Remote Sensing of Agriculture

NASS' Cropland Data Layer Program

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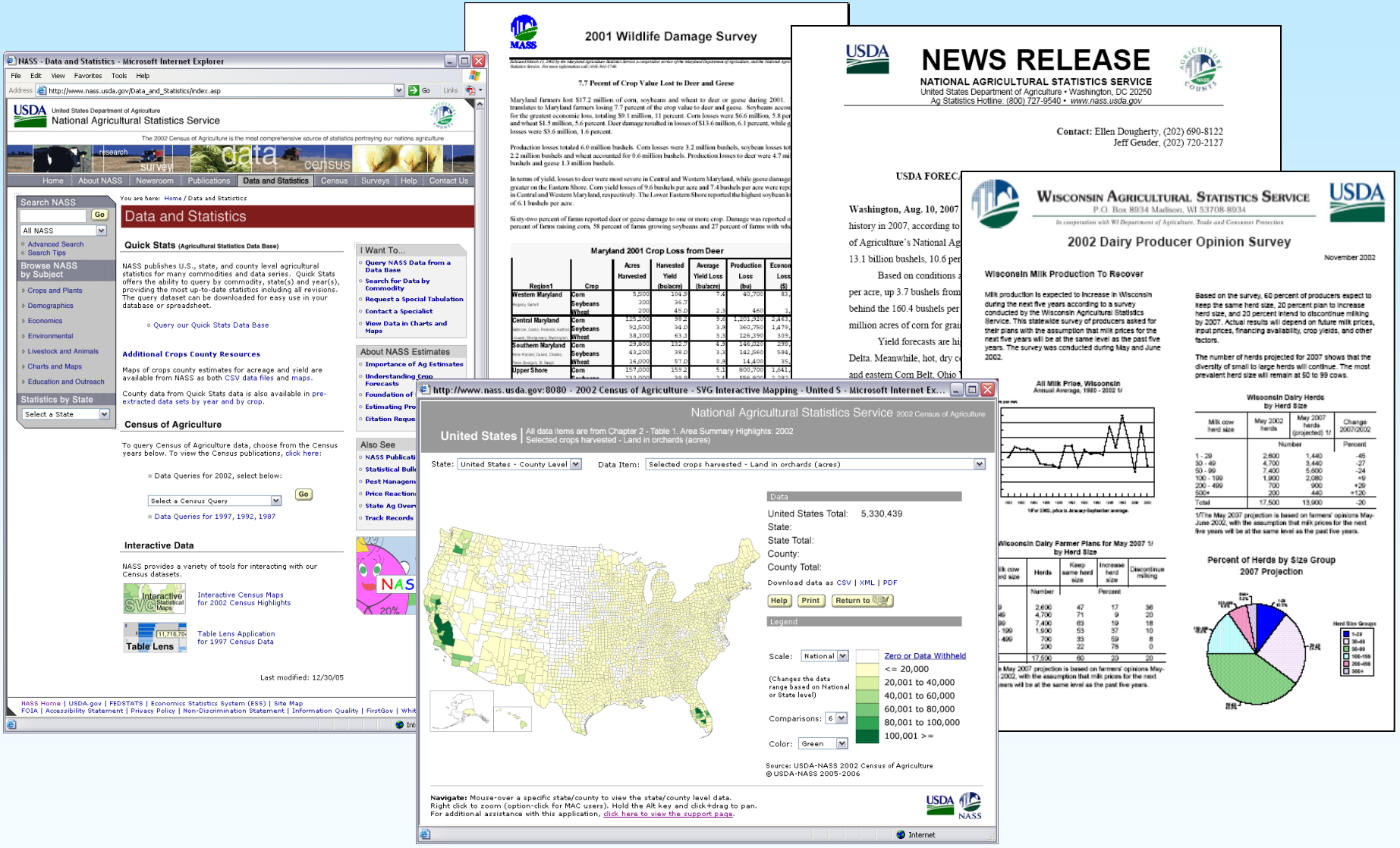
USDA/NASS

NASS Overview

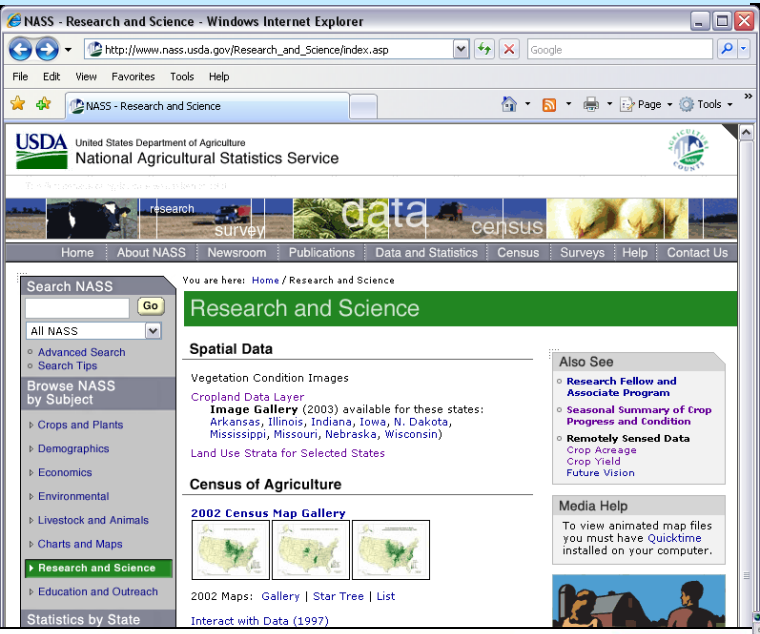
Provider of timely, accurate, and useful statistics in service to U.S. agriculture

