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 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
• Produce acreage estimates with reduced error rates over the June Agricultural Survey.

• Create and distribute the Cropland Data Layer Product.
June Agricultural Survey

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

Source: USGS, Landsat Project:
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

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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

### Analysis Districts & Scene Observation Dates

<table>
<thead>
<tr>
<th>Corn</th>
<th>---------</th>
<th>TM</th>
<th>---------</th>
<th>AWIFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Multi</td>
<td>Uni</td>
<td>Uni</td>
<td></td>
</tr>
<tr>
<td>AD01</td>
<td>93.89%</td>
<td></td>
<td>73.42%</td>
<td></td>
</tr>
<tr>
<td>AD02</td>
<td>96.18%</td>
<td></td>
<td>93.54%</td>
<td></td>
</tr>
<tr>
<td>AD03</td>
<td>93.91%</td>
<td></td>
<td>92.67%</td>
<td>86.47%</td>
</tr>
<tr>
<td>AD04</td>
<td>92.85%</td>
<td></td>
<td>89.90%</td>
<td></td>
</tr>
<tr>
<td>AD05</td>
<td>96.85%</td>
<td></td>
<td>93.22%</td>
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</table>

<table>
<thead>
<tr>
<th>Soybean</th>
<th>---------</th>
<th>TM</th>
<th>---------</th>
<th>AWIFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Multi</td>
<td>Uni</td>
<td>Uni</td>
<td></td>
</tr>
<tr>
<td>AD01</td>
<td>99.12%</td>
<td></td>
<td>93.39%</td>
<td></td>
</tr>
<tr>
<td>AD02</td>
<td>96.81%</td>
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<td>89.93%</td>
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<tr>
<td>AD03</td>
<td>98.72%</td>
<td></td>
<td>93.40%</td>
<td>77.41%</td>
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<tr>
<td>AD04</td>
<td>95.41%</td>
<td></td>
<td>88.37%</td>
<td></td>
</tr>
<tr>
<td>AD05</td>
<td>96.67%</td>
<td></td>
<td>85.69%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall</th>
<th>---------</th>
<th>TM</th>
<th>---------</th>
<th>AWIFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Multi</td>
<td>Uni</td>
<td>Uni</td>
<td></td>
</tr>
<tr>
<td>AD01</td>
<td>96.01%</td>
<td></td>
<td>80.02%</td>
<td></td>
</tr>
<tr>
<td>AD02</td>
<td>96.19%</td>
<td></td>
<td>86.57%</td>
<td></td>
</tr>
<tr>
<td>AD03</td>
<td>95.60%</td>
<td></td>
<td>85.37%</td>
<td>75.18%</td>
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<tr>
<td>AD04</td>
<td>93.50%</td>
<td></td>
<td>81.79%</td>
<td></td>
</tr>
<tr>
<td>AD05</td>
<td>92.88%</td>
<td></td>
<td>85.91%</td>
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</tr>
</tbody>
</table>
Nebraska 2004
State Level Estimates as % Over/Under
Agricultural Statistics Board (Final)

Source of Estimate

% Over/Under ASB Final

Source of Estimate:
- June Ag
- TM-Mult
- TM-Uni
- AWIFS

Legend:
- Corn
- Soybeans
Nebraska 2004
State Level Estimates
+/- 2 CVs (Coefficient of Variation)

Source of Estimate

% Over/Under ASB Final

June Ag
TM-Mult
TM-Uni
AWIFS

Corn
Soybeans
Multitemporal Landsat TM and AWiFS Classifications of the Mississippi River Delta, 2005
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
Kappa Statistics for Classifier Accuracy
Arkansas Region 2005
of Mississippi River Delta

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Landsat TM</th>
<th>AWiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>.986</td>
<td>.985</td>
</tr>
<tr>
<td>Cotton</td>
<td>.993</td>
<td>.992</td>
</tr>
<tr>
<td>Soybeans</td>
<td>.978</td>
<td>.978</td>
</tr>
<tr>
<td>Sorghum</td>
<td>.953</td>
<td>.962</td>
</tr>
<tr>
<td>Rice</td>
<td>.979</td>
<td>.981</td>
</tr>
<tr>
<td>Other Crop</td>
<td>.793</td>
<td>.782</td>
</tr>
<tr>
<td>Non Crop</td>
<td>.629</td>
<td>.670</td>
</tr>
<tr>
<td>Overall</td>
<td>.917</td>
<td>.925</td>
</tr>
</tbody>
</table>

* Kappa Statistics based on June Area Survey (JAS) ground truth data
Regression Analysis from Sample Estimation
Arkansas 2005

Landsat TM Rice

AWiFS Rice

No Outliers Removed
Regression Analysis from Sample Estimation
Arkansas 2005

Landsat TM Cotton

AWiFS Cotton

No Outliers Removed
Arkansas 2005
State Level Estimates as % Over/Under
Agricultural Statistics Board (Final)
Arkansas 2005
State Level Estimates +/- 2 CV

