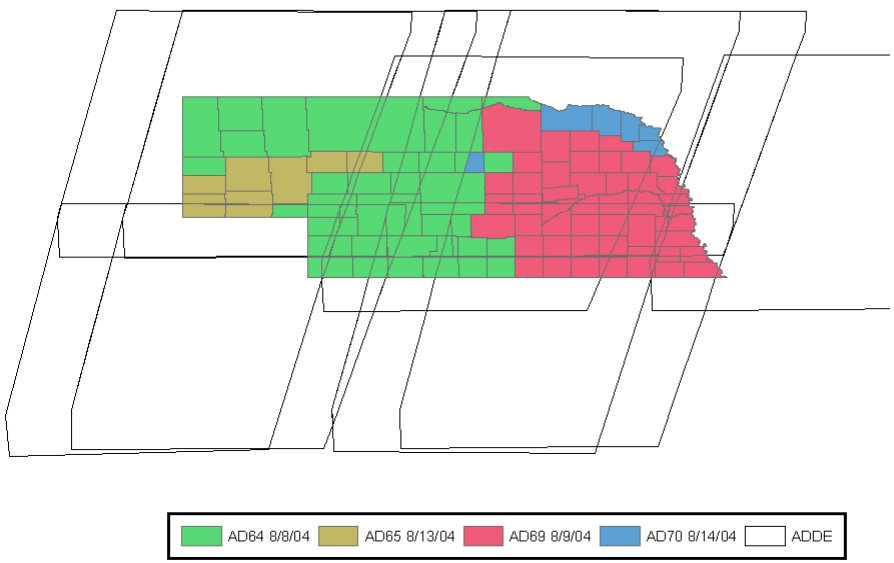
Multitemporal Analysis of Nebraska 2004 using Landsat TM data



Nebraska – 2004
Unitemporal Analysis

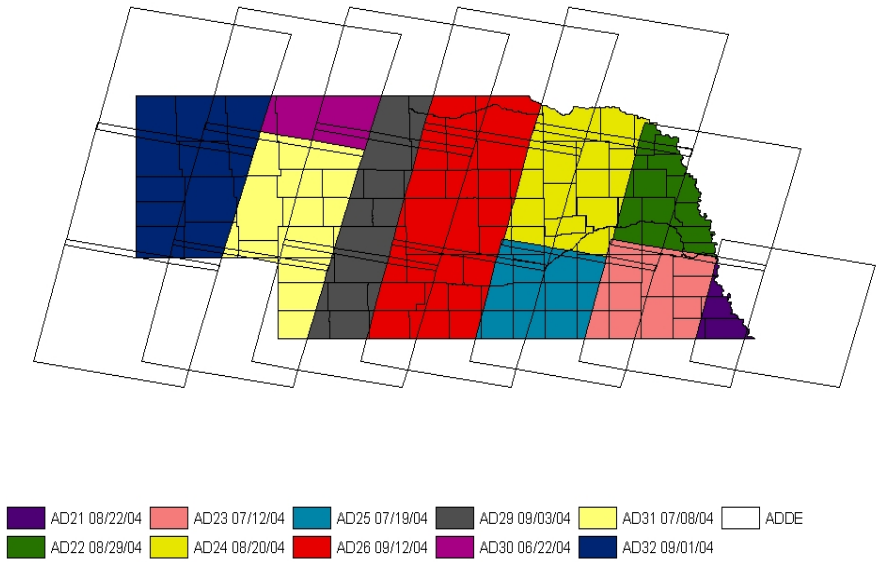
AWiFS

Analysis Districts (AD)
and Scene Observation Dates

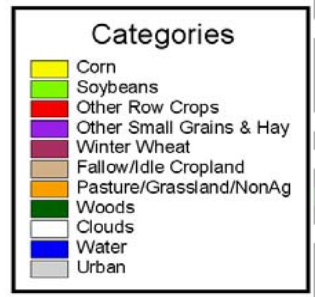


Landsat TM

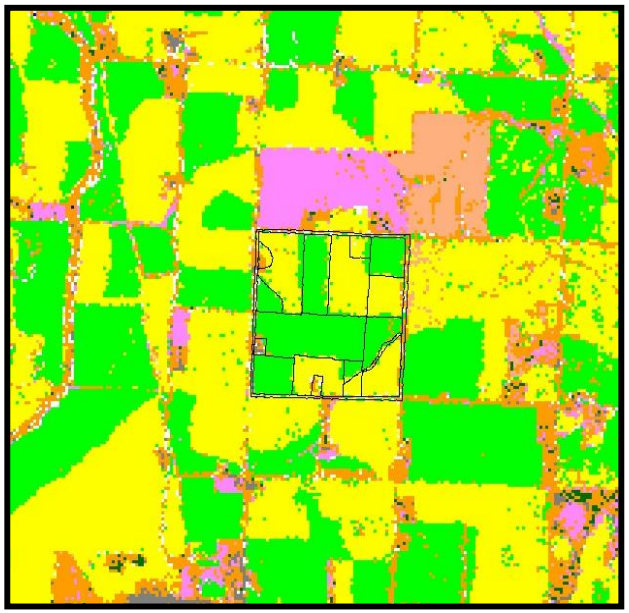
Analysis Districts (AD)
and Scene Observation Dates



Segment Area Classifications

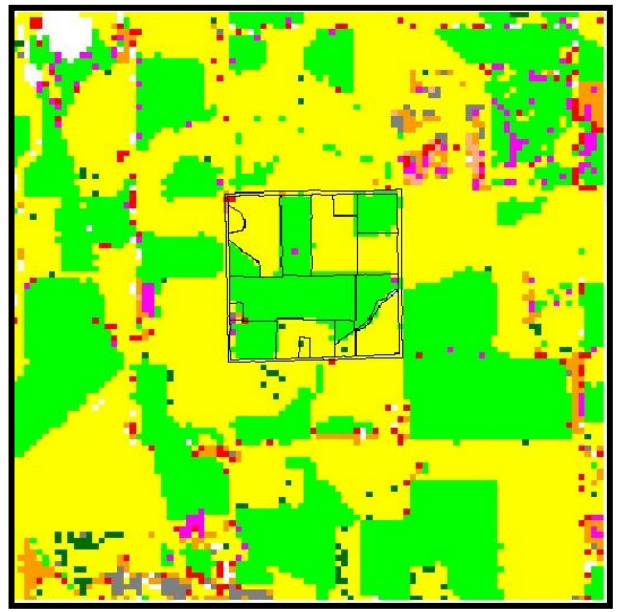


Multitemporal TM
4/07/04 & 08/19/04



Unitemporal LandsatTM
08/29/2004

Unitemporal AWiFS
08/09/2004



Kappa Statistics for Classifier Accuracy

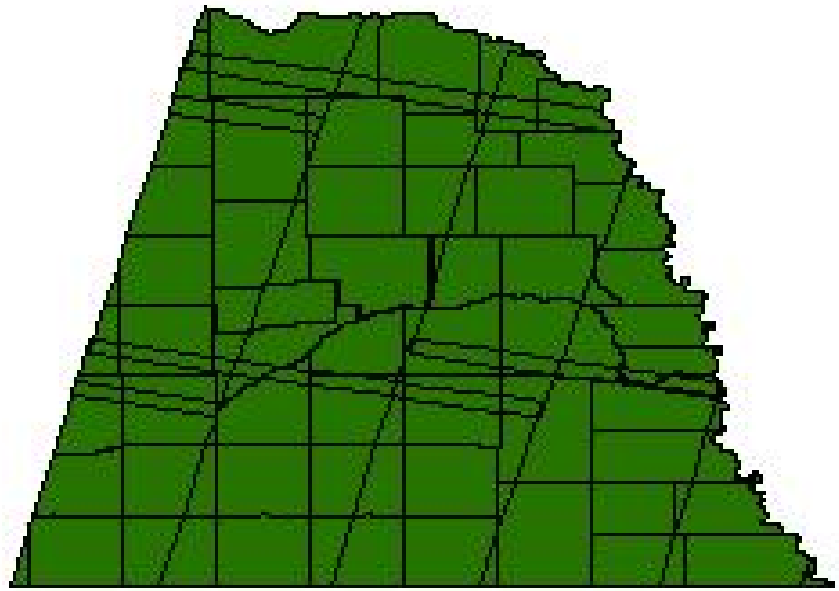
Eastern Nebraska 2004

Corn	-------- TM ---------		AWIFS
Area	Multi	Uni	Uni
AD01	93.89%	73.42%	
AD02	96.18%	93.54%	
AD03	93.91%	92.67%	86.47%
AD04	92.85%	89.90%	
AD05	96.85%	93.22%	

Soybean	-------- TM ---------		AWIFS
Area	Multi	Uni	Uni
AD01	99.12%	93.39%	
AD02	96.81%	89.93%	
AD03	98.72%	93.40%	77.41%
AD04	95.41%	88.37%	
AD05	96.67%	85.69%	

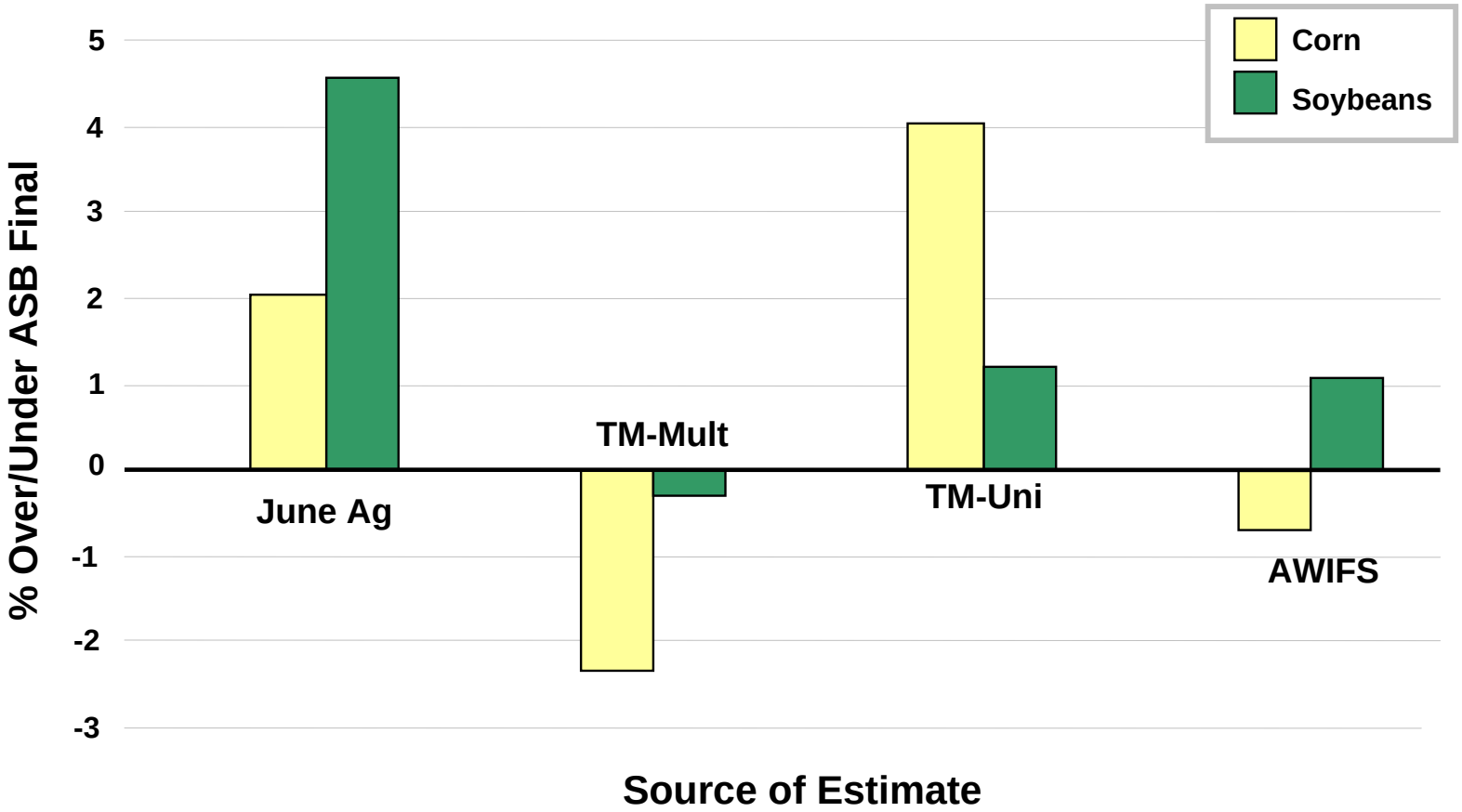
Overall	-------- TM ---------		AWIFS
Area	Multi	Uni	Uni
AD01	96.01%	80.02%	
AD02	96.19%	86.57%	
AD03	95.60%	85.37%	75.18%
AD04	93.50%	81.79%	
AD05	92.88%	85.91%	