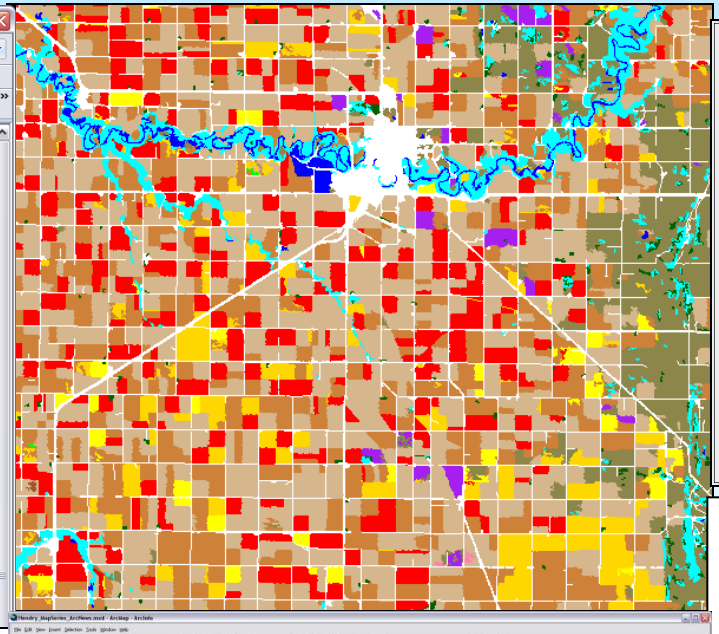


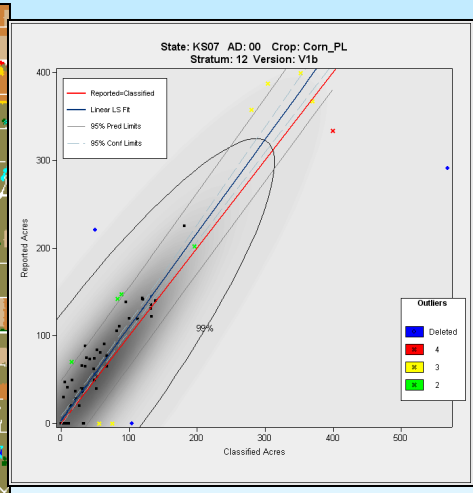
Research and Development Division

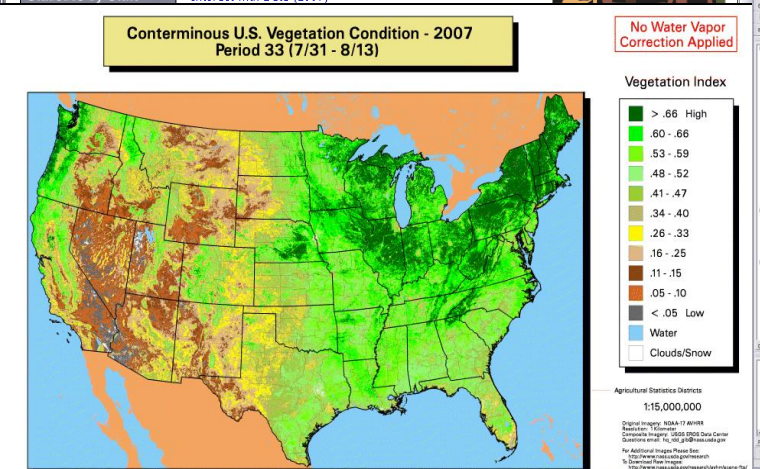
Geospatial Information Branch

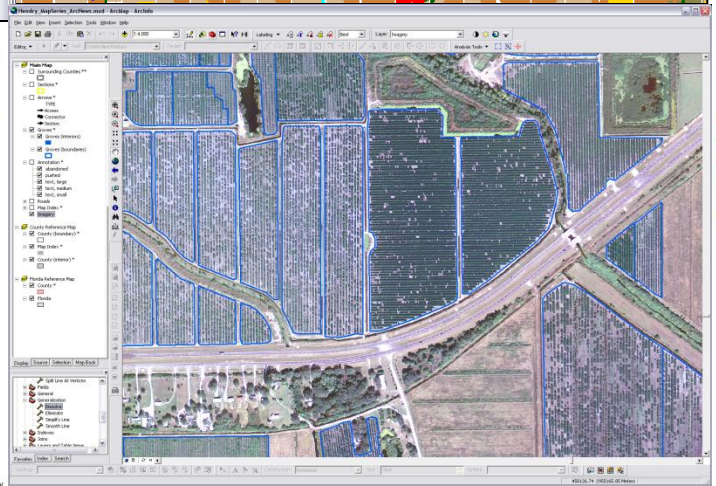
Spatial Analysis Research

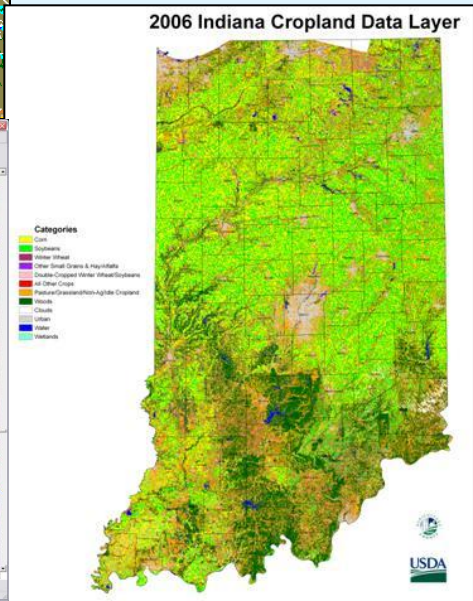




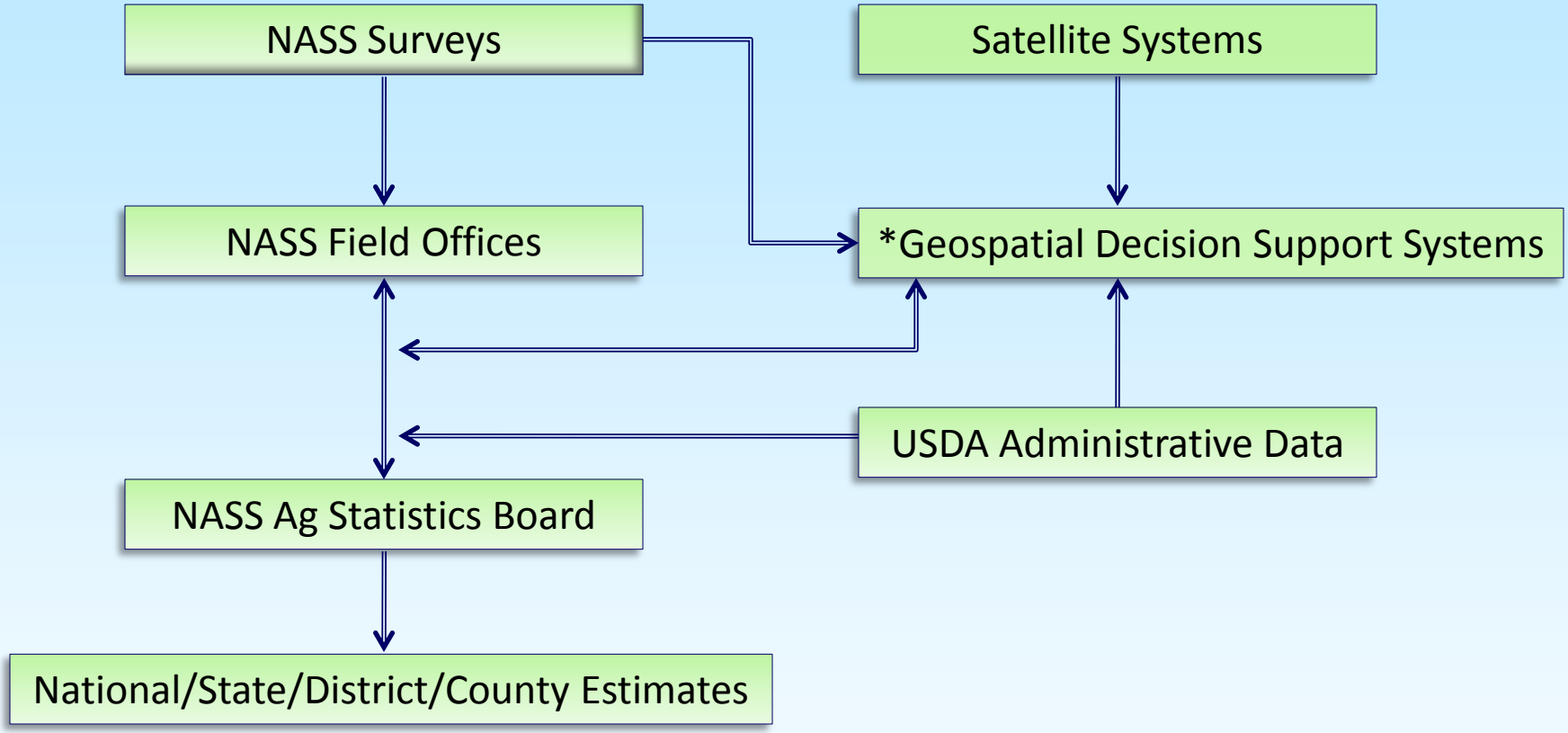








NASS Estimation Systems

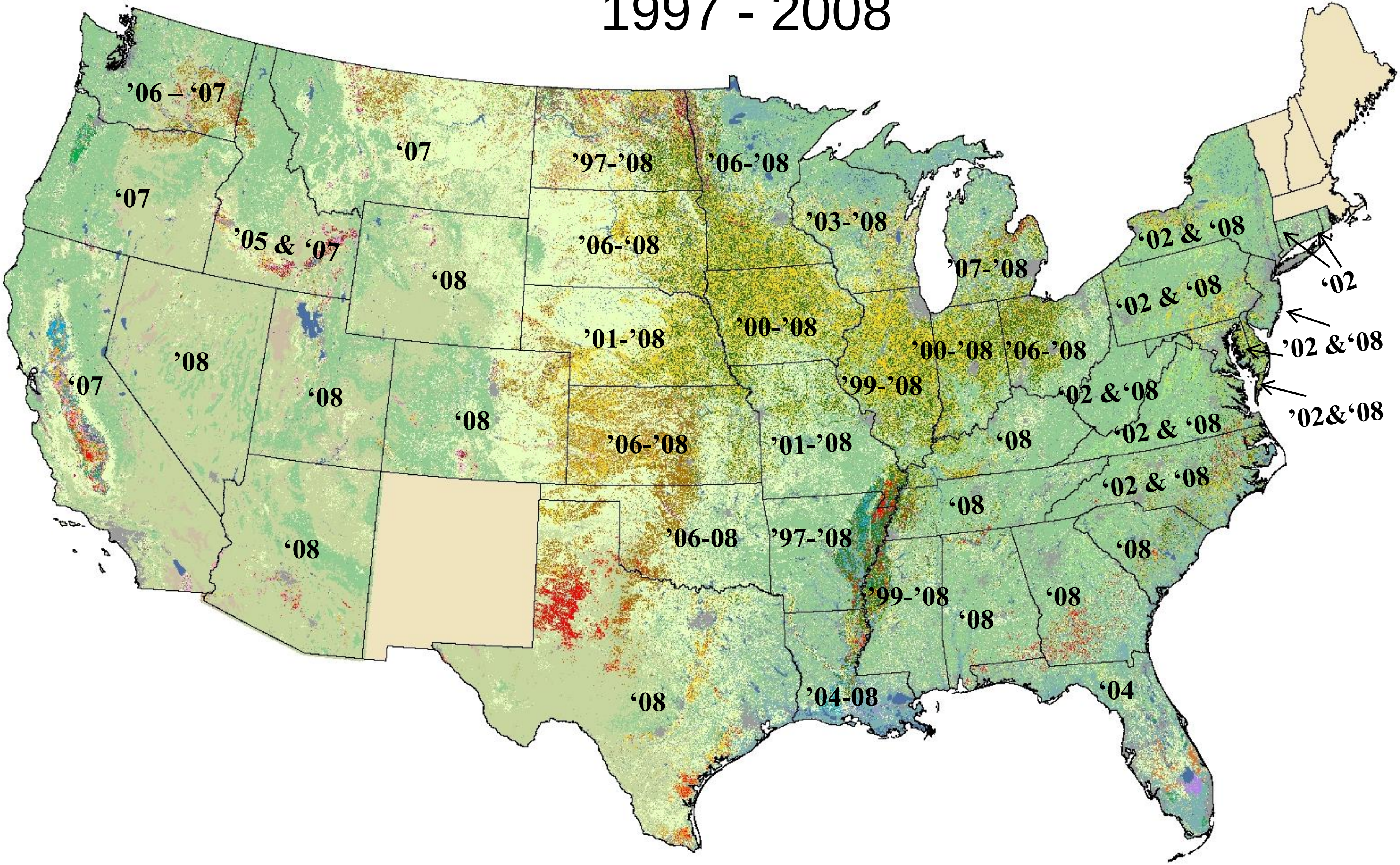


*NASS uses Geospatial Decision Support Systems to provide updated information to the Ag Statistics Board and data users.

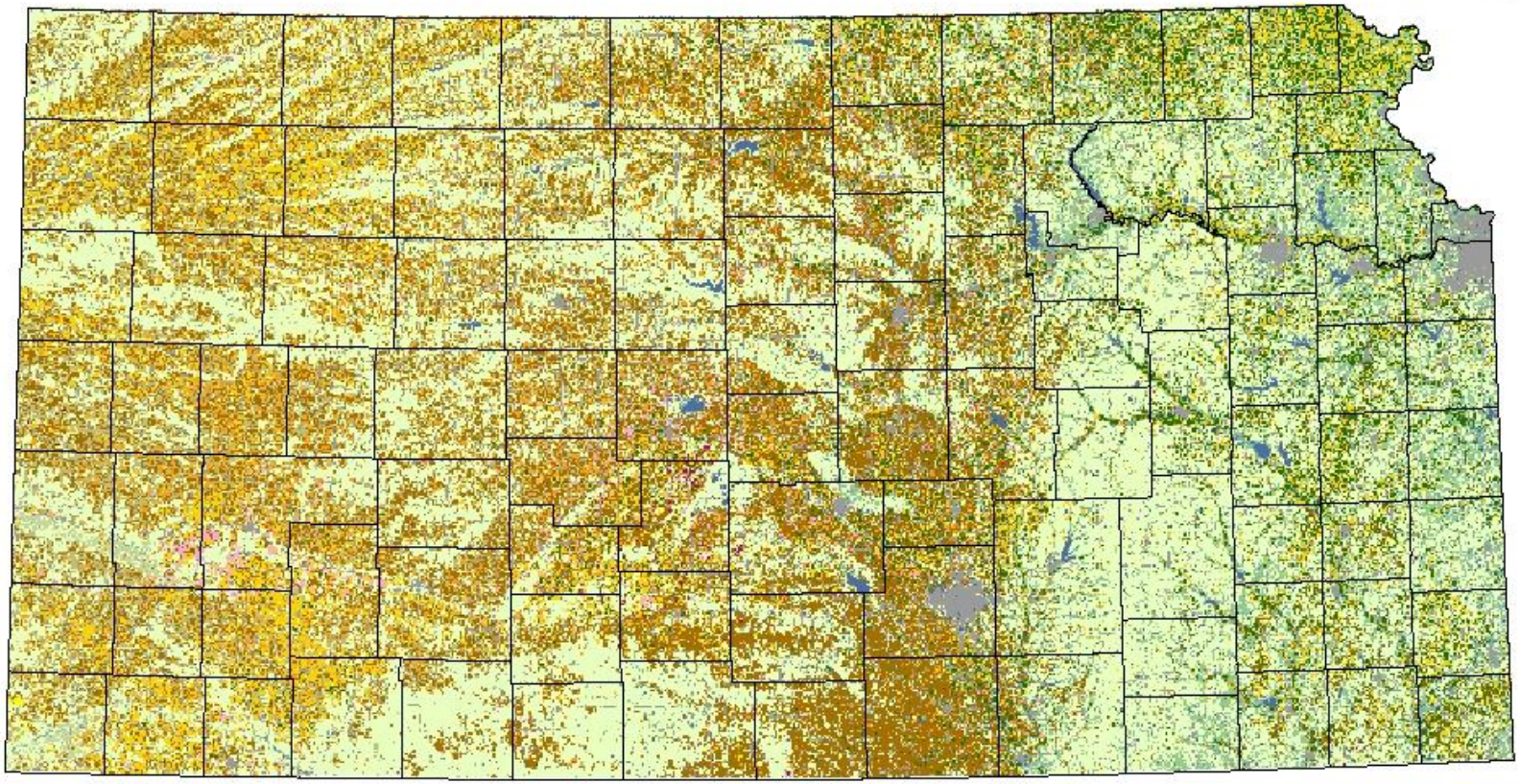
Cropland Data Layer Program Objectives

- "Census by Satellite"
  - Without area duplication
  - Major corn and soybean regions
- Provide timely, accurate, useful independent estimates
  - Measurable error
  - County and state level
- Output crop specific Cropland Data Layer
  - Distribute free to public NRCS Geospatial Data Gateway or http://www.nass.usda.gov/Research_and_Science/
  - Publish accuracy statistics/metadata
  - County and state level

Cropland Data Layers
1997 - 2008



Kansas 2008 Cropland Data Layer



Land Cover Categories

(Ordered by Decreasing Acreage)

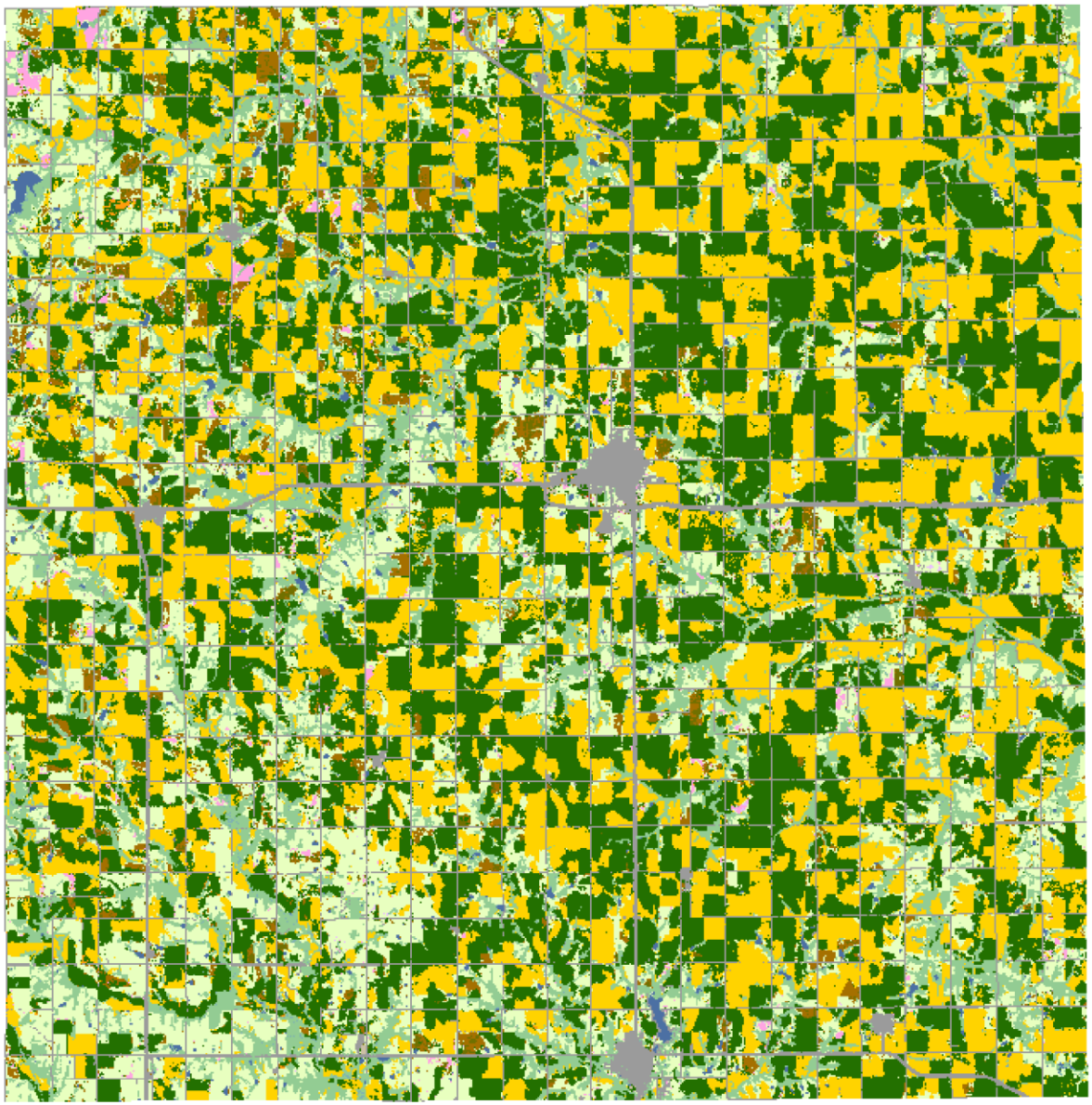
Agriculture

- Pasture/Grass
- Winter Wheat
- Corn
- Fallow/Idle Cropland
- Sorghum
- Soybeans
- Alfalfa
- W. Wht./Soy. Dbl. Crop.
- Sunflowers
- Rye
- Cotton
- Other Small Grains
- Clover/Wildflowers
- Oats
- Potatoes
- Seed/Sod Grass
- Canola
- Millet
- Other Crops
- Barley
- Other Tree Nuts & Fruits

