USDA/NASS Cropland Layer Program

Rick Mueller
Head - Spatial Analysis Research
NASS Overview

Provider of timely, accurate, and useful statistics in service to U.S. agriculture.
Remote Sensing Mission

- Provide updates on current events
  - Crop condition/acreage/yield
- Area frame stratification and sampling
- Produce annual land use/land cover classification
  - Derive acreage estimates
- Create derivative change products
Cropland Data Layer (CDL) Discussion

• Legacy program
  – Issues: Budget/Satellites/Agency Support/Technology
Cropland Data Layer (CDL) Discussion

Operational Paradigm

- Deliver in-season acreage estimates
  - Multiple times during growing season
- Increase program scope/coverage
  - “Manifest Destiny”
- Public domain crop specific
  - Land Use/Land Cover Classification
  - Creation of derivative analysis products
CDL Program Objectives

- **“Census by Satellite”**
  - Annually cover major producing corn and soybean regions
  - Indications reflect actual location of the crops
    - Not address on record via survey

- **Provide timely, accurate, useful indications**
  - Measurable error
  - Unbiased/independent estimator
  - State, County, Agricultural Statistics Districts

- **Operationalize indications delivery**
  - For June, August, and October
    - Agricultural Statistics Board
    - Field Offices
  - Update planted area

- **Output crop specific CDL**
  - Distribute to public at the cost of reproduction
    - [NRCS Geospatial Data Gateway](#)
### CDL Production Schedule

<table>
<thead>
<tr>
<th>January</th>
<th>February</th>
<th>March</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<table>
<thead>
<tr>
<th>April</th>
<th>May</th>
<th>June</th>
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<tbody>
<tr>
<td>Su Mo Tu We Th Fr Sa</td>
<td>Su Mo Tu We Th Fr Sa</td>
<td>Su Mo Tu We Th Fr Sa</td>
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<table>
<thead>
<tr>
<th>July</th>
<th>August</th>
<th>September</th>
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<tr>
<td>Su Mo Tu We Th Fr Sa</td>
<td>Su Mo Tu We Th Fr Sa</td>
<td>Su Mo Tu We Th Fr Sa</td>
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<table>
<thead>
<tr>
<th>October</th>
<th>November</th>
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<tbody>
<tr>
<td>Su Mo Tu We Th Fr Sa</td>
<td>Su Mo Tu We Th Fr Sa</td>
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<td></td>
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</tr>
<tr>
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</tr>
</tbody>
</table>

- **Crop Production Report** CDL all crops
- **Crop Acreage Report** CDL winter wheat
- **Small Grains Annual Summary** CDL small grains
- **Historical:**
  - Crop Production Annual Summary CDL all crops
  - CDL all crops/county estimates
## Current CDL Coverage

<table>
<thead>
<tr>
<th>Commodity</th>
<th>CDL States</th>
<th>US Total Acres (mill)</th>
<th>% US Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>18</td>
<td>78,177</td>
<td>92</td>
</tr>
<tr>
<td>Soybeans</td>
<td>18</td>
<td>74,374</td>
<td>91</td>
</tr>
<tr>
<td>Cotton</td>
<td>14</td>
<td>7,755</td>
<td>66</td>
</tr>
<tr>
<td>Wheat</td>
<td>13</td>
<td>40,252</td>
<td>70</td>
</tr>
<tr>
<td>Rice</td>
<td>5</td>
<td>2,924</td>
<td>82</td>
</tr>
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</table>
CDL Program

- **Inputs**
  - Resourcesat-1 AWiFS imagery
  - Farm Service Agency – Common Land Unit
  - JAS segment boundaries & summaries
  - Ancillary data
  - Commercial software suite

- **Outputs**
  - Acreage Estimates
  - Cropland Data Layer
IRS Resourcesat-1 AWiFS Imagery

340 km swath per head
740 km combined

5-day revisit

4 spectral bands
- B2: 0.52 - 0.59
- B3: 0.62 - 0.68
- B4: 0.76 – 0.86
- B5: 1.55 – 1.7

56 m nadir/70 m field edges

Data provided by Arctic Slope Regional Corporation

13 Aug 2007
AWiFS Acquisitions 7/6/08-7/11/08
Background on the USDA-Satellite Imagery Archive (USDA-SIA)

Operated by the Foreign Agricultural Service:

- Provides shared access to satellite imagery purchased by USDA for participating agencies
- Cost-sharing program to maximize the cost effectiveness of Department expenditures on satellite imagery
- Reduces per-image price paid
- Leverages the power of a single USDA purchasing body
- RMA provided additional funding for Pasture/Range/Forage year round collections
Agricultural Ground Truth
FSA Common Land Unit

½ sample for training & ½ sample for testing
Filter multi-field CLU/high acreage variance
Comprehensive program crop coverage
Agricultural Ground Truth

- Farm Service Agency (FSA)
- Common Land Unit (CLU)
- 578 attributed reporting data
NASS June Ag Survey

• Probability based
• Area frame stratification based on land use
• Sample units one square mile
- Proportional sampling
- 2001 National Land Cover Dataset from USGS
- Improve CDL coverage of non-ag classes
Ancillary Data – USGS/NASA Products

Elevation

Imperviousness

Forest Canopy

NASA MODIS Terra (16-day NDVI composite)
Commercial Software Suite

- Imagery Preparation
  - ERDAS Imagine

- Image classification
  - Decision tree software
    - See5.0 [www.rulequest.com](http://www.rulequest.com)

- Ground Truth Preparation
  - ESRI ArcGIS

- Acreage Estimation
  - SAS/IML workshop
Classification – See5 Decision Tree

- Capable of handling large and complex data sets
- Able to incorporate missing and non-continuous data
- NLCD Mapping Tool acts as an interface between Imagine and See5
## Accuracy Statistics