Analysis Districts & Scene Observation Dates

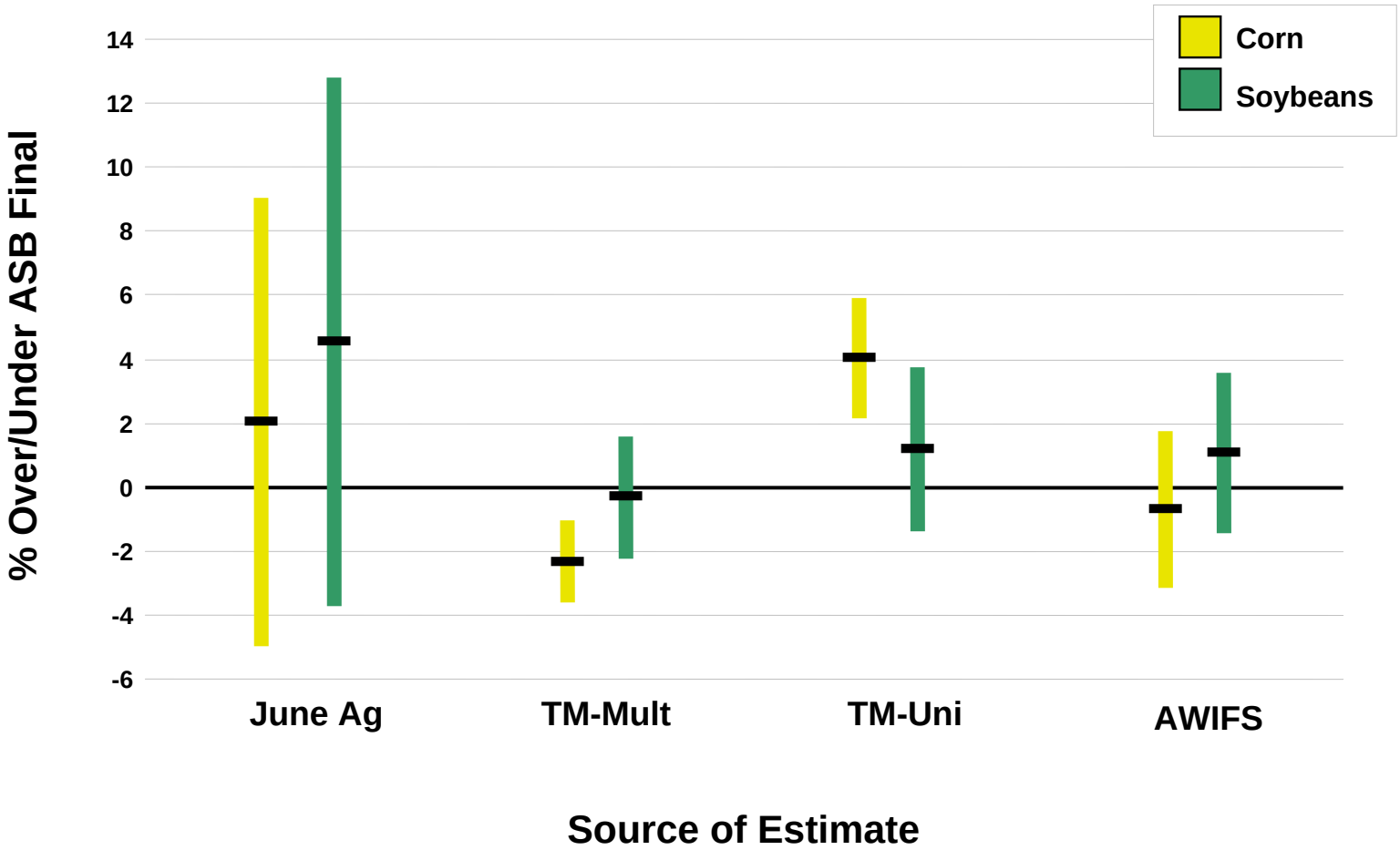


Nebraska 2004

State Level Estimates as % Over/Under Agricultural Statistics Board (Final)

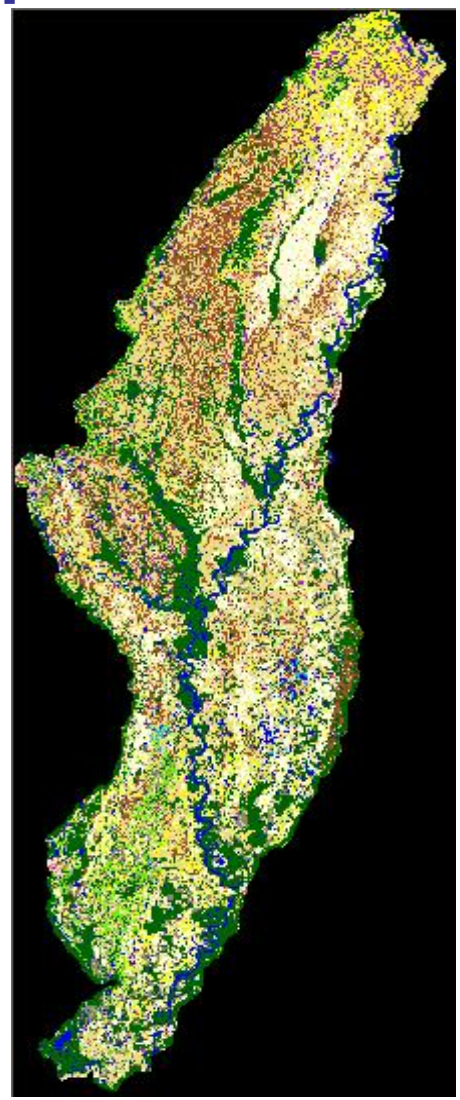


Nebraska 2004
State Level Estimates
+/- 2 CVs (Coefficient of Variation)



Multitemporal Landsat TM and AWiFS Classifications of the Mississippi River Delta, 2005

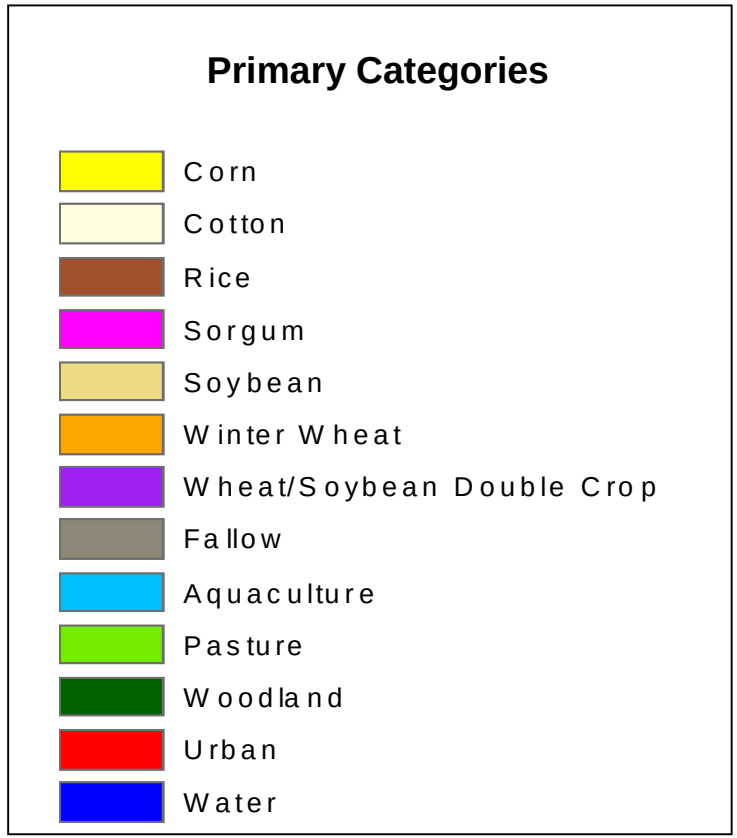
Landsat-5 TM



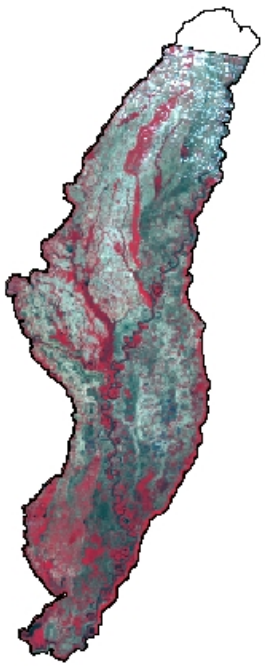
AWiFS

Multitemporal
Landsat TM and AWiFS cropland classifications

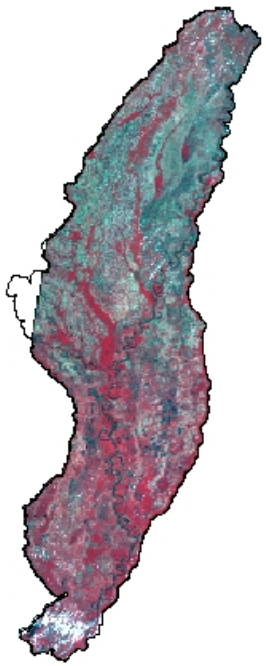
- **All Imagery clipped to Zone 45: NLCD**
- **TM imagery analyzed at 30m**
- **AWiFS imagery resampled to 30m**
- **5,000 (approx) randomly distributed polygons (280,000 acres) used for ground truth from JAS survey**
- **Classification tree analysis (See5.0)**
- **Minimum mapping unit of 5 pixels applied**



AWiFS Time Series 2005



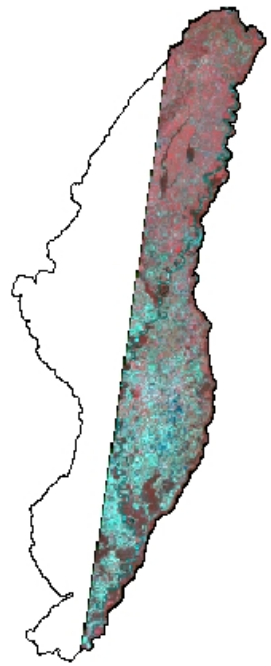
April 27



June 19

August 20

September 3

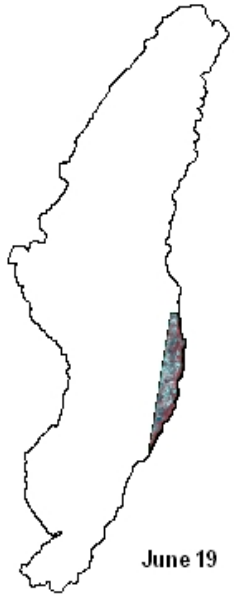


September 4

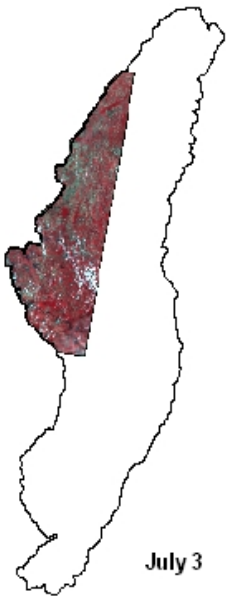
Landsat 5 Time Series 2005

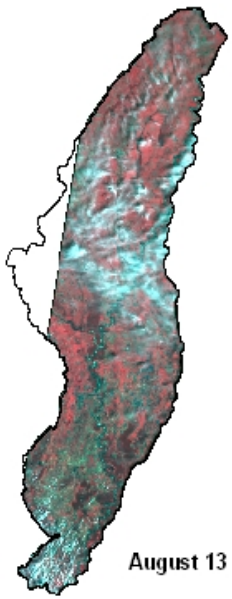
April 14

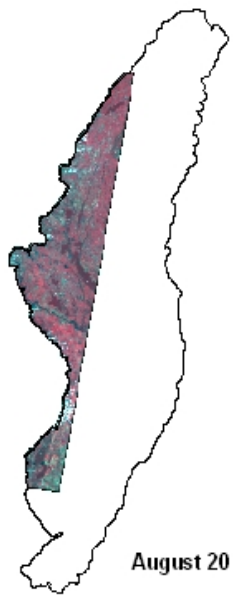
May 25

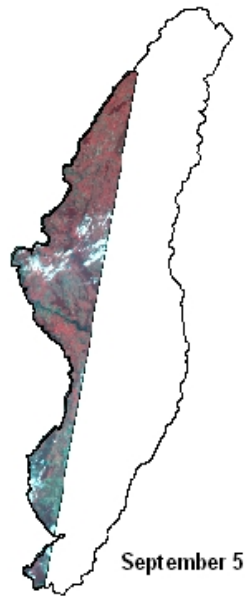

June 19

June 26


July 3


August 13

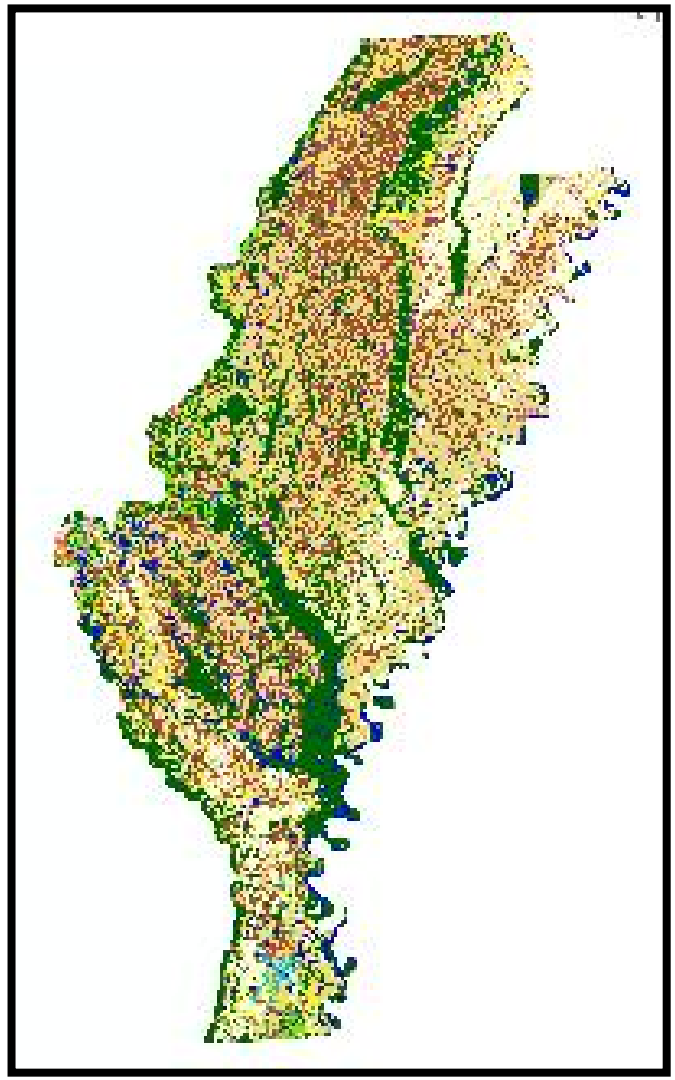

August 20


September 5

Kappa Statistics for Classifier Accuracy Arkansas Region 2005 of Mississippi River Delta