Non-Agriculture

- Urban/Developed
- Woodland
- Water
- Wetlands
- Shrubland
- Barren

Brown County, Kansas
2008 Cropland Data Layer



Land Cover Categories

(Ordered by Decreasing Acreage)

Agricultural

- Soybeans
- Corn/Sweet Corn
- Winter Wheat
- Alfalfa
- Win. Wht./Soyb. Dbl. Cropped
- Sorghum
- Clover/Wildflowers
- Other Crops/Grass Seed/Sod
- Other Small Grains
- Sunflowers
- Oats
- Cotton
- Barley
- Seed/Sod Grass
- Other Tree Nuts

Non-Agricultural

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

Cropland Data Layer Program Components

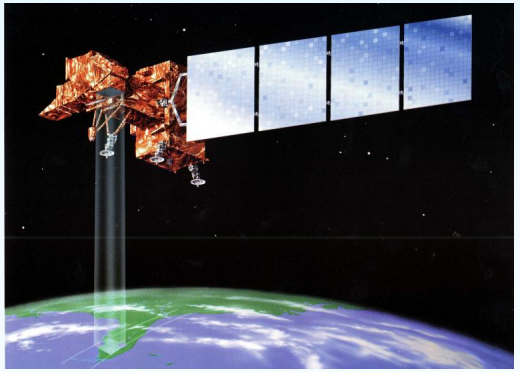
- Advanced Wide Field Sensor (AWiFS) data
- Ground truth: FSA/CLU + 578 & NLCD
- Ancillary data sets
- Commercial Software Suite
- See5 Decision Tree Methodology
- Estimation

Landsat Imagery
1997-2005, 2008-2009

Landsat 5 launched 1984 (3 yr design life!)

- Thematic Mapper (TM) Sensor

Landsat 7 launched 1999 Thematic Mapper (ETM+) Sensor



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

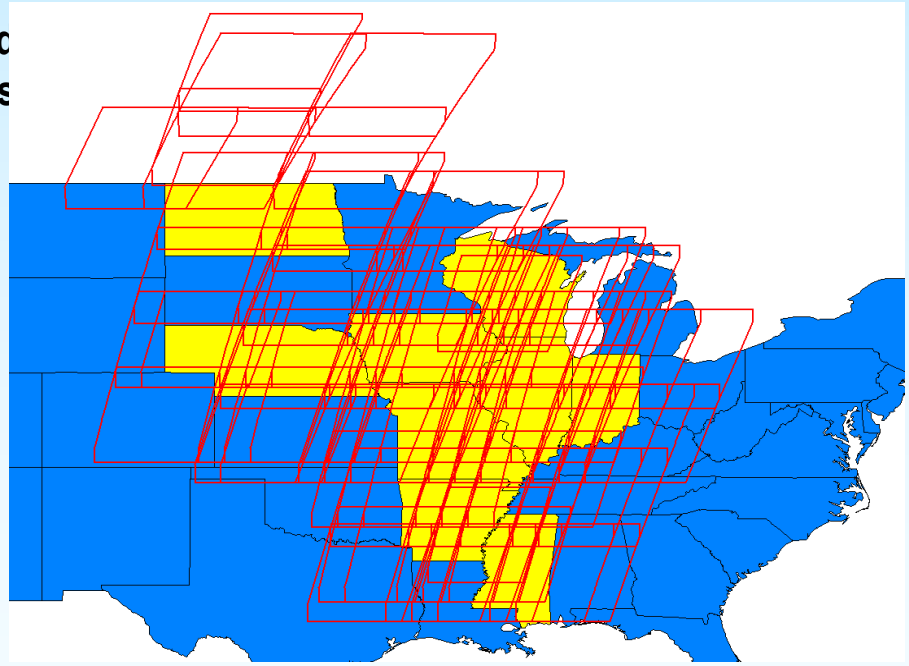
Indian Remote Sensing Satellite: RESOURCESAT-1

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 (Shortwave Infrared)**

- **Temporal Resolution (5 Days)**

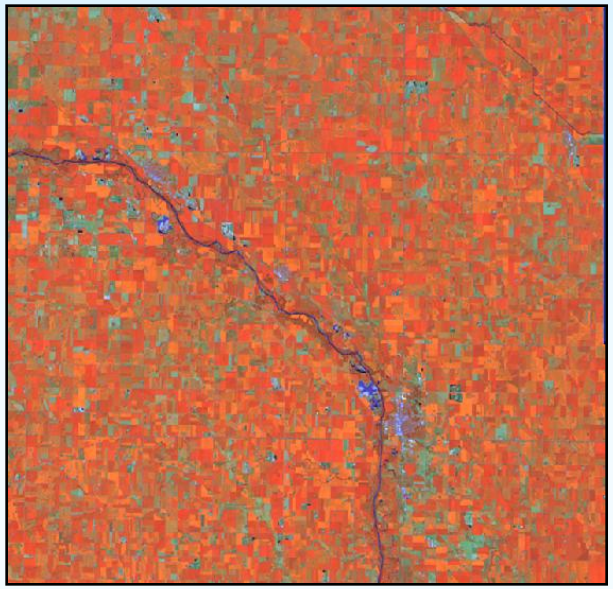


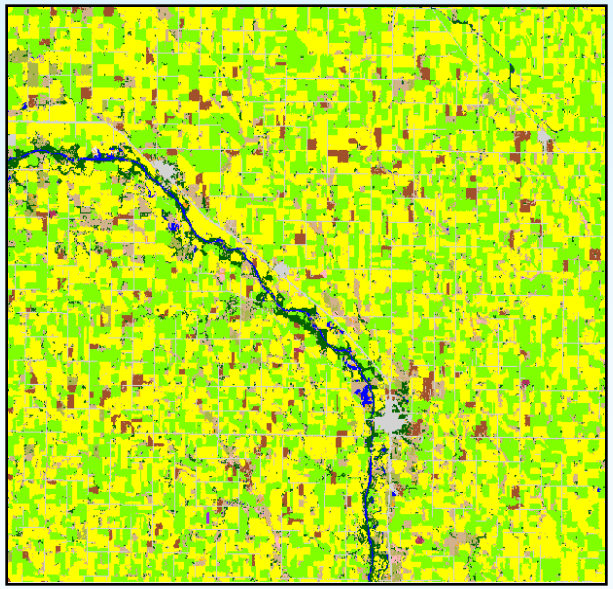
Sensor Specifications Compared

	TM	**AWiFS**
Altitude	705 km	817 km
Equatorial crossing time	9:45 ± 15 minutes	10:30 ± 5 minutes
Temporal Resolution	16 days	5 days
Spatial Resolution	30 x 30 m (reflective) 120 x 120 m (thermal)	56 x 56 m
Radiometric Resolution	8 bit (256)	10 bit (1024)
Spectral Resolution	6 (B, G, R, NIR, SWIR, MIR) + Thermal IR	4 (G, R, NIR,SWIR)
Swath wide	185 km	737 km
Scene size	184 x 152 km	370 x 370 km

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

- Nebraska, 2004
- Arkansas (Delta Region), 2005
- Nebraska, 2005
- Coincident studies (AR, IL, IA) 2005

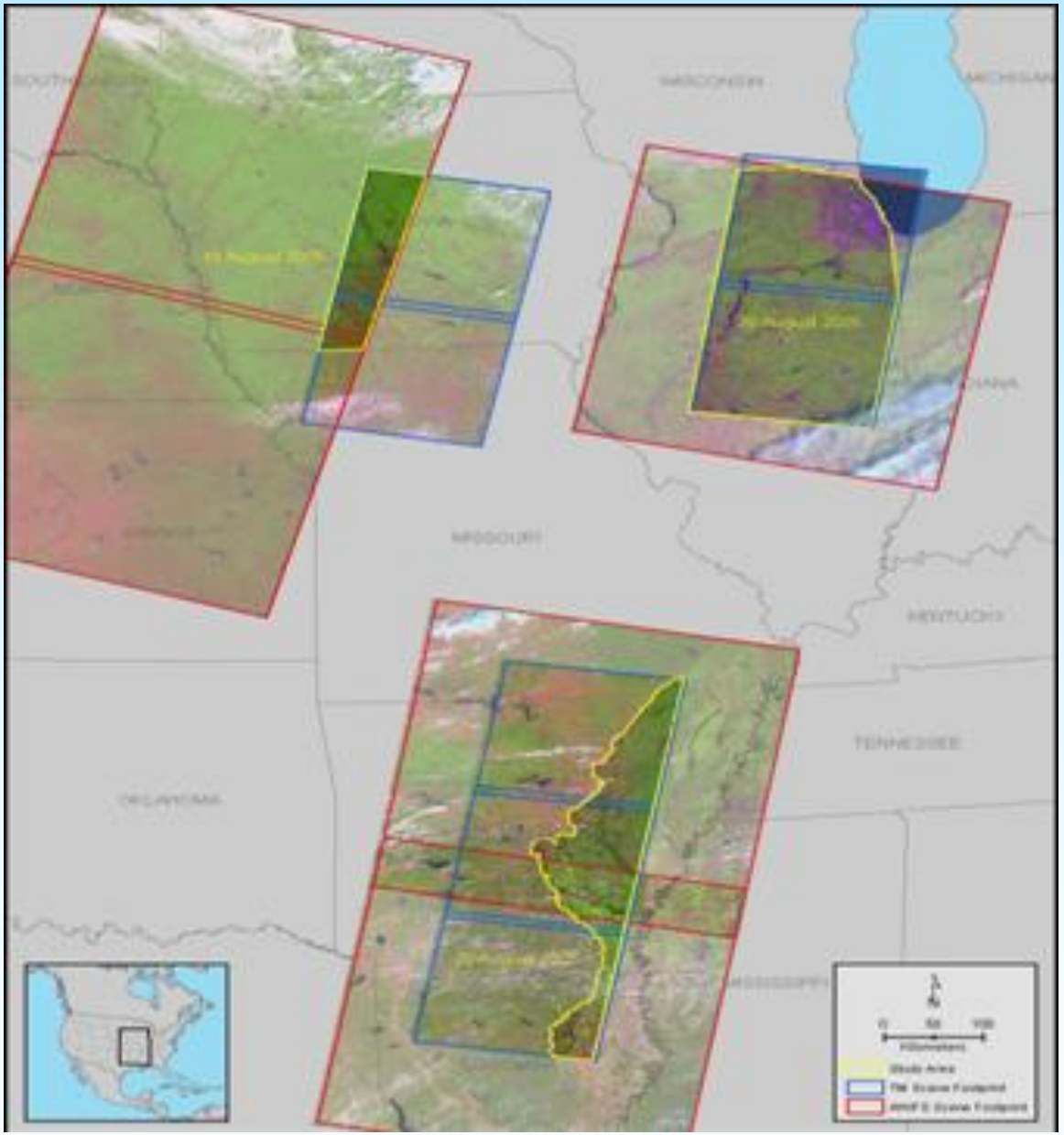




Coincident study sites

Three coincident areas chosen for analysis:

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



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

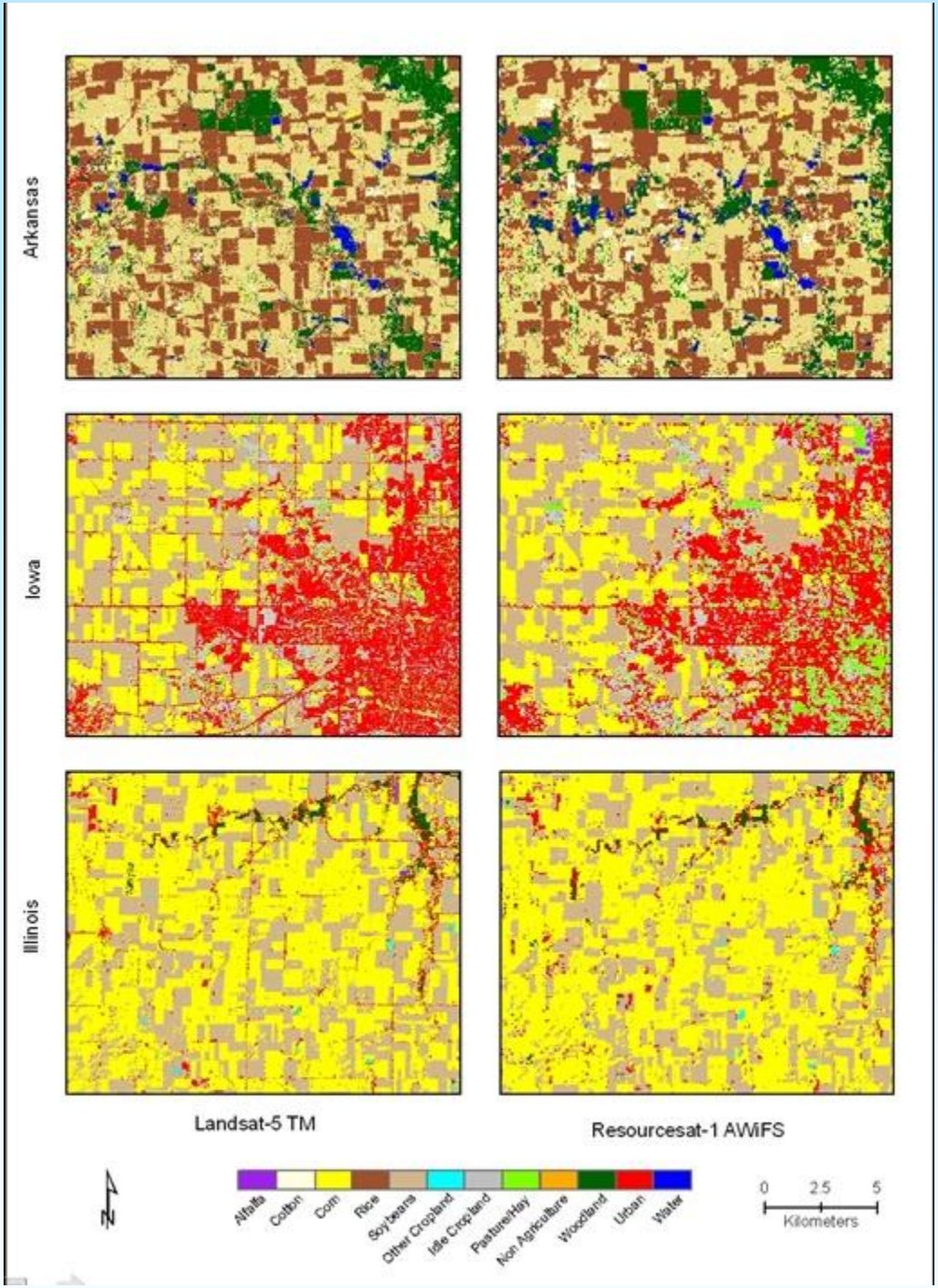
- Clouds
- Haze
- Smoke

Ground conditions

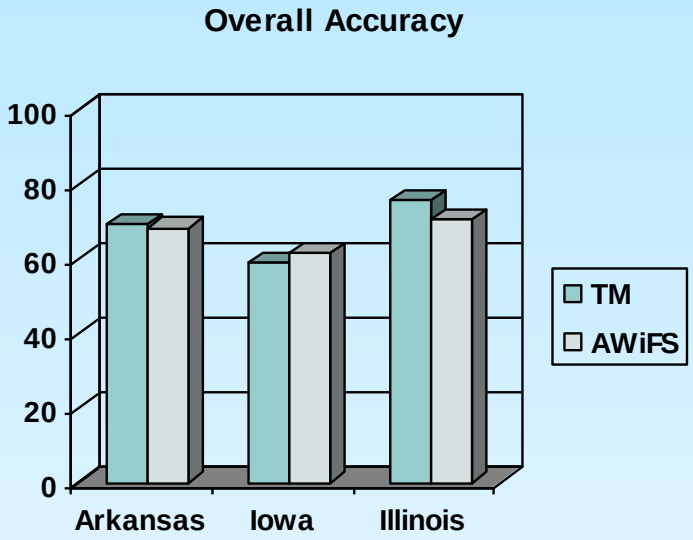
- Soil moisture
- Vegetation phenology

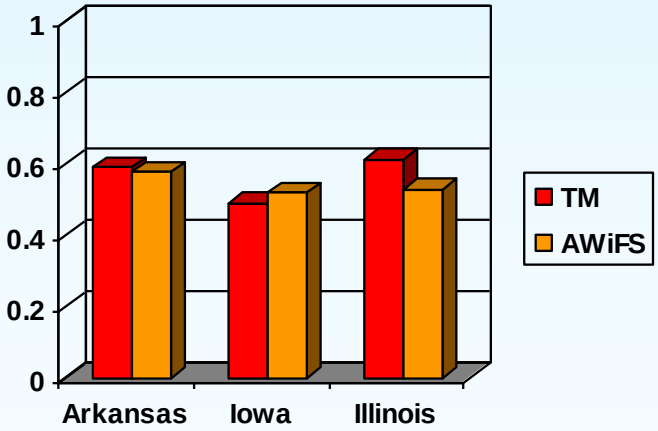
Sun angle

- Seasonal variation


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

Results


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

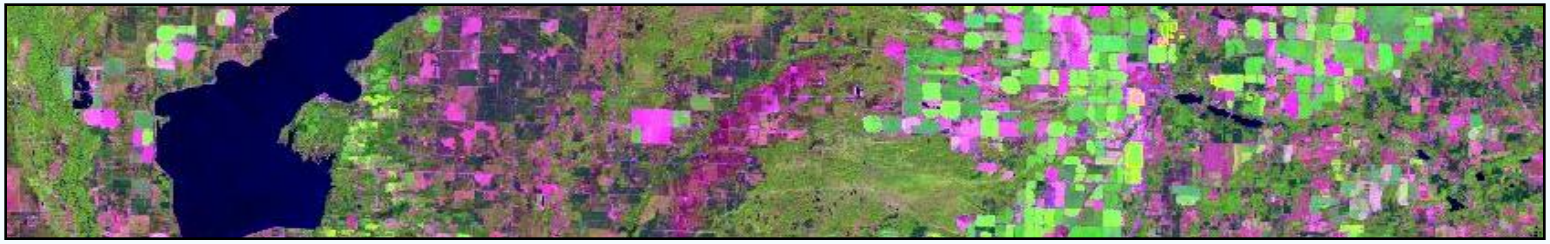
Conclusions:

AWiFS vs. TM evaluations 2004-2005

- AWiFS data are acceptable for crop acreage estimation over large crop areas such as the Midwest, the Delta and the Northern Great Plains.

- Improvements in classification accuracy are achieved due to increased temporal frequency of the AWiFS sensor (5 day) vs. the TM sensor (16 day) repeat cycle.

- The large footprint of the AWiFS sensor provides the opportunity to utilize training and ancillary data over large areas which leads to improved classification accuracies and production efficiencies.