<table>
<thead>
<tr>
<th>Cover Type</th>
<th>Attribute Code</th>
<th>*Correct Pixels</th>
<th>Producer's Accuracy</th>
<th>Omission Error</th>
<th>Kappa</th>
<th>User's Accuracy</th>
<th>Commission Error</th>
<th>Kappa</th>
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<tr>
<td>Corn</td>
<td>803251</td>
<td><strong>94.29%</strong></td>
<td>5.71%</td>
<td>0.9342</td>
<td><strong>95.78%</strong></td>
<td>4.22%</td>
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<td>Sorghum</td>
<td>9047</td>
<td>46.49%</td>
<td>53.60%</td>
<td>0.4630</td>
<td>79.16%</td>
<td>20.84%</td>
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<td>Soybeans</td>
<td>707383</td>
<td><strong>95.03%</strong></td>
<td>4.97%</td>
<td>0.9439</td>
<td><strong>97.72%</strong></td>
<td>2.28%</td>
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<td>Sunflowers</td>
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<td>14.01%</td>
<td>0.8572</td>
<td>92.15%</td>
<td>7.85%</td>
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<td>Sweet corn</td>
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<td>100.00%</td>
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<td>n/a</td>
<td>n/a</td>
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<td>Popcorn</td>
<td>627</td>
<td>64.77%</td>
<td>35.23%</td>
<td>0.6477</td>
<td>94.86%</td>
<td>5.14%</td>
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<td>Barley</td>
<td>1995</td>
<td>25.85%</td>
<td>74.15%</td>
<td>0.2582</td>
<td>64.17%</td>
<td>35.83%</td>
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<td>Durum wheat</td>
<td>280</td>
<td>13.53%</td>
<td>86.47%</td>
<td>0.1352</td>
<td>57.49%</td>
<td>42.51%</td>
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<td>Spring wheat</td>
<td>255912</td>
<td>86.02%</td>
<td>13.98%</td>
<td>0.8537</td>
<td>91.04%</td>
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<td>Winter wheat</td>
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<td>15.47%</td>
<td>0.8368</td>
<td>94.00%</td>
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<td>Other grains</td>
<td>92</td>
<td>4.75%</td>
<td>95.25%</td>
<td>0.0475</td>
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<td>35.21%</td>
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<td>WW / Soybeans</td>
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<td>96.34%</td>
<td>0.0366</td>
<td>100.00%</td>
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<td>Rye</td>
<td>126</td>
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<td>93.29%</td>
<td>0.0671</td>
<td>78.26%</td>
<td>21.74%</td>
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<td>Oats</td>
<td>2799</td>
<td>14.85%</td>
<td>85.15%</td>
<td>0.1479</td>
<td>58.23%</td>
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<td>Millet</td>
<td>12879</td>
<td>49.50%</td>
<td>50.50%</td>
<td>0.4936</td>
<td>74.76%</td>
<td>25.24%</td>
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<td>Flaxseed</td>
<td>150</td>
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<td>82.31%</td>
<td>0.1769</td>
<td>66.37%</td>
<td>33.63%</td>
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<td>Safflower</td>
<td>212</td>
<td>14.89%</td>
<td>85.11%</td>
<td>0.1488</td>
<td>57.30%</td>
<td>42.70%</td>
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<tr>
<td>Rape seed</td>
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<td>0.00%</td>
<td>100.00%</td>
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<tr>
<td>Alfalfa</td>
<td>56603</td>
<td>56.37%</td>
<td>43.63%</td>
<td>0.5593</td>
<td>90.69%</td>
<td>9.31%</td>
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<td>Beets</td>
<td>14</td>
<td>8.96%</td>
<td>91.14%</td>
<td>0.0866</td>
<td>93.33%</td>
<td>6.67%</td>
<td>0.9333</td>
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<tr>
<td>Dry beans</td>
<td>827</td>
<td><strong>51.02%</strong></td>
<td>48.98%</td>
<td>0.5101</td>
<td><strong>94.19%</strong></td>
<td>5.81%</td>
<td>0.9419</td>
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<tr>
<td>Other crops</td>
<td>8</td>
<td>13.33%</td>
<td>86.67%</td>
<td>0.1333</td>
<td>42.11%</td>
<td>57.89%</td>
<td>0.4210</td>
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<tr>
<td>Misc. vegetables</td>
<td>0</td>
<td>0.00%</td>
<td>100.00%</td>
<td>0.0000</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Watermelon</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>0.00%</td>
<td>100.00%</td>
<td>0.0000</td>
<td>0.0000</td>
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<tr>
<td>Lentils</td>
<td>253</td>
<td>87.54%</td>
<td>12.46%</td>
<td>0.8754</td>
<td>99.61%</td>
<td>0.39%</td>
<td>0.9961</td>
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<td>Peas</td>
<td>950</td>
<td>35.26%</td>
<td>64.74%</td>
<td>0.3525</td>
<td>88.29%</td>
<td>11.71%</td>
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<td>Herbs</td>
<td>639</td>
<td>78.21%</td>
<td>21.79%</td>
<td>0.7821</td>
<td>98.61%</td>
<td>1.39%</td>
<td>0.9861</td>
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</tr>
<tr>
<td>Clover / Wildflowers</td>
<td>27</td>
<td>13.24%</td>
<td>86.76%</td>
<td>0.1323</td>
<td>93.10%</td>
<td>6.90%</td>
<td>0.9310</td>
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<tr>
<td>Seed / Sod Grass</td>
<td>319</td>
<td>18.07%</td>
<td>81.93%</td>
<td>0.1807</td>
<td>89.86%</td>
<td>10.14%</td>
<td>0.8986</td>
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<tr>
<td>Idle / Fallow</td>
<td>34514</td>
<td>56.97%</td>
<td>43.03%</td>
<td>0.5668</td>
<td>82.73%</td>
<td>17.27%</td>
<td>0.8257</td>
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<tr>
<td>Apples</td>
<td>0</td>
<td>0.00%</td>
<td>100.00%</td>
<td>0.0000</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

*Correct Pixels represents the total number of independent validation pixels correctly identified in the error matrix.*
**Cropland Data Layer and Acreage Estimation Processing Flow**

**Input Raster Data**
- USGS Resourcesat-1 raw AWiFS summer time series
- NASA Terra MODIS 16-day NDVI prior fall and summer time series
- USGS NLCD 2001 Impervious & Canopy
- USGS NED Elevation

**Input Vector Data**
- NASS JAS segments
- FSA CLU
- USGS NLCD

**Tabular Data**
- JAS eData
- FSA 578

**Rulequest See5.0**
- Derives decision tree-based classification rules
- Manages and visualizes datasets
- Generated rule set

**Output**
- State and county crop acreage statistics
- NASS Internal Only
- Accuracy Assessment
- Confidence Layer

**Diagnostics**

**Estimation**
- Customized for acreage estimation
- Pixel count vs. reported acreage

**ERDAS IMAGINE**

**ESRI ArcGIS**
- Link and assess data sets
- Non-agricultural Ground truth

**FSA CLU**

**Extract JAS intersecting pixels**
South Dakota 2008 CDL

Land Cover Categories
(Ordered by Decreasing Acreage)