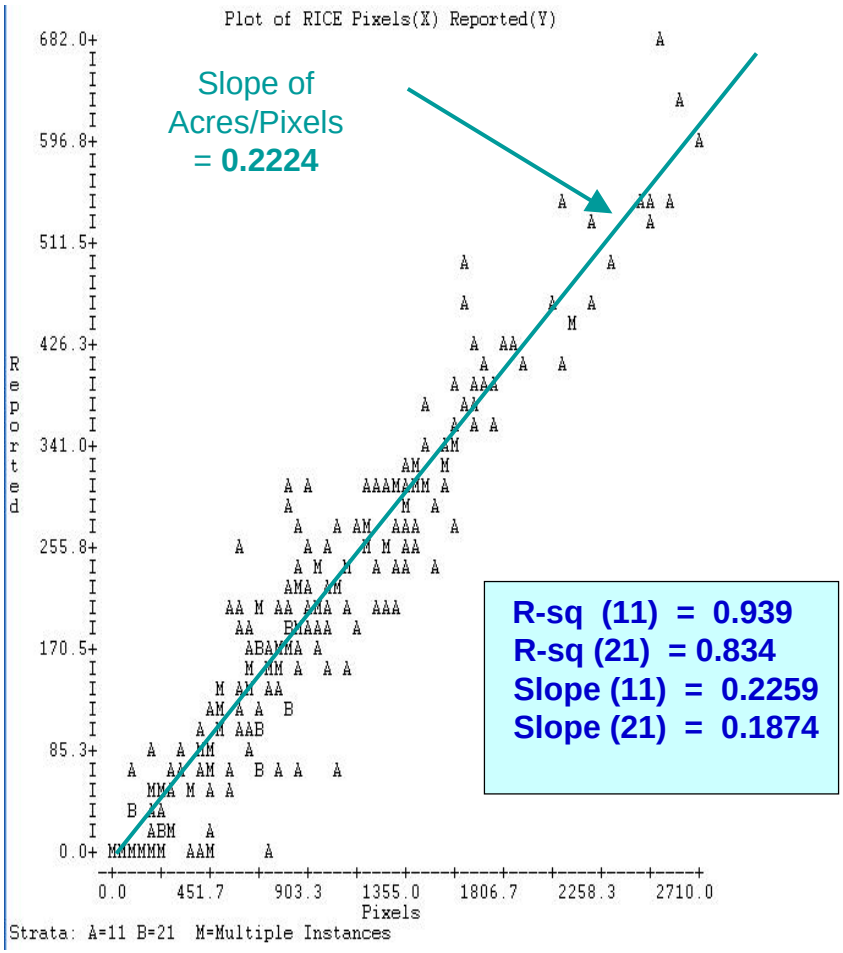
	Landsat TM	AWiFS
Corn	.986	.985
Cotton	.993	.992
Soybeans	.978	.978
Sorghum	.953	.962
Rice	.979	.981
Other Crop	.793	.782
Non Crop	.629	.670
Overall	.917	.925

*** Kappa Statistics based on June Area Survey (JAS) ground truth data**



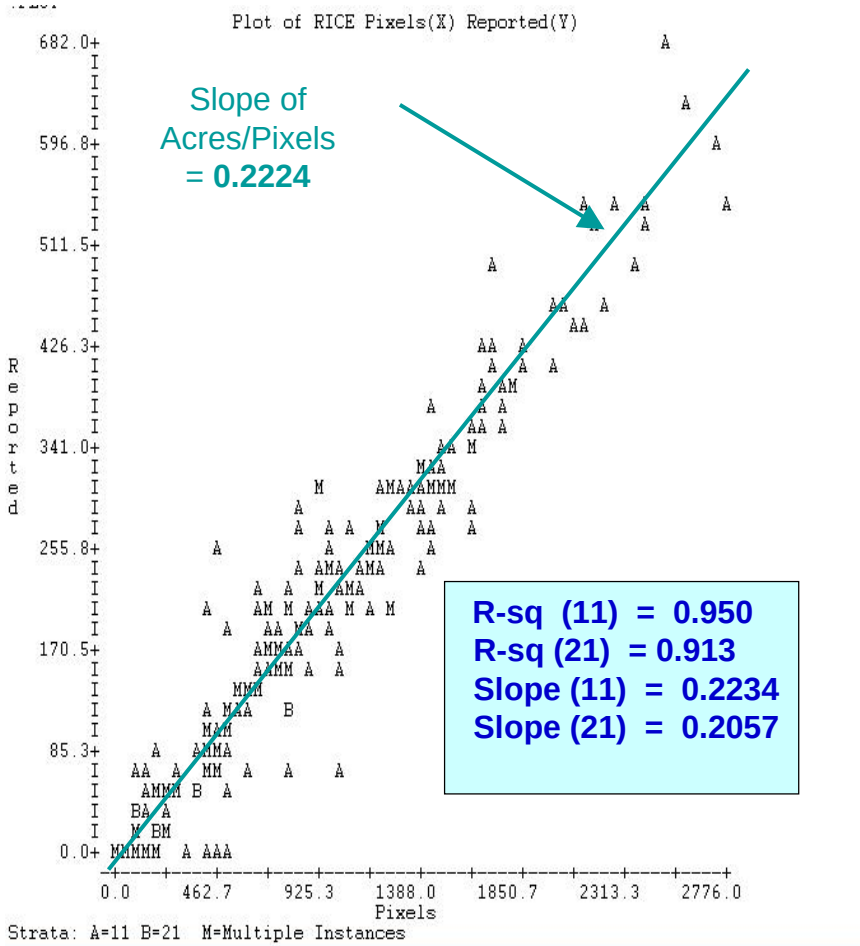
Regression Analysis from Sample Estimation Arkansas 2005

Landsat TM Rice



R-sq (11) = 0.939
R-sq (21) = 0.834
Slope (11) = 0.2259
Slope (21) = 0.1874

AWiFS Rice

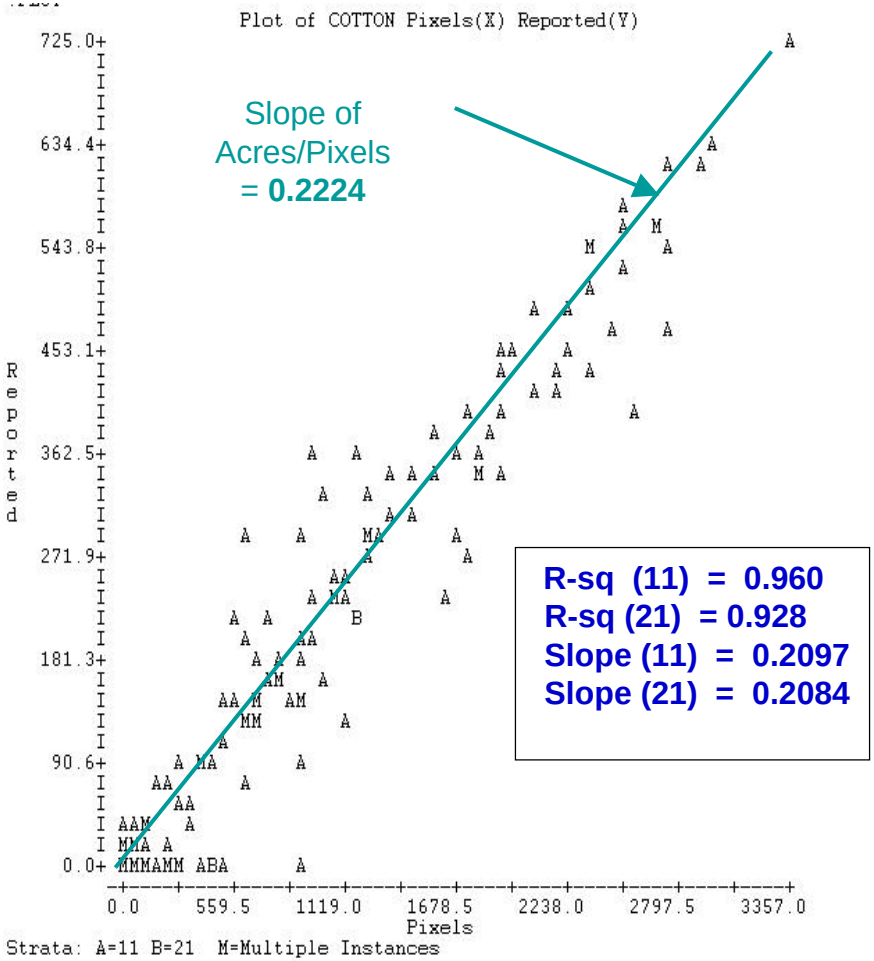


R-sq (11) = 0.950
R-sq (21) = 0.913
Slope (11) = 0.2234
Slope (21) = 0.2057

No Outliers Removed

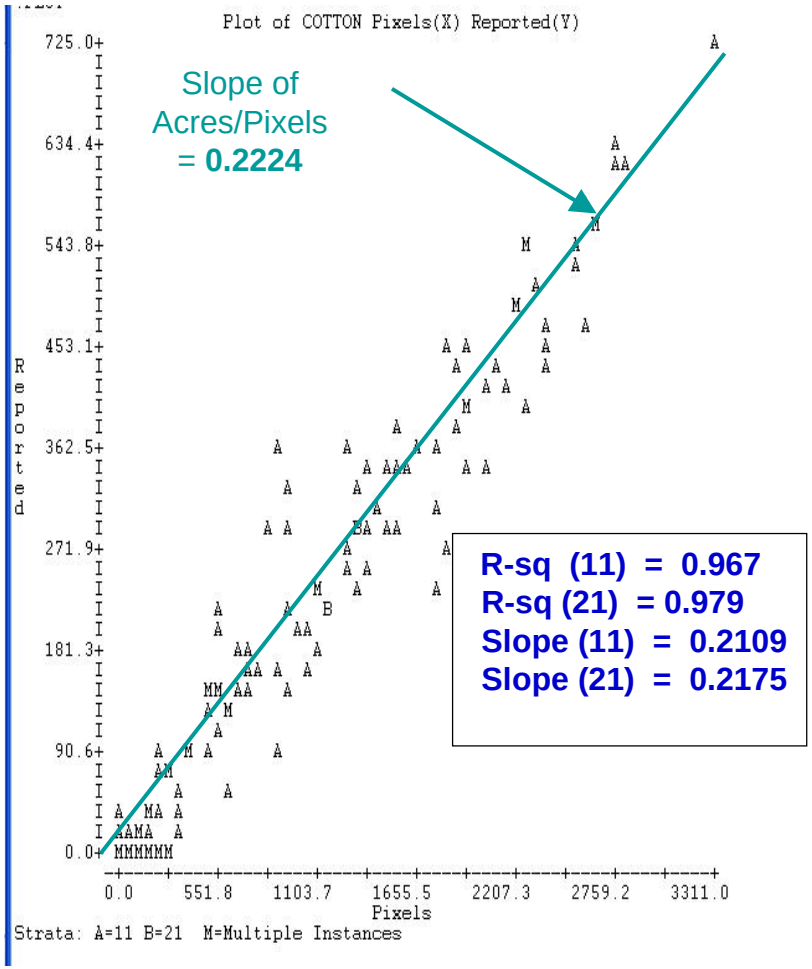
Regression Analysis from Sample Estimation Arkansas 2005