IRS Resourcesat-1 AWiFS Imagery

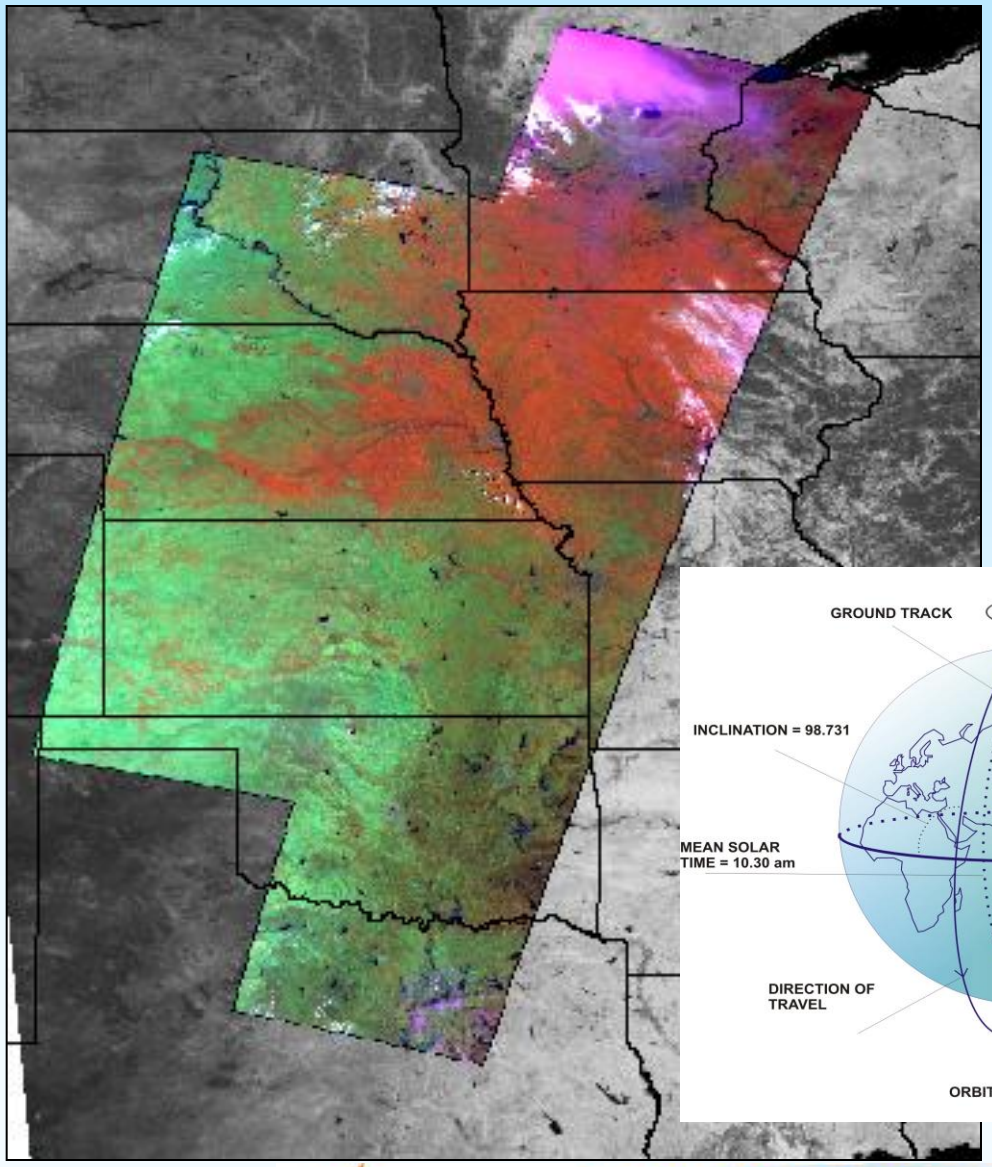
340 km swath per head
740 km combined

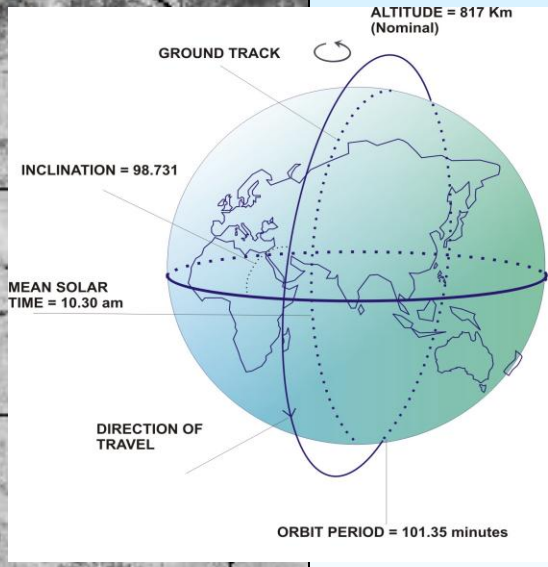
5-day revisit

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





13 Aug 2007

Department of Space
Indian Space Research Organisation

USDA Satellite Image Archive

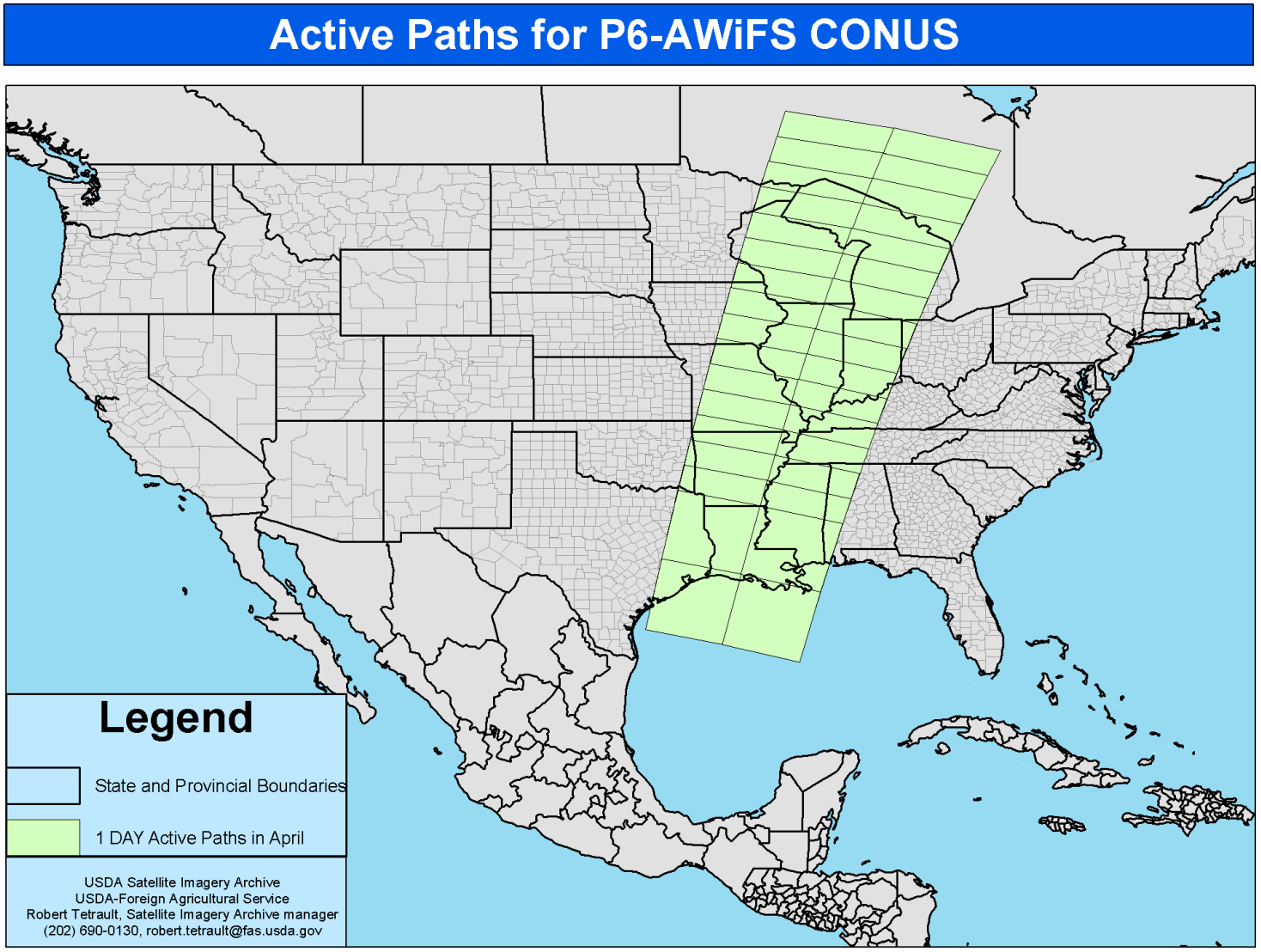
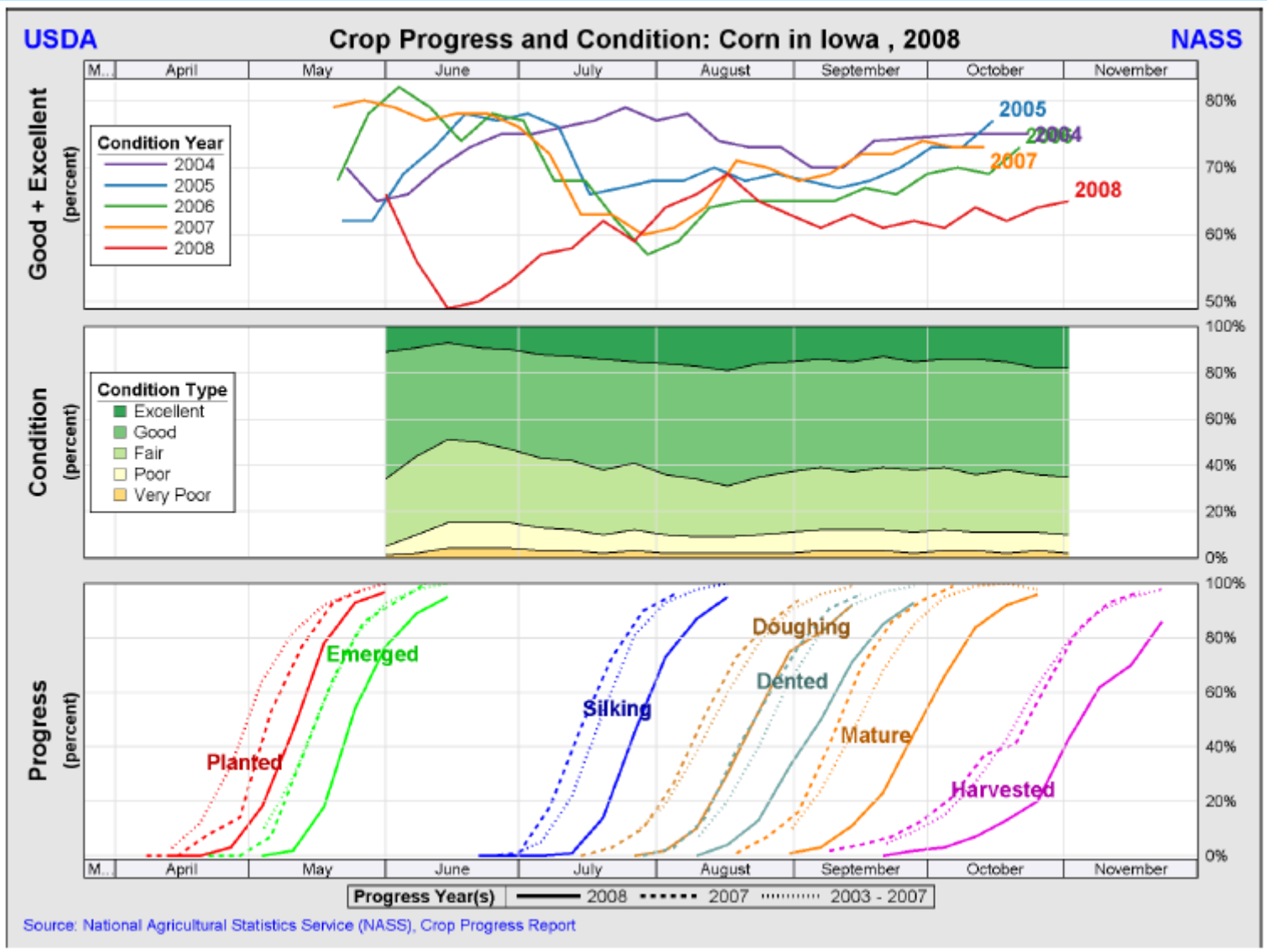
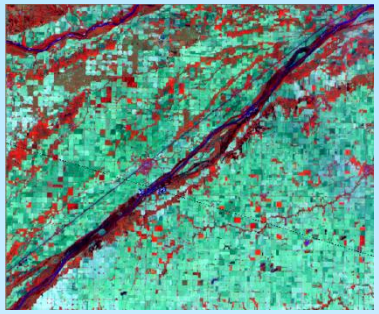


Image Timing

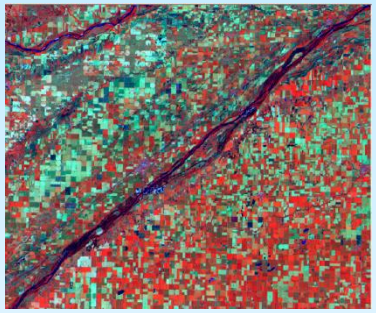


http://www.nass.usda.gov/Charts_and_Maps/Crop_Progress_&_Condition/

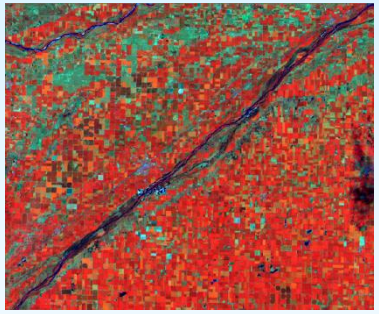
AWiFS Imagery Time Series



May 18



June 21



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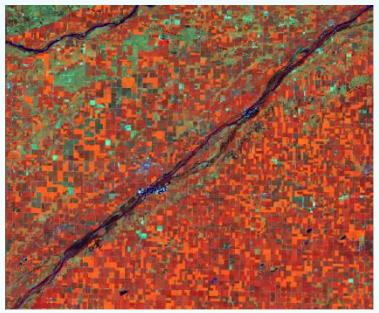

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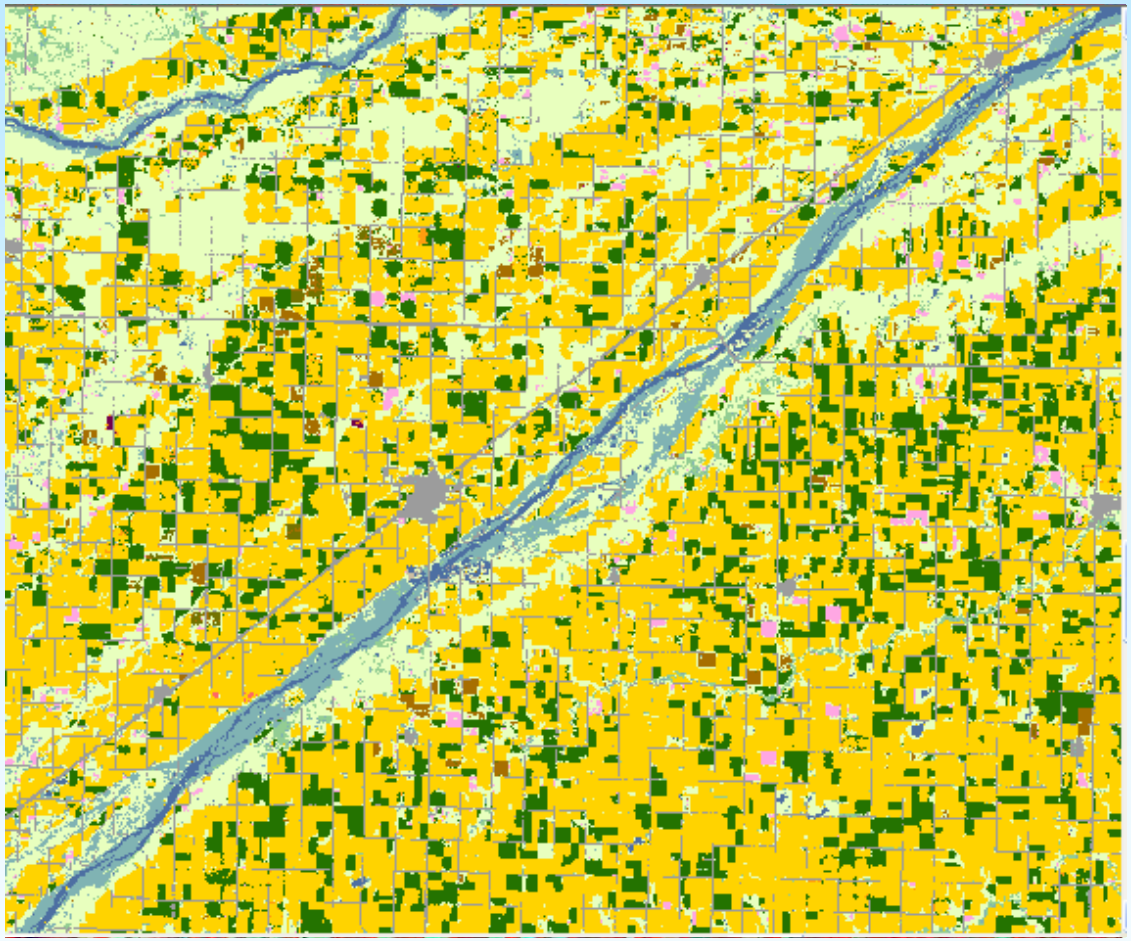
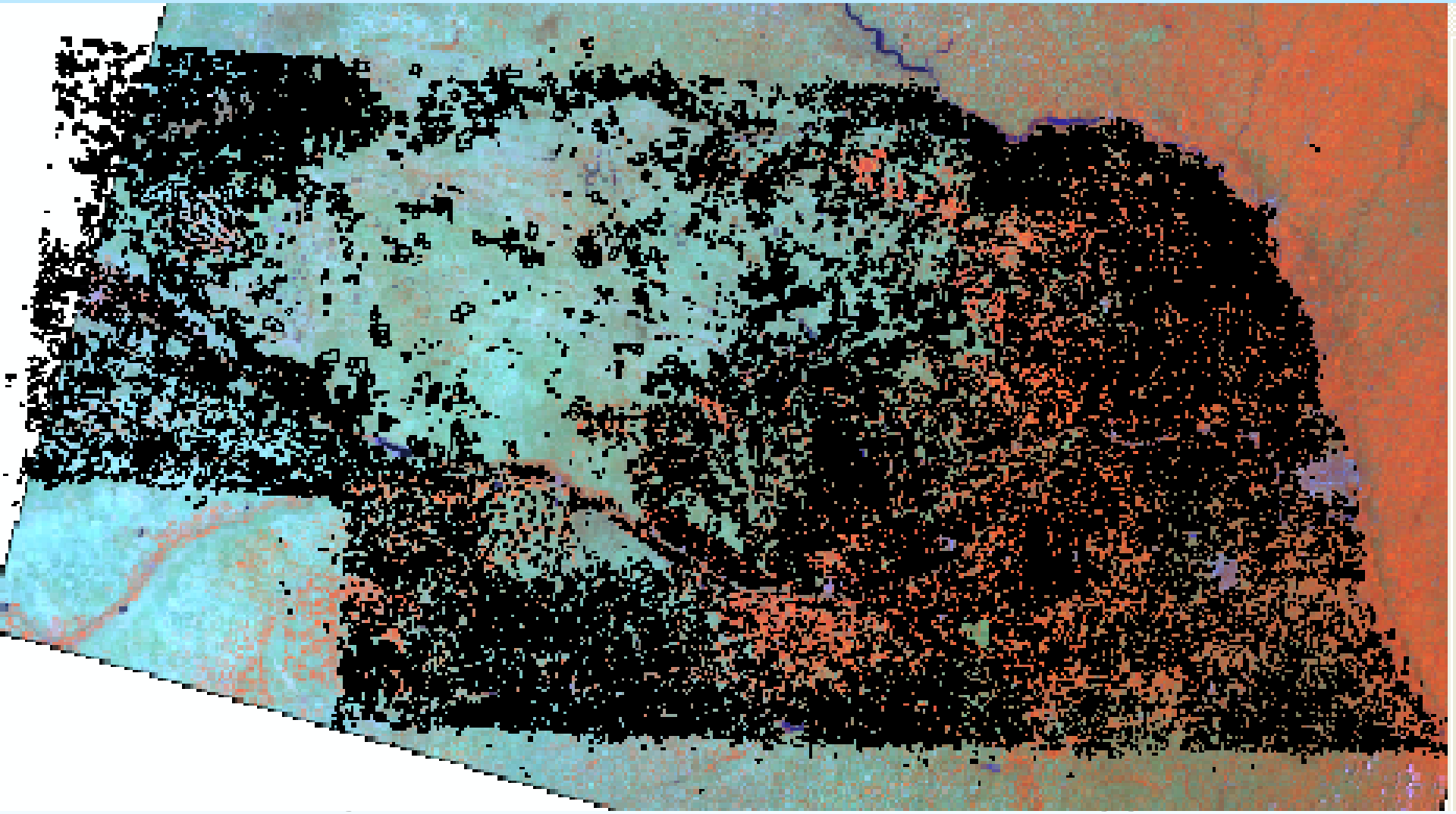