Agricultural:
- Corn
- Soybeans
- Winter Wheat
- Spring Wheat
- Alfalfa
- Sunflowers
- Millet
- Sorghum
- Oats
- Barley
- Peas
- Other Crops
- Dry Beans
- Safflower
- Durum Wheat
- Other Small Grains

Non-Agricultural:
- Grass/Pasture/Non-Ag
- Woodland
- Urban/Developed
- Water
- Wetlands
- Barren
- Shrubland
- Fallow/Idle Cropland

Rye
- Flaxseed
- Lentils
- Clover/Wildflowers
- Sugarbeets
- Misc. V.gs. & Fruits
Non Ag NLCD Updates (urban sprawl)
Remote Sensing
Regression Estimation

Acreage: South Dakota
Estimation Components:

- Area Sampling Frame
- June Ag Survey
- Questionnaire

**SECTION D - CROPS AND LAND USE ON TRACT**

How many acres are inside this blue tract boundary drawn on the photo (map)?

Now I would like to ask about each field inside this blue tract boundary and its use during 2000.

<table>
<thead>
<tr>
<th>FIELD NUMBER</th>
<th>01</th>
<th>02</th>
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<tbody>
<tr>
<td>1. Total acres in field</td>
<td>828</td>
<td>828</td>
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<tr>
<td>2. Crop or land use. [Specify]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Occupied farmstead or dwelling</td>
<td>843</td>
<td></td>
</tr>
<tr>
<td>4. Waste, unoccupied dwellings, buildings and structures, roads, ditches, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Woodland</td>
<td>831</td>
<td>831</td>
</tr>
<tr>
<td>6. Pasture</td>
<td>842</td>
<td>842</td>
</tr>
</tbody>
</table>

Permanent (not in crop rotation) | 856 | 856 | 856 |
Regression-based Acreage Estimator

Regression used to relate categorized pixel counts to the ground reference data

- \((X)\) – Cropland Data Layer (CDL) classified acres
- \((Y)\) – June Agricultural Survey (JAS) reported acres

Using both CDL and JAS acreage results in estimates with reduced error rates over JAS alone

Outlier segment detection - removal from regression analysis

Acreage not just about counting pixels
CDL Program Estimation

- **State level/large domain**
  - Classification accuracy
  - Apply regression equations to population level classified pixel counts within area frame land use strata
  - Sum across strata

- **County level/small domain**
  - Battese-Fuller approach
    - Incorporate an additional term that accounts for county (random) effects
  - Pixel count ~ biased
    - Not subject to sampling error
    - Nonsampling error due to pixel misclassification
\[ \hat{Y}_{ca\text{ (reg)}} = \sum_{h=1}^{H_a} N_{ah} [\bar{Y}_{ca\text{ h}} - \bar{X}_{ca\text{ h}} - \hat{b}_{ca\text{ h}}] \]

\( \hat{Y}_{ca\text{ (reg)}} = \) Number of frame units in stratum

\( \bar{Y}_{ca\text{ h}} = \) mean acres per segment from

\( \bar{X}_{ca\text{ h}} = \) mean categorized pixel count

\( \hat{b}_{ca\text{ h}} = \) coefficient from regression of acres on pixel counts

\( \bar{X}_{ca\text{ h}} = \) mean categorized pixel count (scenes)

c = crop

a = analysis region

h = stratum
CDL Acreage Summary

**STATE-LEVEL**
- CDL indications are as good or better than survey-based indicators
- Timeliness meets survey deadlines
- Accuracy & consistency have been improved, and further research improvements are ongoing

**COUNTY-LEVEL**
- Great majority of county indications are within 10% of Official Estimates
- Issues with non-program/specialty crop coverage
- CDL indications come with variance statistics
Derivative Products

- Crop rotations
- Land use change/conversion
- Planting intensity
Crop Rotations
How many times was the same crop planted?
Land Use Change/Conversion

Legend
- background
- MI07 crops to MI08 crops
- MI07 crops to MI08 grass/pasture/nonag
- MI07 crops to MI08 urban

MI07 CDL versus MI08 CDL Crop Comparison
Corn Planting Intensity
5 years vs. 9 years
Illinois

Years Planted to Corn

2003-2007

1999-2007
Thank you from the Spatial Analysis Research Section