Landsat TM Cotton



R-sq (11) = 0.960
R-sq (21) = 0.928
Slope (11) = 0.2097
Slope (21) = 0.2084

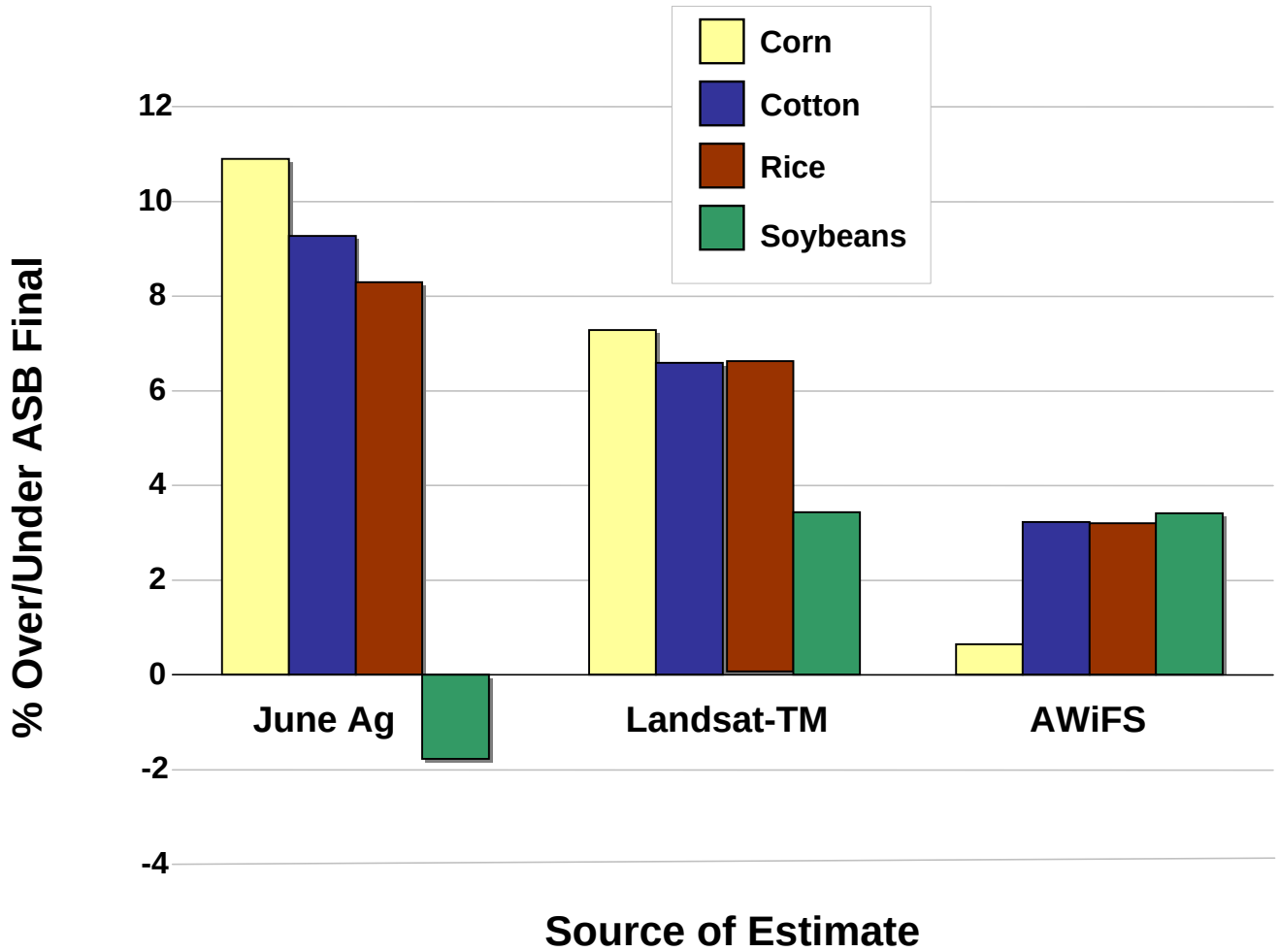
AWiFS Cotton



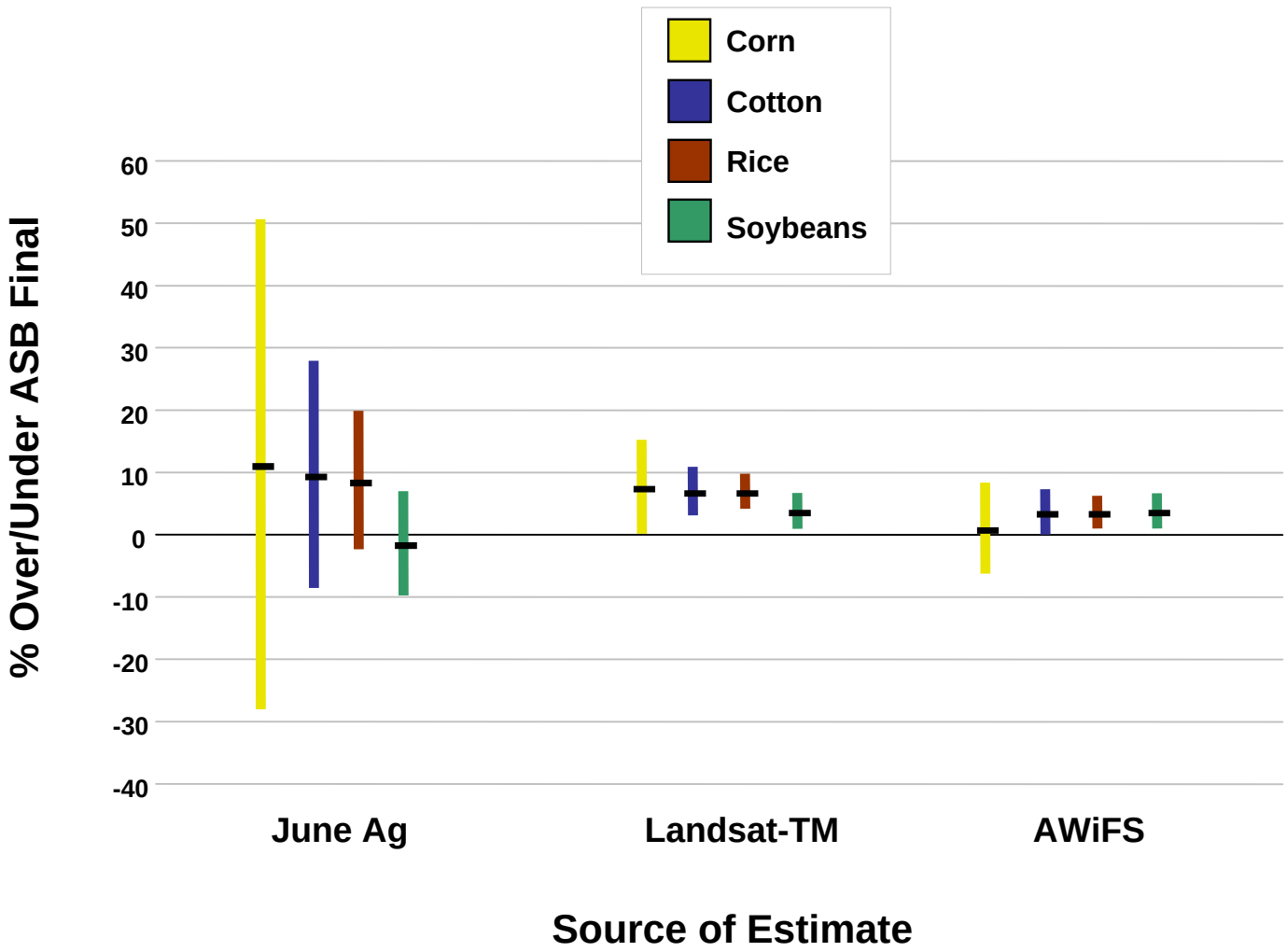
R-sq (11) = 0.967
R-sq (21) = 0.979
Slope (11) = 0.2109
Slope (21) = 0.2175

No Outliers Removed

Arkansas 2005
State Level Estimates as % Over/Under Agricultural Statistics Board (Final)



Arkansas 2005
State Level Estimates +/- 2 CV

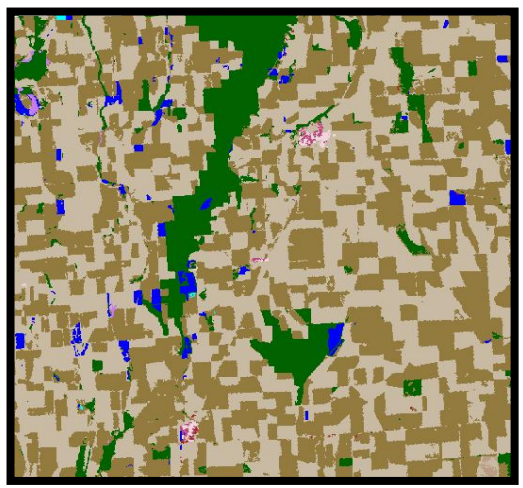


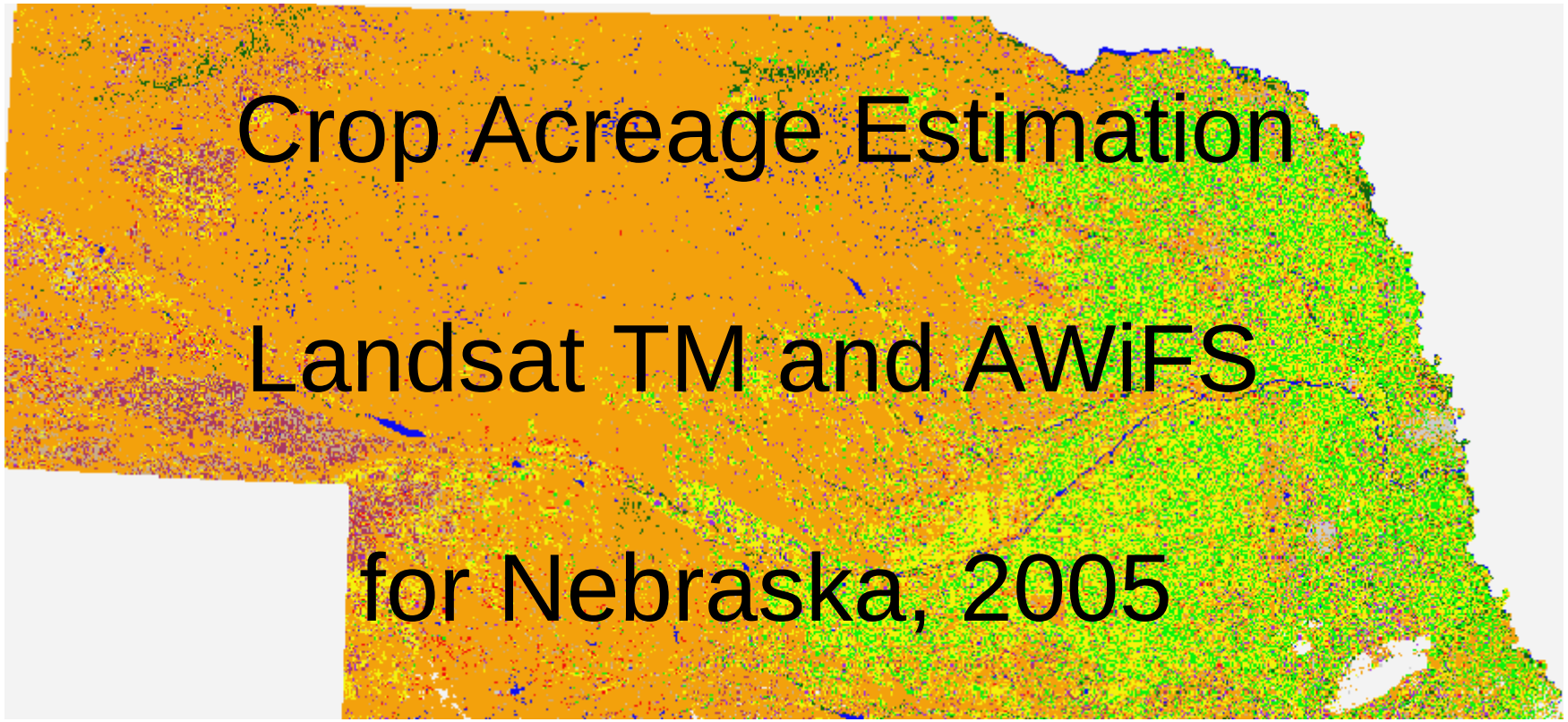
Summary after Initial Assessments

2004 AWiFS cropland classification results were not as accurate as results derived from multitemporal or unitemporal Landsat data.

2005, multitemporal AWiFS (Kappa = 0.9254) cropland classification results, exceeded those derived from Landsat TM data (Kappa = 0.9170).