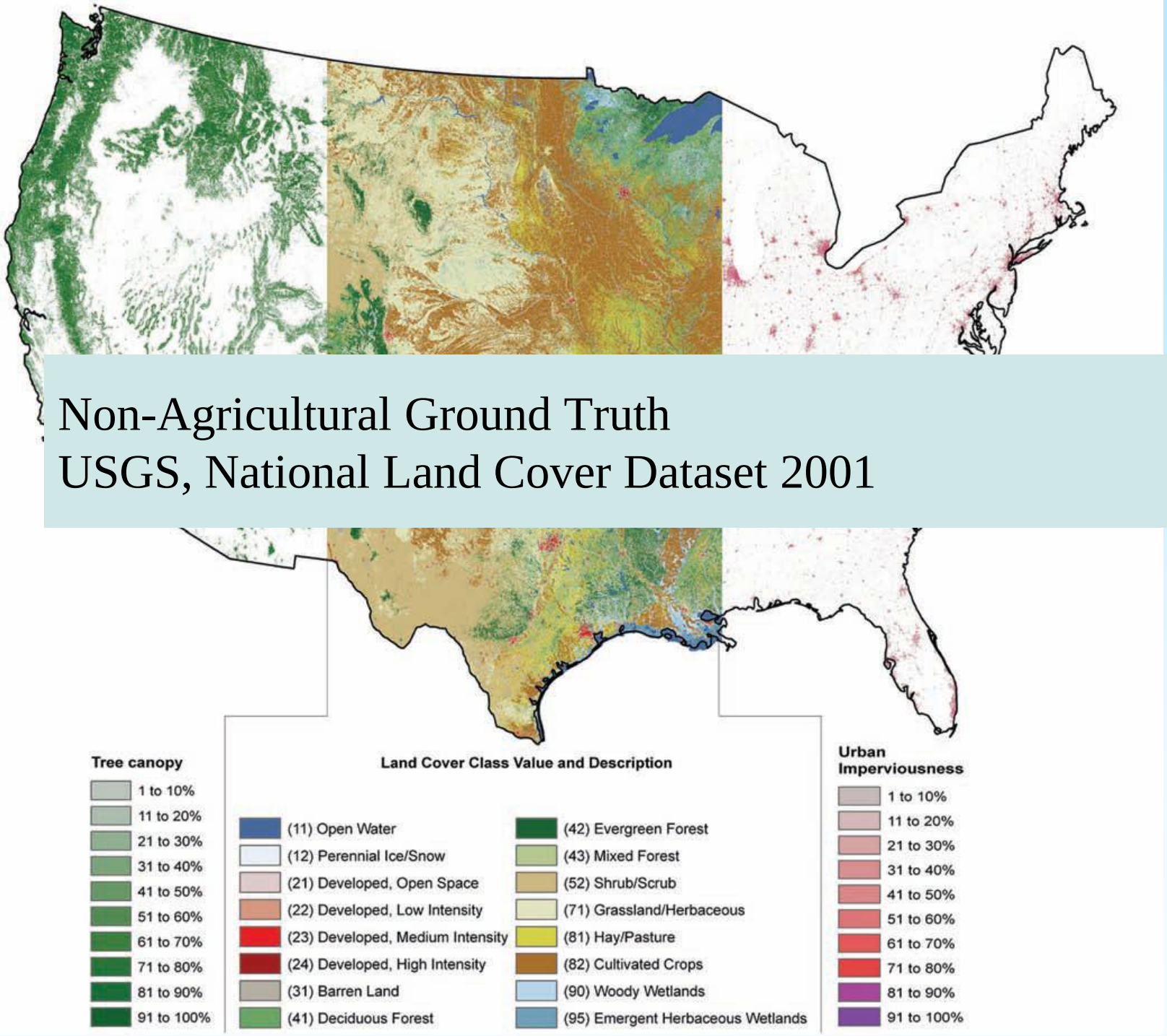
Cropland Data Layer Program Components

- Advanced Wide Field Sensor (AWiFS)
- Ground truth: FSA/CLU + 578 & NLCD
- Ancillary data sets
- Commercial Software Suite
- See5 Decision Tree Methodology
- Estimation

Ground Truth - Agriculture



NASS June Agricultural Survey (JAS) data still
used for acreage estimation

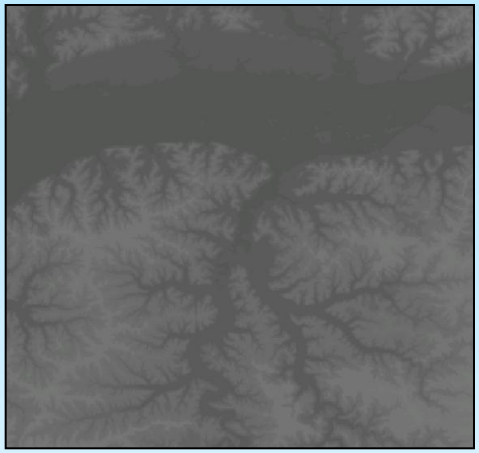


Non-Agricultural Ground Truth
USGS, National Land Cover Dataset 2001

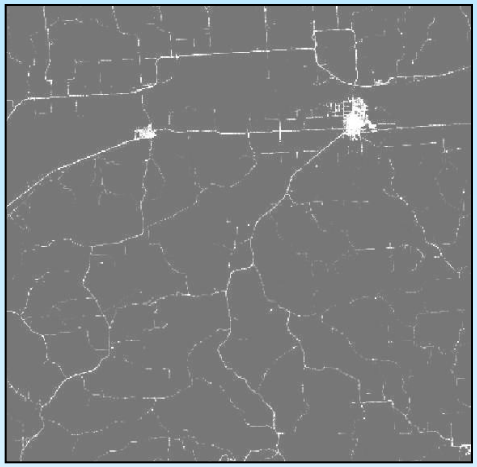
Cropland Data Layer Program Components

- Landsat TM and ETM+ vs. Advanced Wide Field Sensor (AWiFS)
- Ground truth: FSA/CLU + 578 & NLCD
- Ancillary data
- Commercial Software Suite
- See5 Decision Tree Methodology

Ancillary Data – USGS/NASA Products



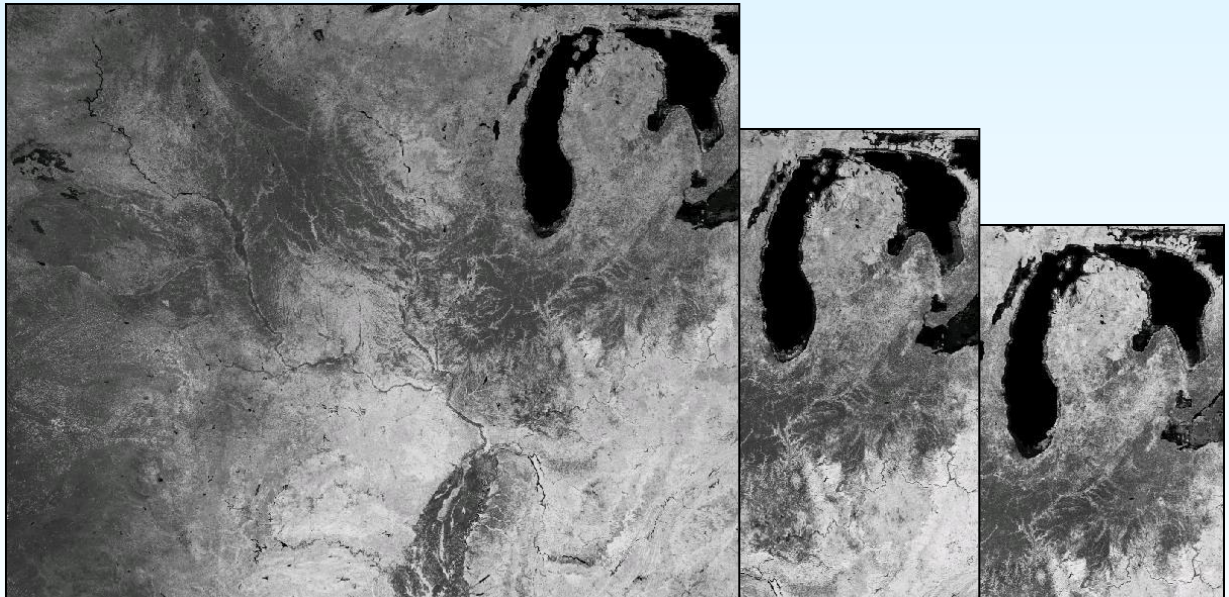
Elevation



Imperviousness

Forest Canopy

NASA MODIS Terra
(16-day NDVI composite)



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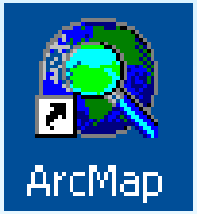
Commercial Software Suite

- Imagery Preparation
  - Leica Geosystems ERDAS Imagine
- Image classification
  - Decision tree software
    - See5.0 www.rulequest.com
- Ground Truth Preparation
  - ESRI ArcGIS
- Acreage Estimation
  - SAS/IML workshop