Source of Estimate:
- June Ag
- Landsat-TM
- AWiFS

% Over/Under ASB Final

Crop Types:
- Corn
- Cotton
- Rice
- Soybeans
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

Analysis Districts & Scene Dates
- AD10 06/21/05 & 08/08/05
- AD11 08/18/05
- AD12 06/22/05 & 08/08/05
- ADDE
## Kappa Statistics and Pixel Counts for Nebraska 2005 Classifier Accuracy

<table>
<thead>
<tr>
<th>District</th>
<th>Kappa Corn</th>
<th>Kappa Soybeans</th>
<th>Training Pixels Corn</th>
<th>Training Pixels Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD01</td>
<td>97.5</td>
<td>.</td>
<td>2,014</td>
<td>.</td>
</tr>
<tr>
<td>AD02</td>
<td>89.7</td>
<td>99.9</td>
<td>9,635</td>
<td>888</td>
</tr>
<tr>
<td>AD03</td>
<td>75.7</td>
<td>81.4</td>
<td>18,440</td>
<td>2,814</td>
</tr>
<tr>
<td>AD04</td>
<td>88.5</td>
<td>95.7</td>
<td>39,219</td>
<td>19,693</td>
</tr>
<tr>
<td>AD05</td>
<td>92.3</td>
<td>90.4</td>
<td>81,409</td>
<td>50,103</td>
</tr>
<tr>
<td>AD07</td>
<td>70.3</td>
<td>91.1</td>
<td>30,181</td>
<td>20,769</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>District</th>
<th>AWiFS Corn</th>
<th>AWiFS Soybeans</th>
<th>AWiFS Corn</th>
<th>AWiFS Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD10</td>
<td>95.3</td>
<td>98.3</td>
<td>3,510</td>
<td>347</td>
</tr>
<tr>
<td>AD11</td>
<td>65.1</td>
<td>66.2</td>
<td>106,721</td>
<td>61,581</td>
</tr>
<tr>
<td>AD12</td>
<td>65.6</td>
<td>64.1</td>
<td>81,273</td>
<td>51,978</td>
</tr>
</tbody>
</table>
NEBRASKA - 2005
Analysis Districts and
Scene Observation Dates

Nebraska 2005 - Analysis Districts and
AWIFS Scene Observation Dates
Regression Analysis from Sample Estimation

Landsat TM Corn

\[ R^2 (11) = .927 \]
\[ R^2 (12) = .934 \]
\[ \text{Slope}(11) = .251 \]
\[ \text{Slope}(12) = .244 \]

\[ \text{Slope of Acres/Pixels} = 0.2224 \]

AWiFS Corn

\[ R^2 (11) = .834 \]
\[ R^2 (12) = .854 \]
\[ \text{Slope}(11) = .709 \]
\[ \text{Slope}(12) = .745 \]

\[ \text{Slope of Acres/Pixels} = 0.7749 \]
Nebraska 2005 State Level Estimates as % Over/Under
Agricultural Statistics Board (ASB)
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

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

<table>
<thead>
<tr>
<th></th>
<th>Arkansas</th>
<th>Iowa</th>
<th>Illinois</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (sq. miles)</td>
<td>9954</td>
<td>4971</td>
<td>21611</td>
</tr>
<tr>
<td>Average TM view angle (from nadir)</td>
<td>+5°</td>
<td>-5°</td>
<td>-0°</td>
</tr>
<tr>
<td>Average AWiFS view angle (from nadir)</td>
<td>-10°</td>
<td>+20°</td>
<td>+10°</td>
</tr>
<tr>
<td>AWiFS camera</td>
<td>west</td>
<td>east</td>
<td>east</td>
</tr>
<tr>
<td>Average AWiFS GSD (sq. m)</td>
<td>60</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>
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

Overall Accuracy

<table>
<thead>
<tr>
<th></th>
<th>TM</th>
<th>AWiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkansas</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>Iowa</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Illinois</td>
<td>90</td>
<td>85</td>
</tr>
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</table>

Overall Kappa

<table>
<thead>
<tr>
<th></th>
<th>TM</th>
<th>AWiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkansas</td>
<td>0.6</td>
<td>0.55</td>
</tr>
<tr>
<td>Iowa</td>
<td>0.65</td>
<td>0.5</td>
</tr>
<tr>
<td>Illinois</td>
<td>0.7</td>
<td>0.65</td>
</tr>
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</table>
...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

<table>
<thead>
<tr>
<th>Accuracy drop</th>
<th>Arkansas</th>
<th>Iowa</th>
<th>Illinois</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-band TM</td>
<td>1.9%</td>
<td>0.2%</td>
<td>0.6%</td>
</tr>
<tr>
<td>56m TM</td>
<td>1.7%</td>
<td>0.9%</td>
<td>1.7%</td>
</tr>
<tr>
<td>4-band, 56m TM</td>
<td>3.4%</td>
<td>2.5%</td>
<td>2.2%</td>
</tr>
</tbody>
</table>
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.
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