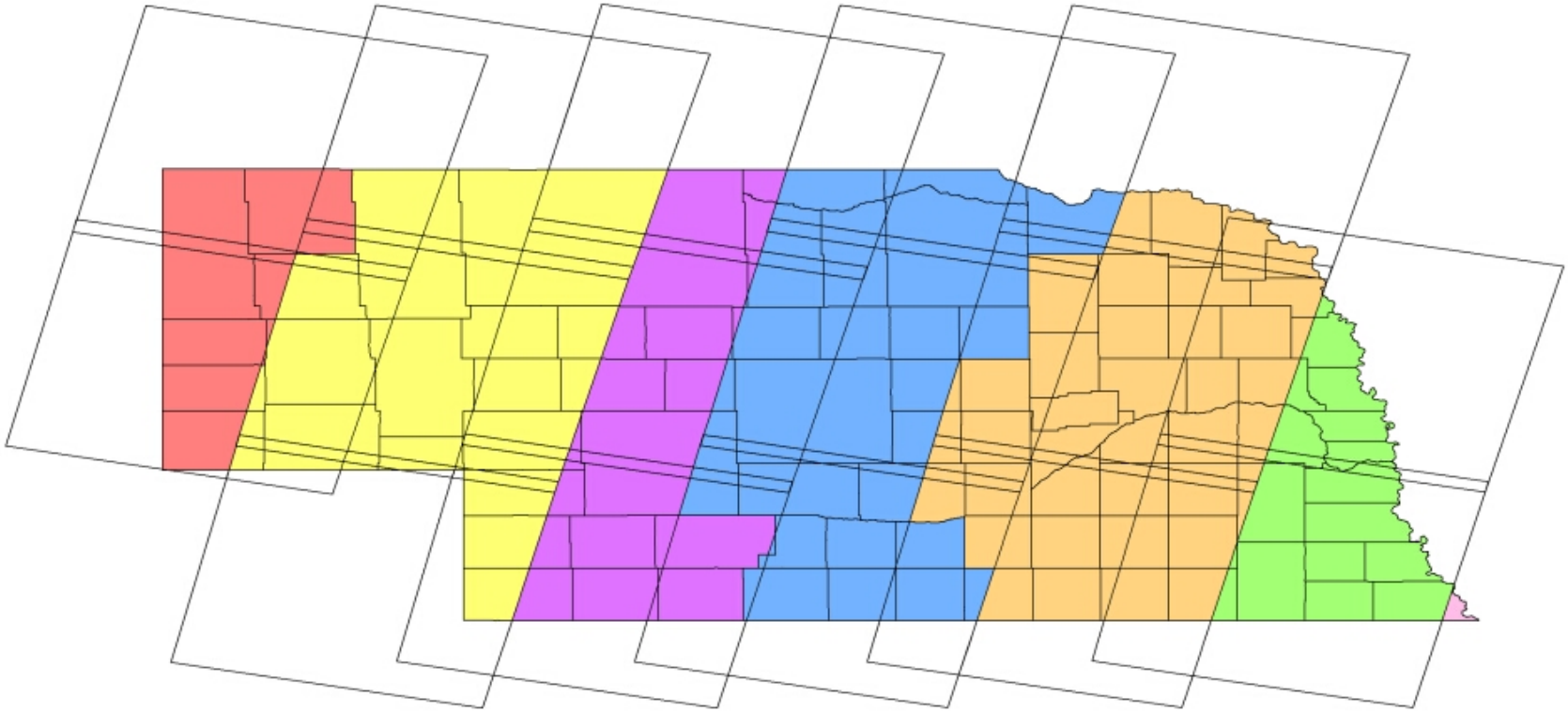
AWiFS data appear to be a suitable alternative or supplement to Landsat TM data for production of NASS' Cropland Data Layer product.




Crop Acreage Estimation
Landsat TM and AWiFS
for Nebraska, 2005

NEBRASKA - 2005 TM

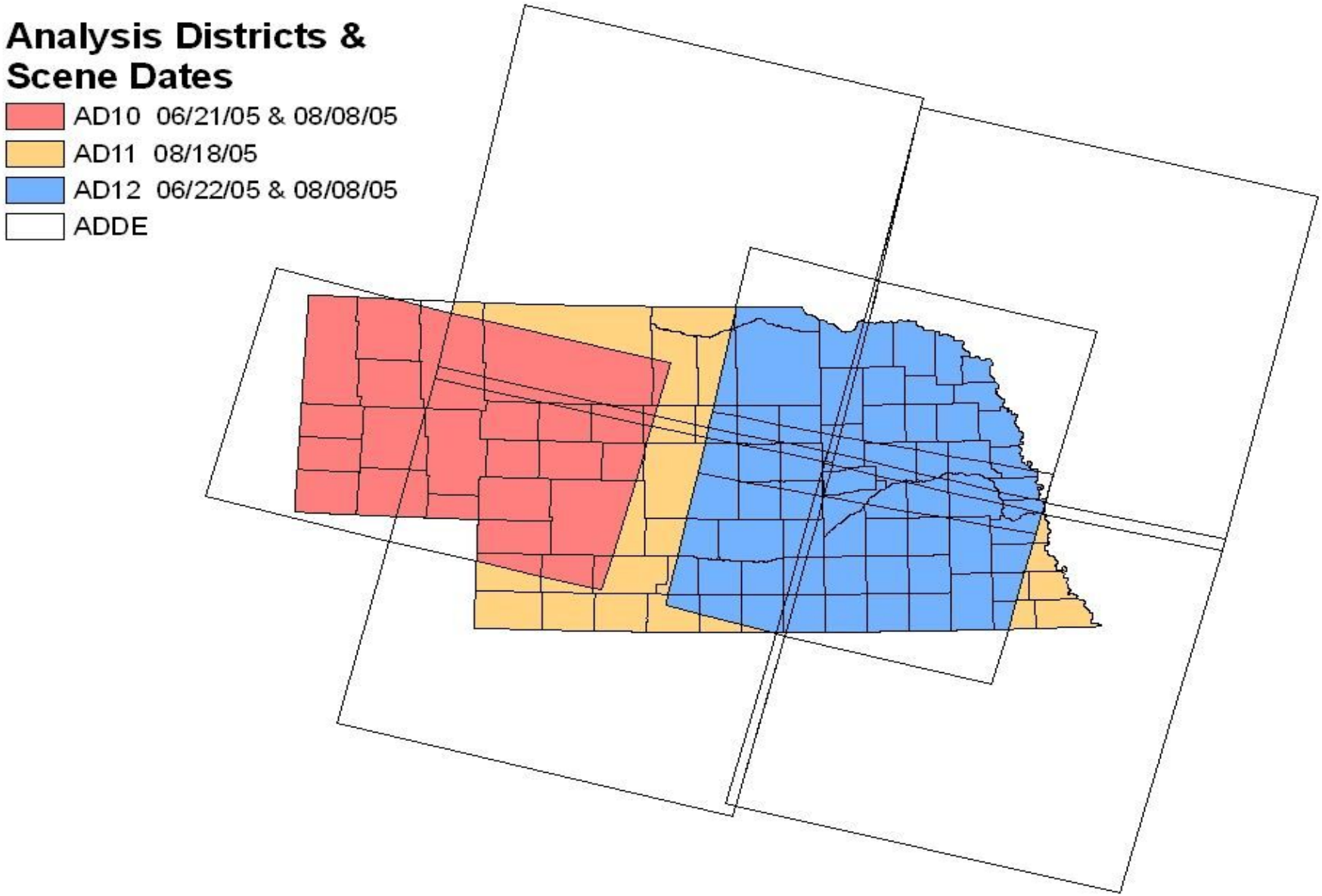
Analysis Districts and
Scene Observation Dates

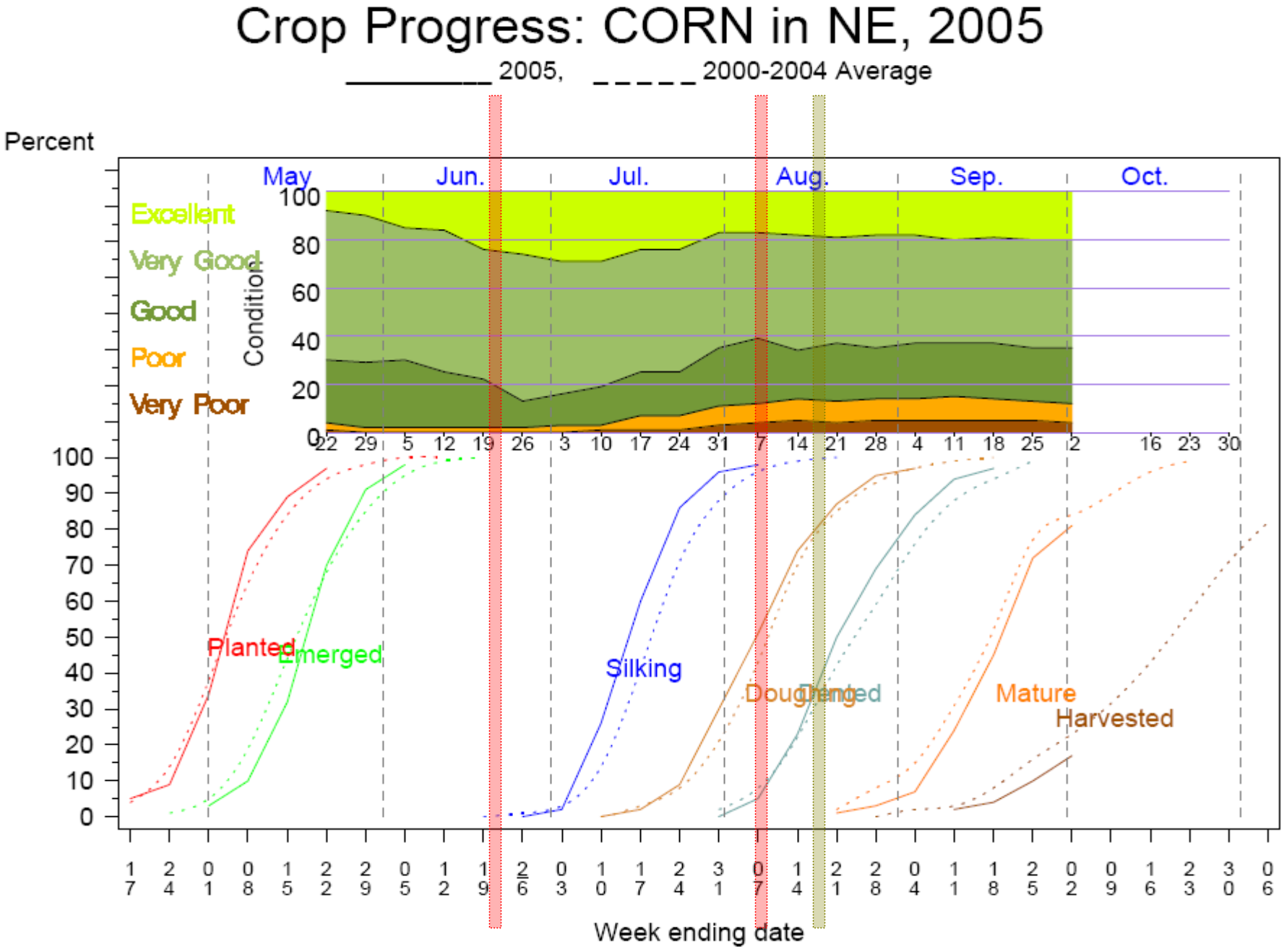


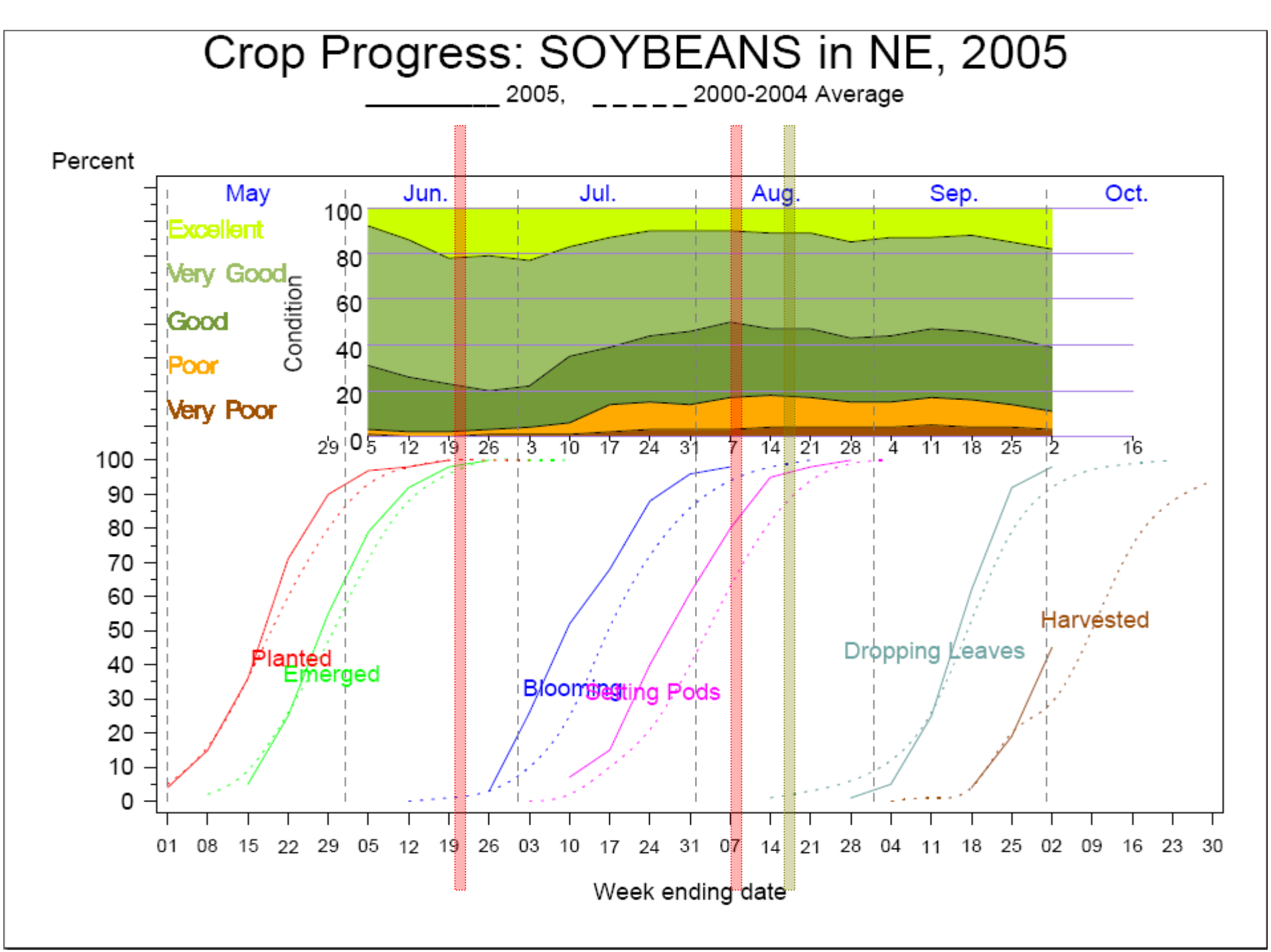
Analysis Districts, Sensor & Scene Dates