See5 Decision Tree Classifier

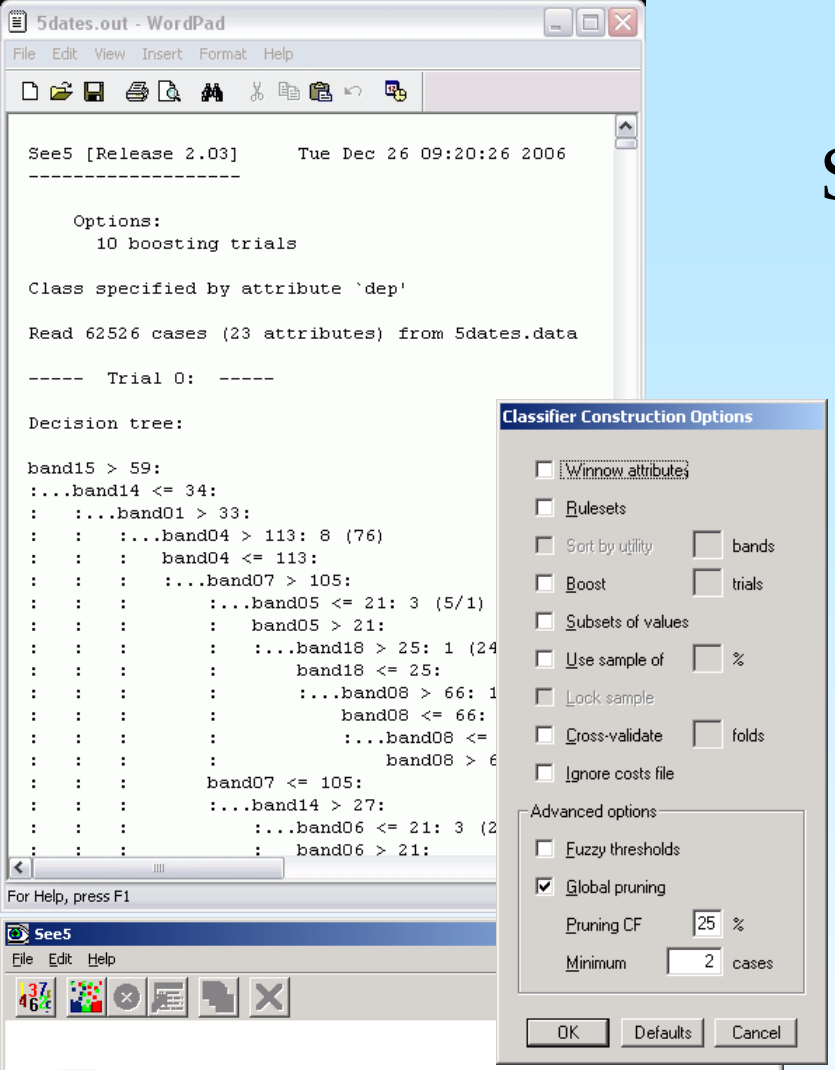
State-of-the-art technique for image classification

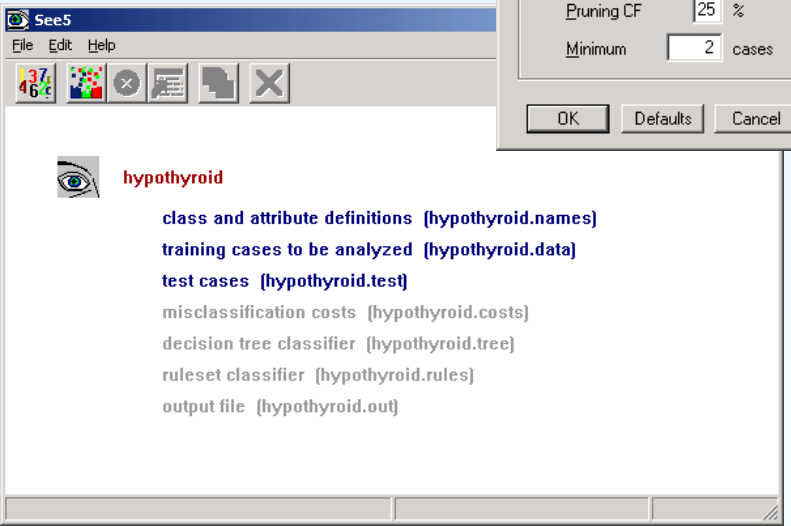
- Relatively cheap ($750)

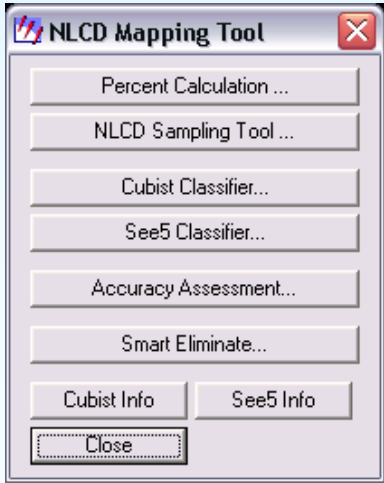
Incorporates a powerful ensemble method known as “boosting”

The “NLCD Mapping Tool” was integrated into ERDAS Imagine

- Provided gratis by USGS







RULEQUEST RESEARCH
data mining tools

Accuracy Assessment

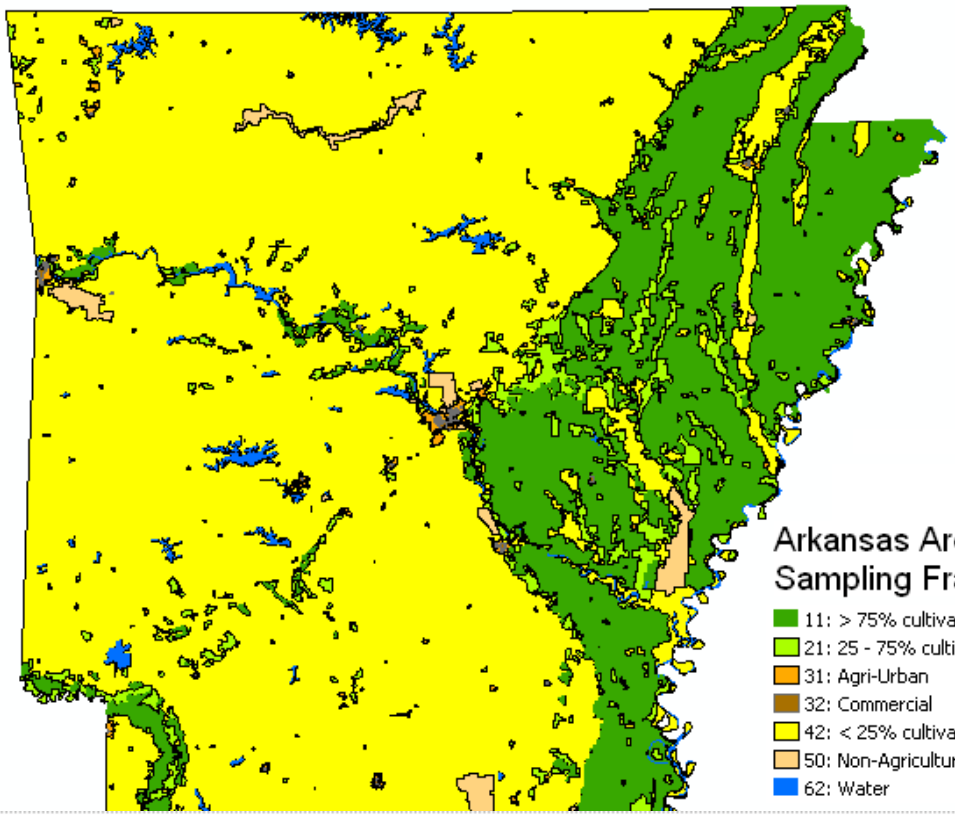
Crop-specific covers only	*Correct	Accuracy	Error	Kappa
OVERALL ACCURACY	740009	93.56%	6.44%	0.8488

Cover Type	Attribute Code	*Correct Pixels	Producer's Accuracy	Omission Error	Kappa	User's Accuracy	Commission Error	Cond'l Kappa
Corn	1	28358	95.36%	4.64%	0.9528	93.08%	6.92%	0.9297
Cotton	2	11757	95.08%	4.92%	0.9505	94.59%	5.41%	0.9456
Rice	3	2	28.57%	71.43%	0.2857	66.67%	33.33%	0.6667
Sorghum	4	21251	89.85%	10.15%	0.8972	92.46%	7.54%	0.9236
Soybeans	5	12885	86.15%	13.85%	0.8604	88.61%	11.39%	0.8851
Sunflowers	6	102	89.47%	10.53%	0.8947	99.03%	0.97%	0.9903
Peanuts	10	512	90.14%	9.86%	0.9014	92.09%	7.91%	0.9208
Barley	21	785	71.95%	28.05%	0.7194	97.39%	2.61%	0.9739
Durum Wheat	22	48	42.86%	57.14%	0.4286	100.00%	0.00%	1.0000
Spring Wheat	23	205	56.47%	43.53%	0.5647	99.03%	0.97%	0.9903
Winter Wheat	24	580437	97.54%	2.46%	0.9631	94.00%	6.00%	0.9117
Other Small Grains	25	1120	56.97%	43.03%	0.5694	93.57%	6.43%	0.9356
Win Wht /Soyb Dbl Crop	26	14758	79.51%	20.49%	0.7932	90.06%	9.94%	0.8996
Rye	27	13249	66.90%	33.10%	0.6664	91.39%	8.61%	0.9129
Oats	28	2941	64.85%	35.15%	0.6479	95.18%	4.82%	0.9517
Millet	29	439	77.02%	22.98%	0.7701	96.48%	3.52%	0.9648
Canola	31	337	75.90%	24.10%	0.7590	98.83%	1.17%	0.9883
Alfalfa	36	19653	88.21%	11.79%	0.8807	91.78%	8.22%	0.9168
Dry Beans	42	115	88.46%	11.54%	0.8846	93.50%	6.50%	0.9350
Potatoes	43	49	96.08%	3.92%	0.9608	100.00%	0.00%	1.0000
Other Crops	44	50	45.87%	54.13%	0.4587	80.65%	19.35%	0.8064
Misc Vegs & Fruits	47	33	54.10%	45.90%	0.5410	86.84%	13.16%	0.8684
Watermelon	48	24	77.42%	22.58%	0.7742	85.71%	14.29%	0.8571
Peas	53	188	72.59%	27.41%	0.7258	96.91%	3.09%	0.9691
Clover/Wildflowers	58	21	36.21%	63.79%	0.3621	75.00%	25.00%	0.7500
Fallow/Idle Cropland	61	30612	69.78%	30.22%	0.6922	90.48%	9.52%	0.9025
Peaches	67	9	36.00%	64.00%	0.3600	100.00%	0.00%	1.0000
Other Tree Nuts & Fruit	71	69	33.82%	66.18%	0.3382	83.13%	16.87%	0.8313

*Correct Pixels represents the total number of independent validation pixels correctly identifed in the error matrix.

Cropland Data Layer Program Components

- Advanced Wide Field Sensor (AWiFS)
- Ground truth: FSA/CLU + 578 & NLCD
- Ancillary data sets
- Commercial Software Suite
- See5 Decision Tree Methodology
- Estimation



PAGE 2

SECTION D - CROPS AND LAND USE ON TRACT

17

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

	FIELD NUMBER	01	02	
1.	Total acres in field	828	828	828
2.	Crop or land use. [*Specify*]			
3.	Occupied farmstead or dwelling	843		
4.	Waste, unoccupied dwellings, buildings and structures, roads, ditches, etc.	---	---	--
5.	Woodland	831	831	831
6.	Pasture — Permanent (not in crop rotation)	842	842	842
		856	856	856