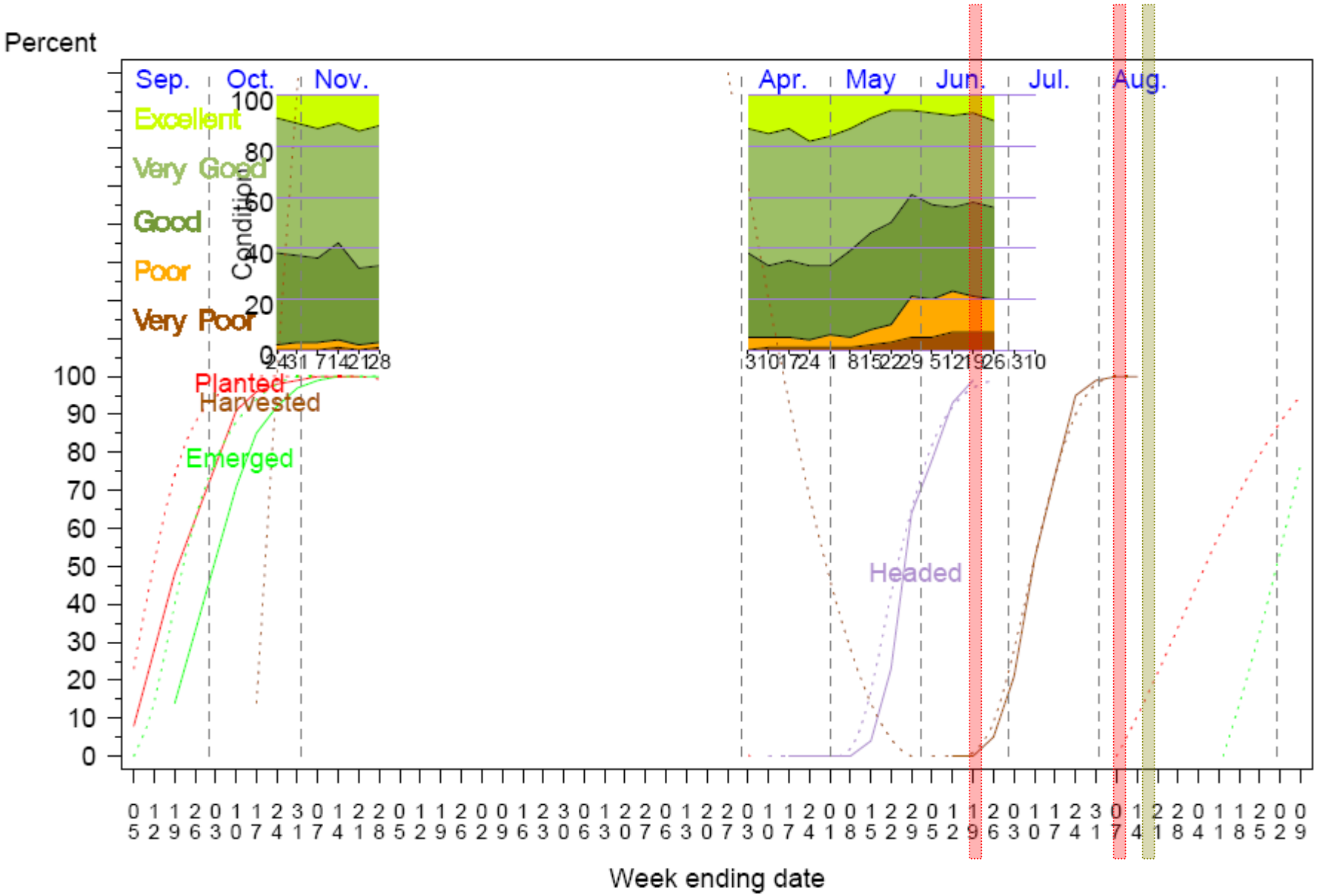
- AD01 TM 05/15/05 & 07/02/05
- AD02 TM 04/06/05 & 08/28/05
- AD03 TM 08/05/05
- AD04 TM 06/27/05 & 08/30/05
- AD05 TM 06/20/05 & 08/07/05
- AD07 TM 09/01/05
- ADIA TM 06/06/05 & 09/10/05
- ADDE

Nebraska 2005 - Analysis Districts and AWIFS Scene Observation Dates




Crop Progress: CORN in NE, 2005
_____ 2005, _ _ _ _ _ 2000-2004 Average
Percent
May
Jun.
Jul.
Aug.
Sep.
Oct.
Excellent
Very Good
Good
Poor
Very Poor
Condition
100
80
60
40
20
0
22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 16 23 30
100
90
80
70
60
50
40
30
20
10
0
Planted
Emerged
Silking
Doughing
Dented
Mature
Harvested
17 24 01 08 15 22 29 05 12 19 26 03 10 17 24 31 07 14 21 28 04 11 18 25 02 09 16 23 30 06
Week ending date


Crop Progress: SOYBEANS in NE, 2005
_____ 2005, _ _ _ _ _ 2000-2004 Average
Percent
May
Jun.
Jul.
Aug.
Sep.
Oct.
Excellent
Very Good
Good
Poor
Very Poor
Condition
100
80
60
40
20
0
29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 16
100
90
80
70
60
50
40
30
20
10
0
Planted
Emerged
Blooming
Setting Pods
Dropping Leaves
Harvested
01 08 15 22 29 05 12 19 26 03 10 17 24 31 07 14 21 28 04 11 18 25 02 09 16 23 30
Week ending date


Crop Progress: WINTER WHEAT in NE, 2005
2005, 2000-2004 Average
Percent
Sep.
Oct.
Nov.
Apr.
May
Jun.
Jul.
Aug.
Excellent
Very Good
Good
Poor
Very Poor
Condition
Planted
Harvested
Emerged
Headed
Week ending date

Kappa Statistics and Pixel Counts for Nebraska 2005 Classifier Accuracy

	Kappa		Training Pixels	
	Corn	Soybeans	Corn	Soybeans
District	TM	TM	TM	TM
AD01	97.5	.	2,014	.
AD02	89.7	99.9	9,635	888
AD03	75.7	81.4	18,440	2,814
AD04	88.5	95.7	39,219	19,693
AD05	92.3	90.4	81,409	50,103
AD07	70.3	91.1	30,181	20,769
District	AWiFS	AWiFS	AWiFS	AWiFS
AD10	95.3	98.3	3,510	347
AD11	65.1	66.2	106,721	61,581
AD12	65.6	64.1	81,273	51,978

NEBRASKA - 2005
Analysis Districts and
Scene Observation Dates

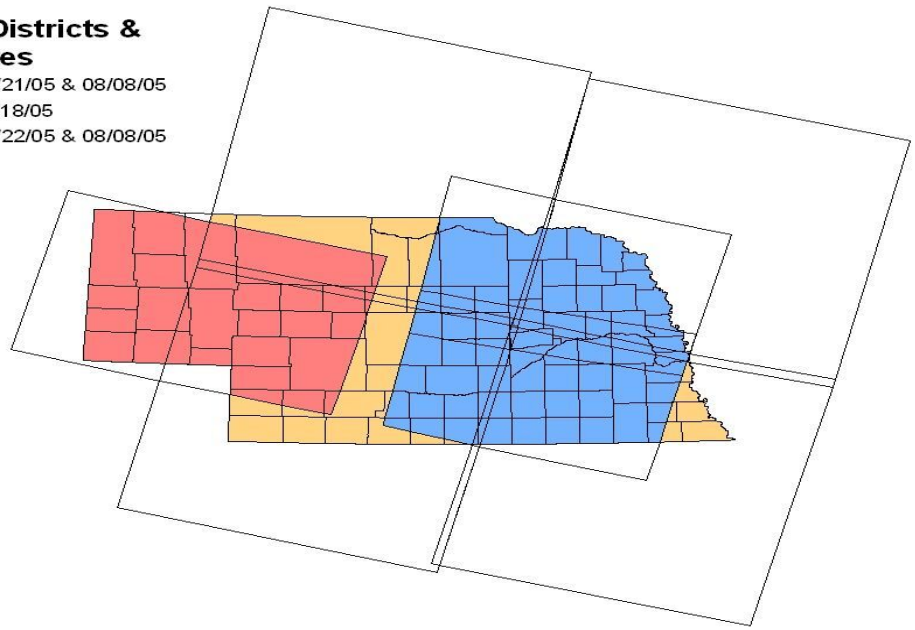
Analysis Districts, Sensor & Scene Dates

AD01 TM 05/15/05 & 07/02/05	AD05 TM 06/20/05 & 08/07/05
AD02 TM 04/06/05 & 08/28/05	AD07 TM 09/01/05
AD03 TM 08/05/05	ADIA TM 06/06/05 & 09/10/05
AD04 TM 06/27/05 & 08/30/05	ADDE

Nebraska 2005 - Analysis Districts and AWIFS Scene Observation Dates

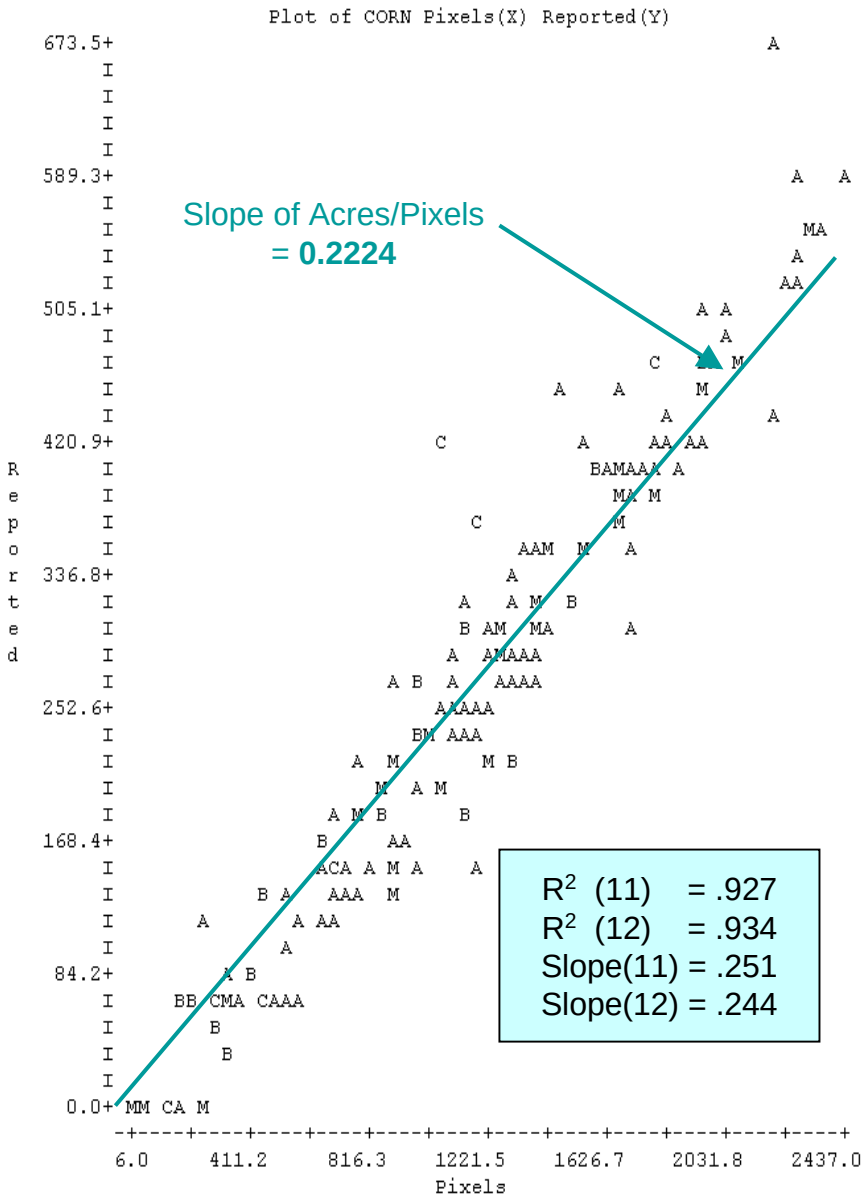
Analysis Districts & Scene Dates

- AD10 06/21/05 & 08/08/05
- AD11 08/18/05
- AD12 06/22/05 & 08/08/05
- ADDE



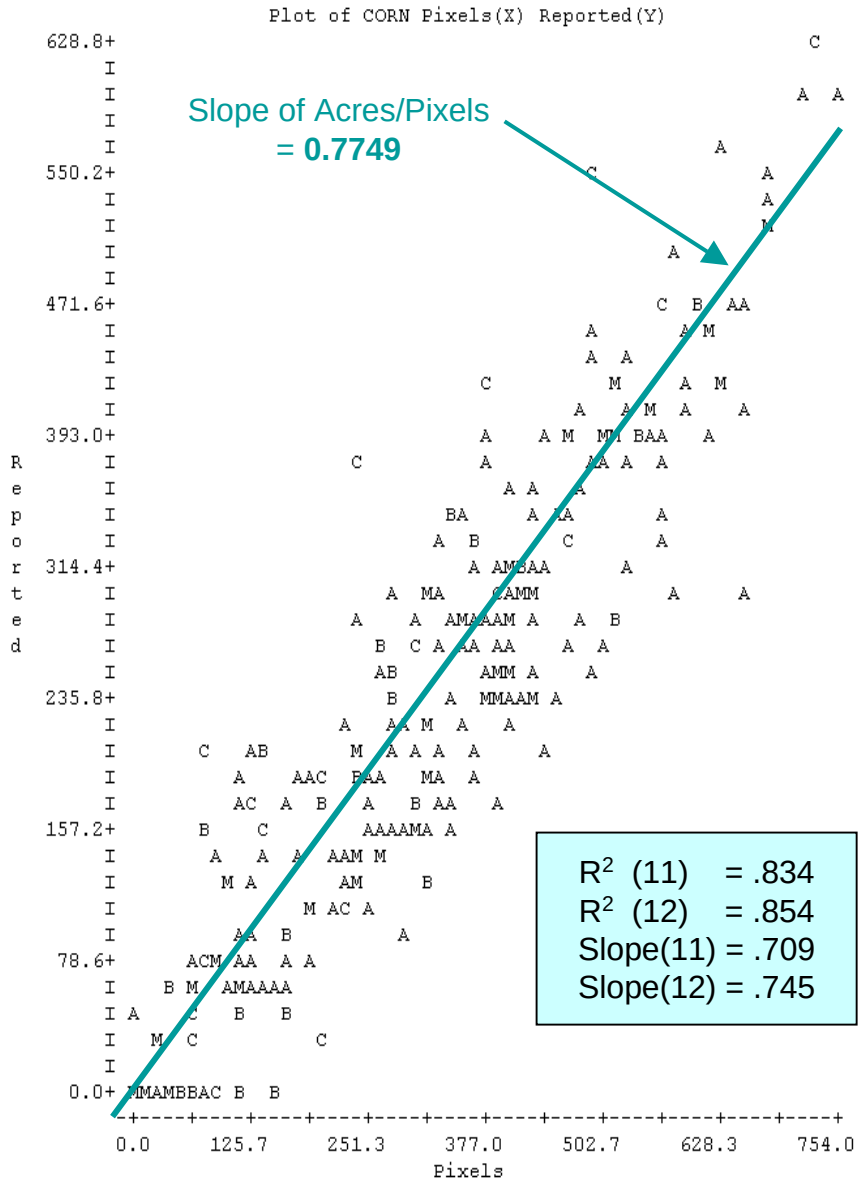
Regression Analysis from Sample Estimation

Landsat TM Corn

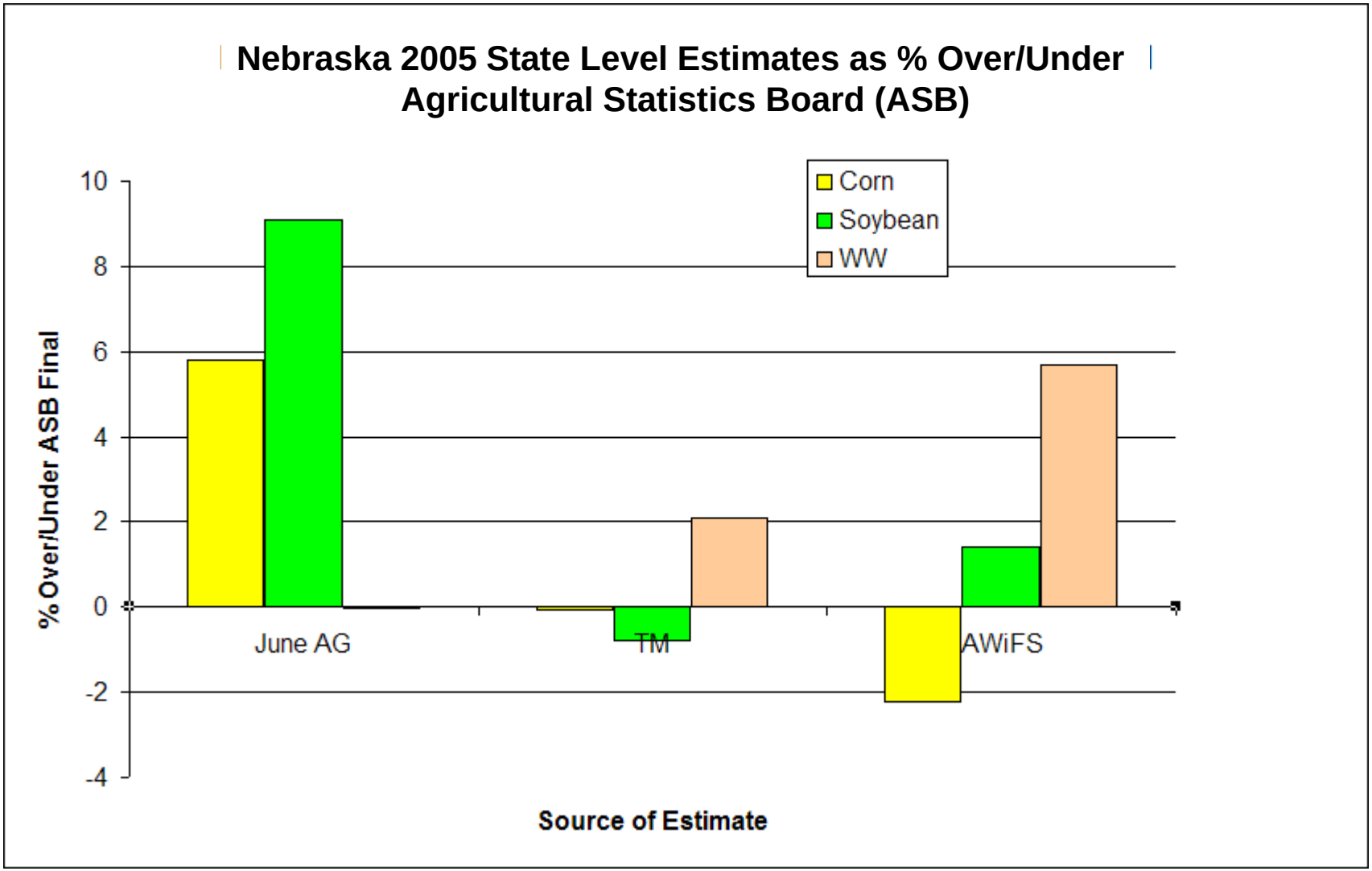


R^2 (11) = .927
R^2 (12) = .934
Slope(11) = .251
Slope(12) = .244

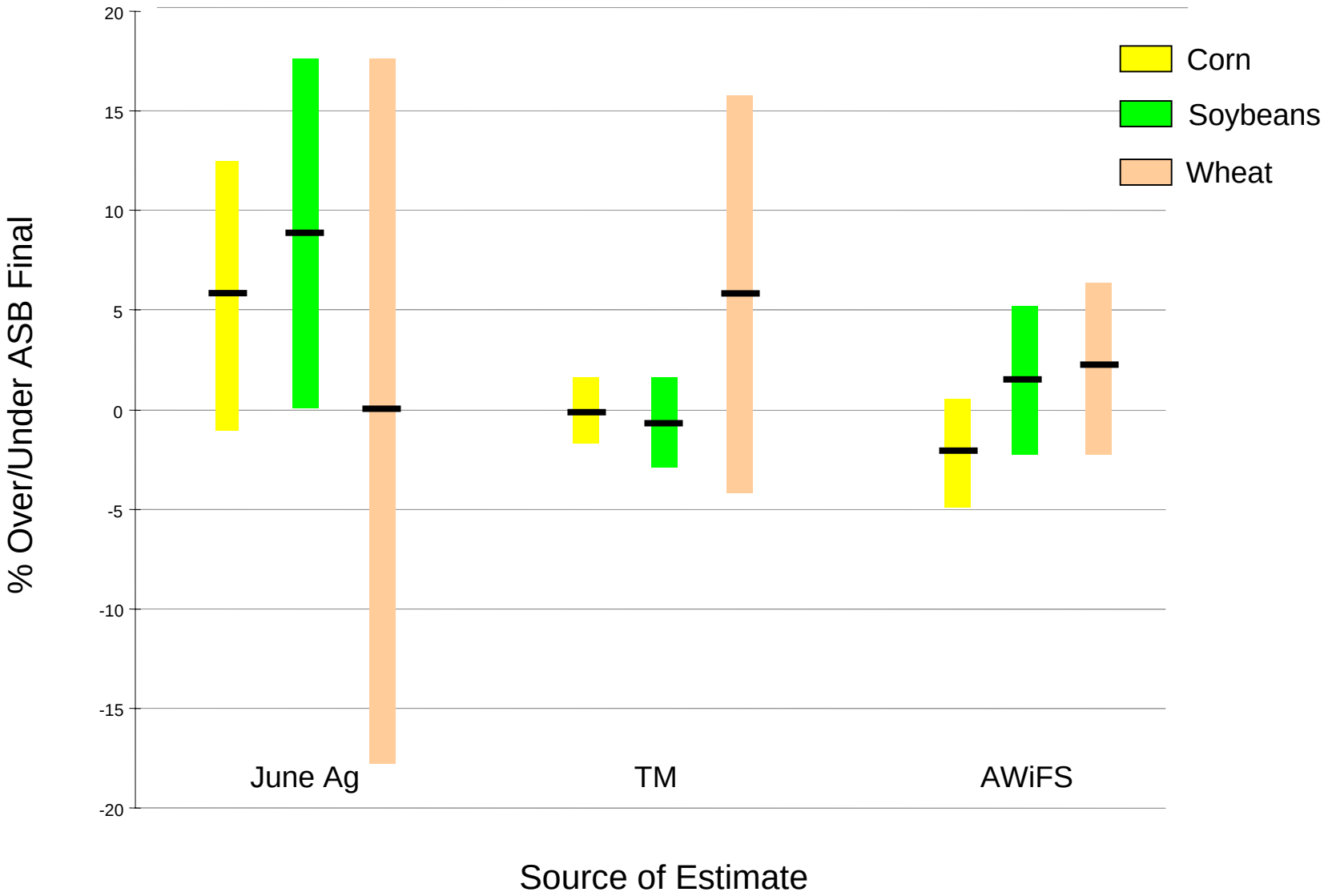
AWiFS Corn



R^2 (11) = .834
R^2 (12) = .854
Slope(11) = .709
Slope(12) = .745


Nebraska 2005 State Level Estimates as % Over/Under
Agricultural Statistics Board (ASB)
Corn
Soybean
WW
10
8
6
4
2
0
-2
-4
% Over/Under ASB Final
June AG
TM
AWiFS
Source of Estimate

Nebraska 2005 State Level Estimates +/- 2% CVs (Coefficient of Variation)



Summary

Overall accuracy as measured by the Kappa statistic is not as high for AWiFS as for TM.

While state level CV are larger for AWiFS than for TM, they are still useful for the NASS estimation program.

AWiFS can provide more frequent cloud-free coverage providing more optimal dates for any crop.

TM *vs.* AWiFS

A comparison of coincident imagery for classifying croplands

Dave M. Johnson, Geographer
USDA/NASS/Research and Development Division

Goal

To objectively quantify the ability of AWiFS to detect and categorize cropland cover types (using TM as a benchmark).

Need for coincident imagery

The best classification comparison would use not only data from the **same area** but from the **same time**. Thus controlling for variables including:

- Atmospherics conditions
  - Clouds
  - Haze
  - Smoke
- Ground conditions
  - Soil moisture
  - Vegetation phenology
- Sun angle
  - Seasonal variation

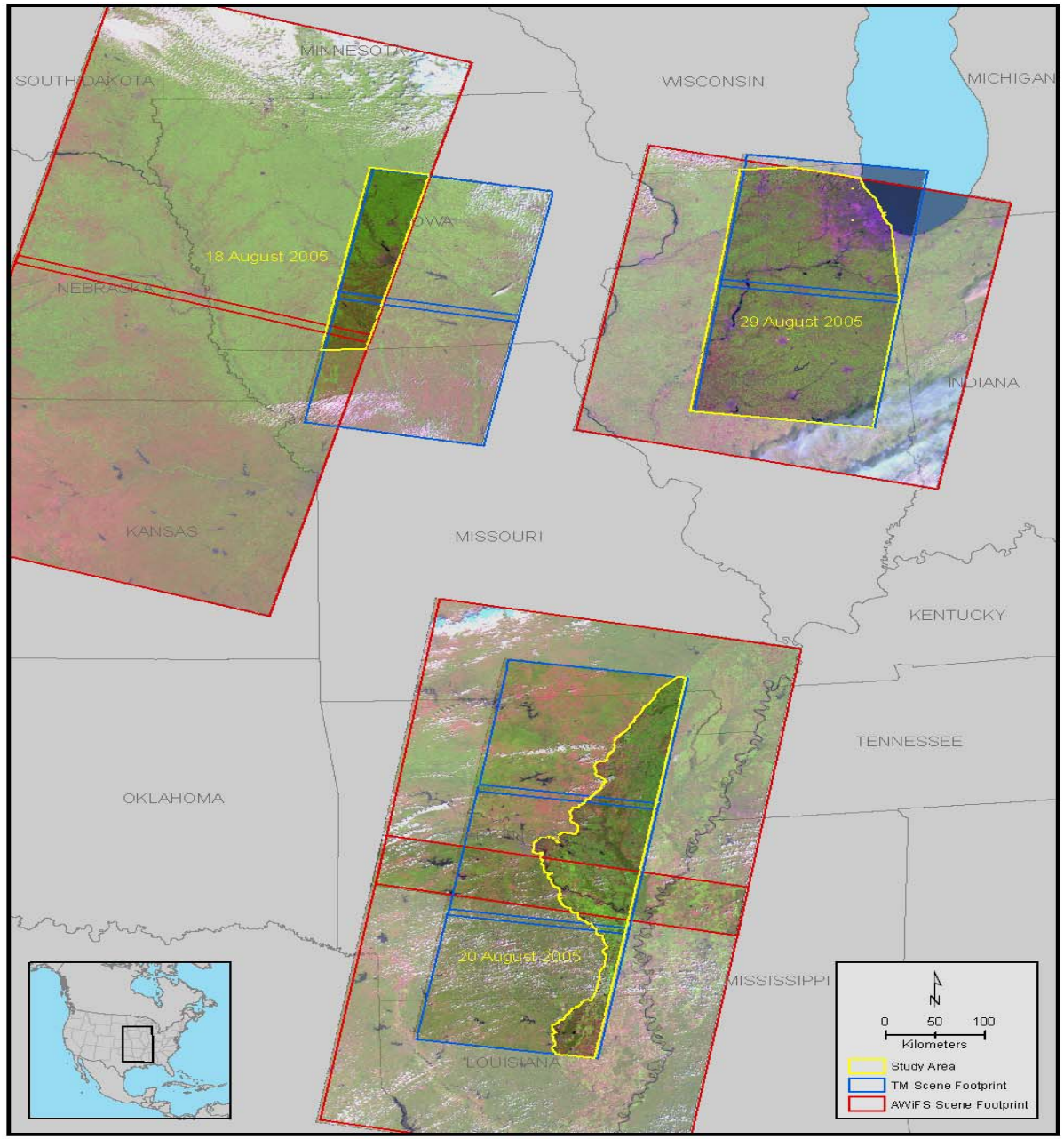
Sensor Specifications Compared

	TM	**AWiFS**
Altitude	705 km	817 km
Equatorial crossing time	9:45 ± 15 minutes	10:30 ± 5 minutes
Orbit time	99 minutes	101 minutes
Pixel size	30 x 30 m (reflective) 120 x 120 m (thermal)	56 x 56 m
Quantization	8	10
Spectral bands	6 (B, G, R, NIR, SWIR, MIR) + Thermal IR	4 (G, R, NIR,SWIR)
Field of view	14.7°	42.1°
Swath wide	185 km	737 km
Scene size	184 x 152 km	370 x 370 km

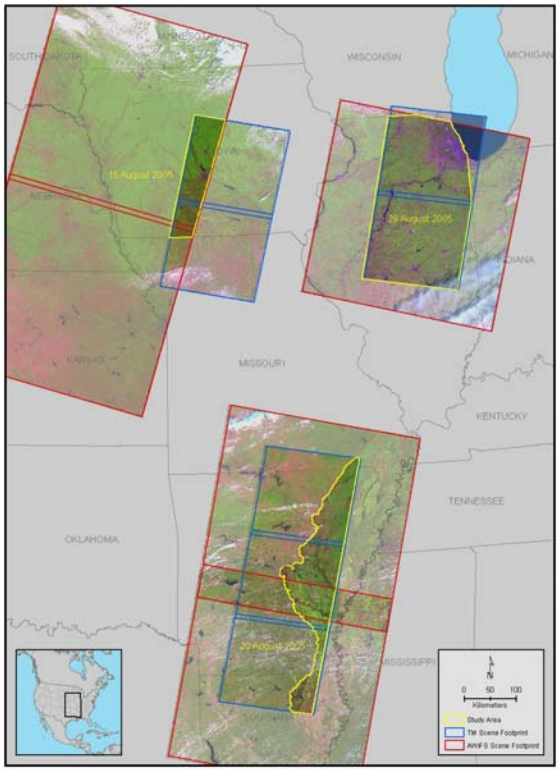
Study sites

Fortunately, several coincident areas were found and three chosen for analysis:

- Arkansas
  - 20 August 2005
- Iowa,
  - 18 August 2005
- Illinois
  - 29 August 2005



Scene specific data statistics

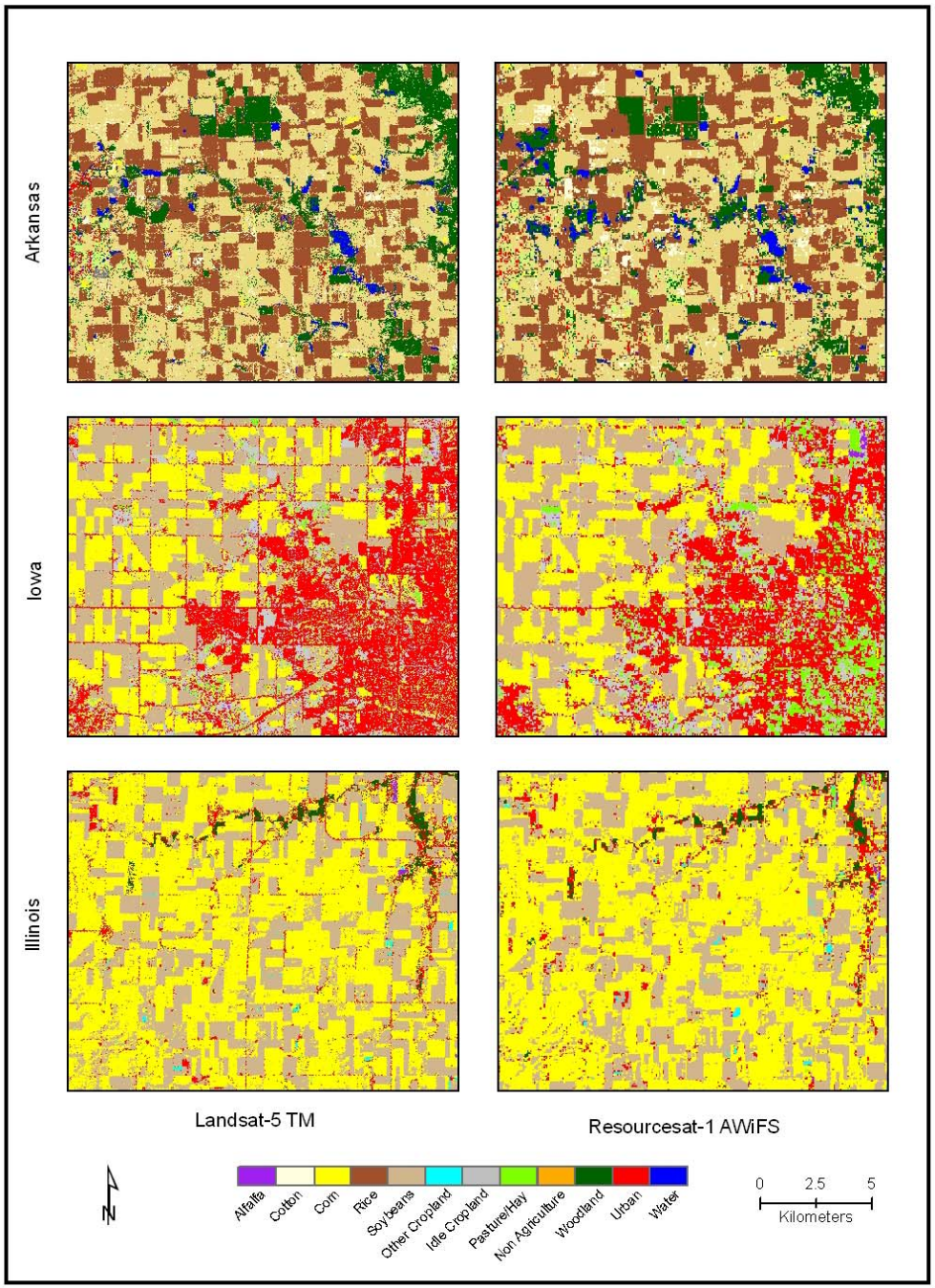


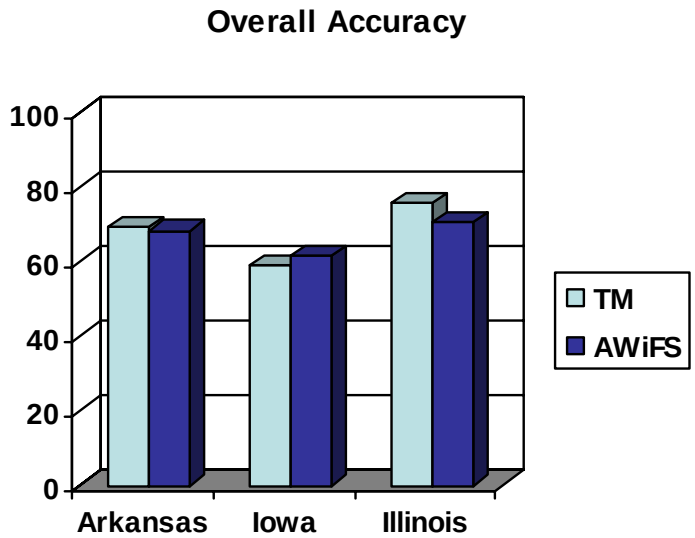
	Arkansas	Iowa	Illinois
Area (sq. miles)	9954	4971	21611
Average TM view angle (from nadir)	+5°	-5°	-0°
Average AWiFS view angle (from nadir)	-10°	+20°	+10°
AWiFS camera	west	east	east
Average AWiFS GSD (sq. m)	60	70	60

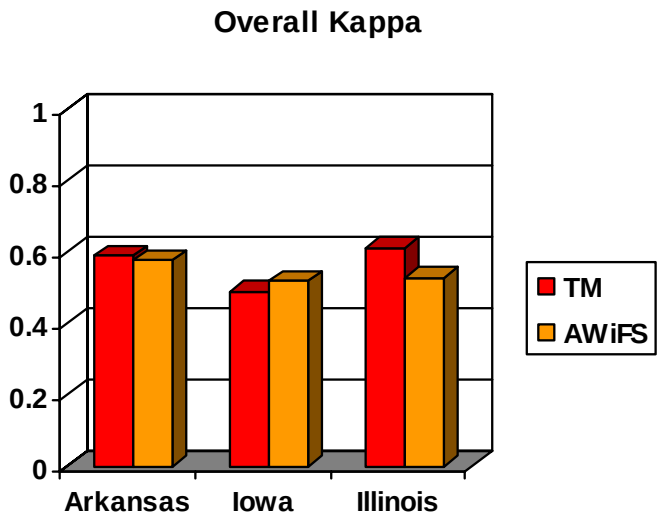
Methodology

- Utilized digitized NASS 2005 June Agriculture Survey data for ground truth
  - Arkansas
    - 199 segments, 3000 polygons
  - Iowa
    - 38 segments, 750 polygons
  - Illinois
    - 163 segments, 3500 polygons
- Only dominant cover types employed
- Half of ground truth used for training classifier, other half for accuracy assessment
- Decision tree classifier applied identically and independent to each image pair

Results


Arkansas
Iowa
Illinois
Landsat-5 TM
Resourcesat-1 AWiFS
Alfalfa
Cotton
Corn
Rice
Soybeans
Other Cropland
Idle Cropland
Pasture/Hay
Non Agriculture
Woodland
Urban
Water
0 2.5 5
Kilometers


Overall Accuracy
100
80
60
40
20
0
Arkansas
Iowa
Illinois
TM
AWiFS


Overall Kappa
1
0.8
0.6
0.4
0.2
0
Arkansas
Iowa
Illinois
TM
AWiFS

…results continued

- Within class accuracies trended similarly to overall accuracies between sensors
- Dominant cropland classes performed best with commission and omission errors typically < 25%
  - Rice, cotton, soybeans in Arkansas
  - Corn and soybeans in Iowa
  - Corn and soybeans in Illinois
- Non-cropland classes tended to struggle for all three cases
  - urban
  - pasture/hay

Simulation of AWiFS with TM

To better understand the impacts of AWiFS having two fewer reflective bands and coarser resolution than TM…

1. Dropped blue and mid-infrared bands (1 & 7) from TM scenes and reran analysis
2. Resampled TM data to 56m and reran analysis
3. Combined both effects and reran analysis

Accuracy drop	Arkansas	Iowa	Illinois
4-band TM	1.9%	0.2%	0.6%
56m TM	1.7%	0.9%	1.7%
4-band, 56m TM	3.4%	2.5%	2.2%

Summary

- TM outperforms AWiFS, but only marginally for cropland cover types.
- Availability of clear-sky and time appropriate data is more important than spatial and spectral resolution.
- AWiFS is more efficient to manage and process.
- Loss of spatial resolution with AWiFS has slightly more impact than loss of TM bands 1 and 7.

….continued summary

- AWiFS could provide benefits to many in the land cover community, especially those in need of imagery:
  - over large regions
  - in often cloudy areas
  - with rapid revisit times
  - cost effectively

- More research needs to be done with AWiFS on the effects of
  - Pixel/sun angle geometry (i.e. bidirectional reflectance)
  - 8 bit versus 10 bit quantization of data
  - smaller field sizes

Thank you

Claire, Bob, Dave, and Rick

United States Department of Agriculture
National Agricultural Statistics Service
Research and Development Division

NASS
FACT FINDERS FOR AGRICULTURE
UNITED STATES DEPARTMENT OF AGRICULTURE