Estimation Components: Area Sampling Frame+ June Ag Survey+ Questionnaire

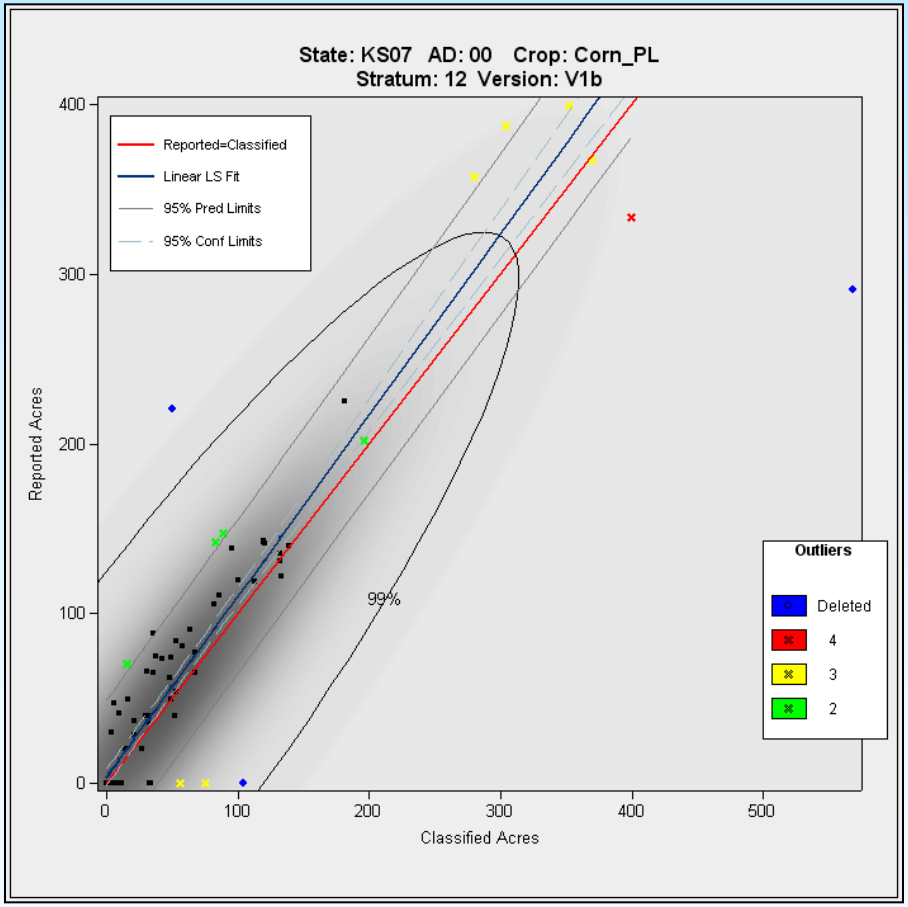
Regression-based Acreage Estimator

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

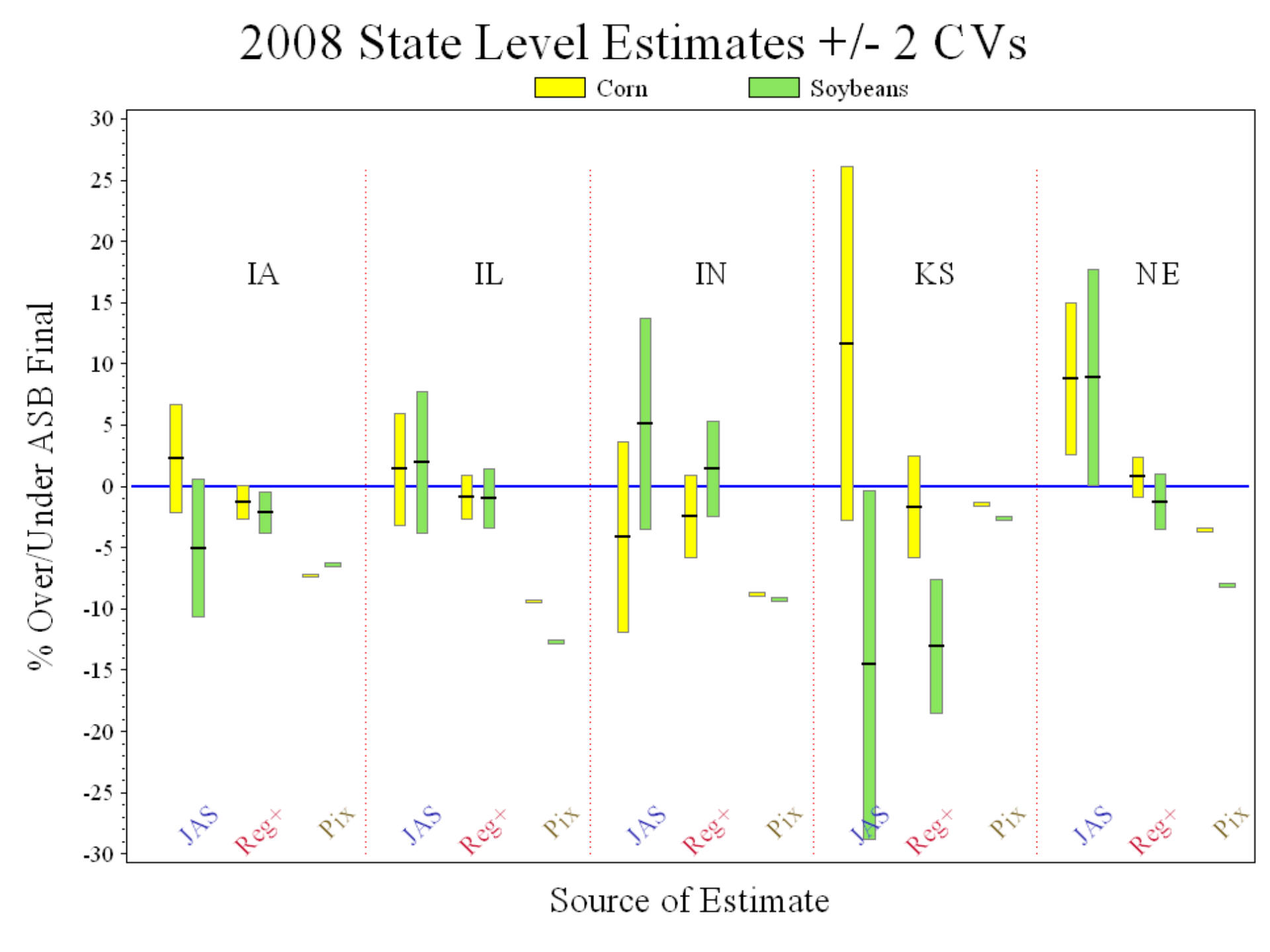
- **(X) – Cropland Data Layer (CDL) classified acres**
- **(Y) – June Agricultural Survey (JAS) reported acres**

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

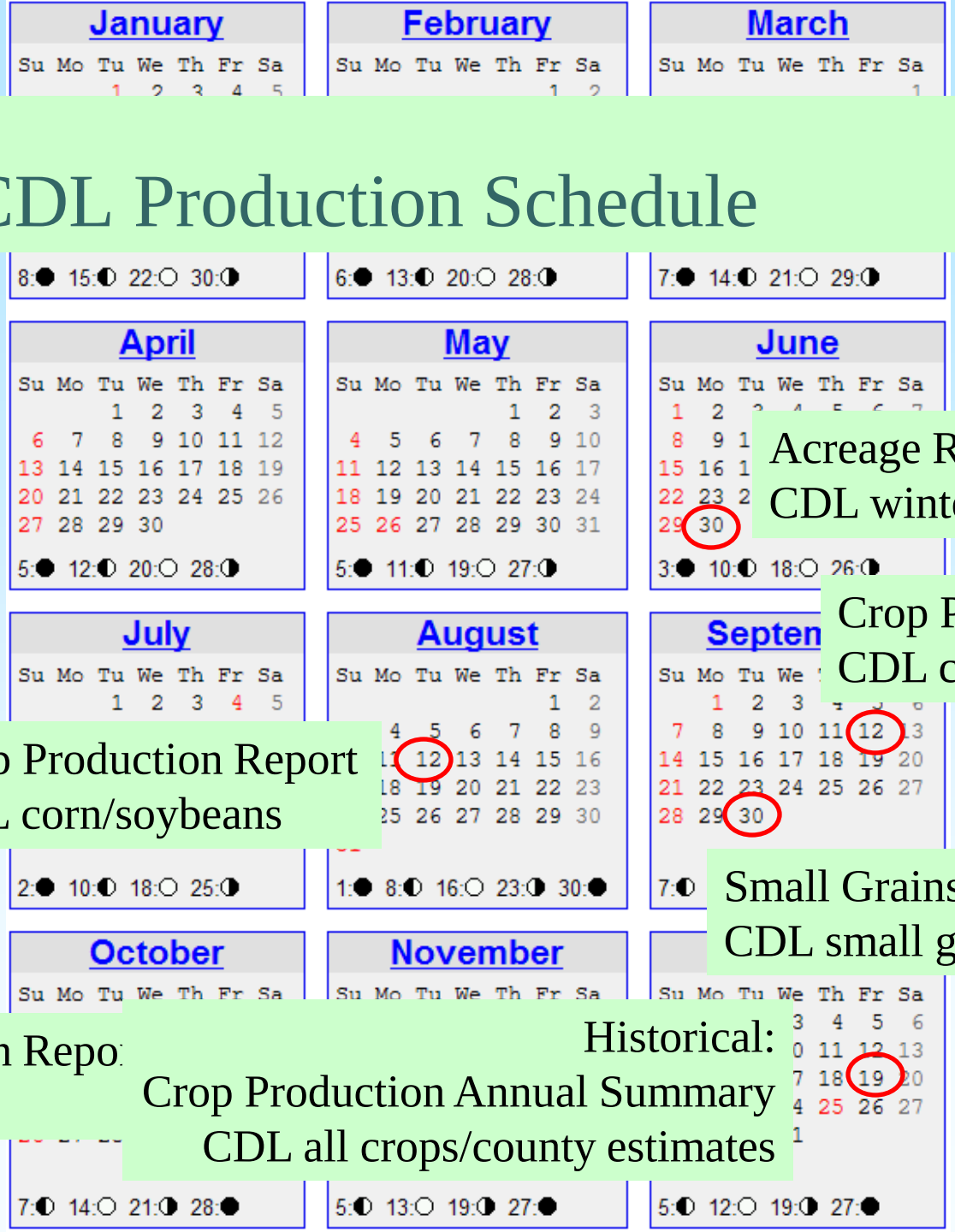
Outlier segment detection - removal from regression analysis



Acreage not just about counting pixels


2008 State Level Estimates +/- 2 CVs
Corn
Soybeans
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
% Over/Under ASB Final
IA
IL
IN
KS
NE
JAS
Reg+
Pix
Source of Estimate

CDL Production Schedule



Acreage Report
CDL winter wheat

Crop Production Report
CDL cotton/rice/peanuts

Crop Production Report
CDL corn/soybeans

Small Grains Annual Summary
CDL small grains

Crop Production Repo
CDL all crops

Historical:
Crop Production Annual Summary
CDL all crops/county estimates

Cropland Data Layer and Acreage Estimation Processing Flow

Input Vector Data

NASS JAS segments

FSA CLU

USGS NLCD

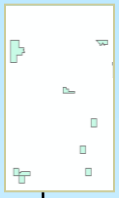
Input Raster Data

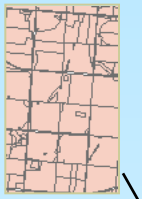
IRS Resourcesat-1 raw AWiFS summer time series

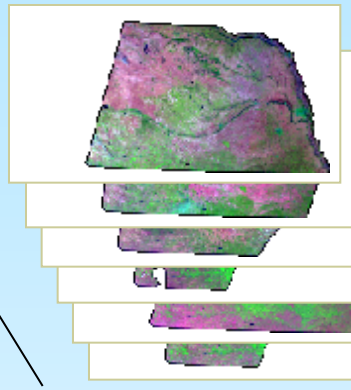
NASA Terra MODIS 16-day NDVI prior fall and summer time series

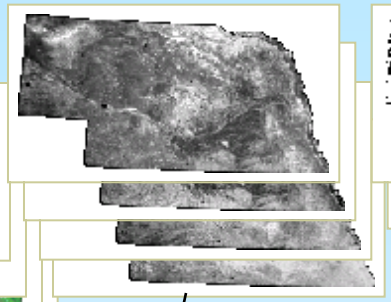
USGS NLCD 2001 Impervious & Canopy

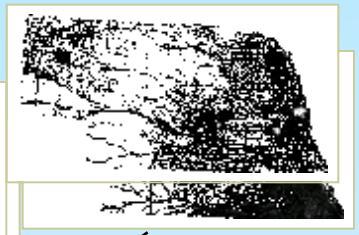
USGS NED Elevation







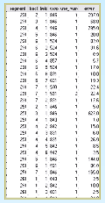


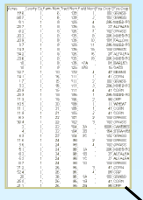


Tabular Data

JAS eData

FSA 578





Non-agricultural Ground truth

ERDAS IMAGINE®

Rulequest See5.0

Derives decision tree-based classification rules

Generated rule set

Manages and visualizes datasets

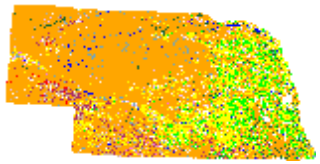
ESRI ArcGIS

Link and assess data sets

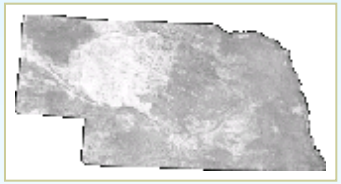
Agricultural Ground truth

ESRI ArcGIS

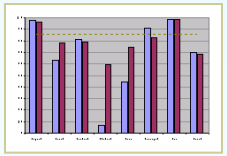
Extract JAS intersecting pixels



-- Cropland Data Layer --



Confidence Layer



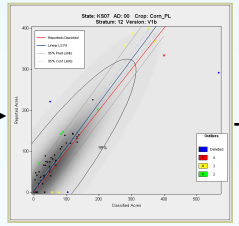
Accuracy Assessment

Diagnostics

Estimation

sas

Customized for acreage estimation



Pixel count vs. reported acreage

State and county crop acreage statistics

NASS Internal Only

Output

Research 2008-2009

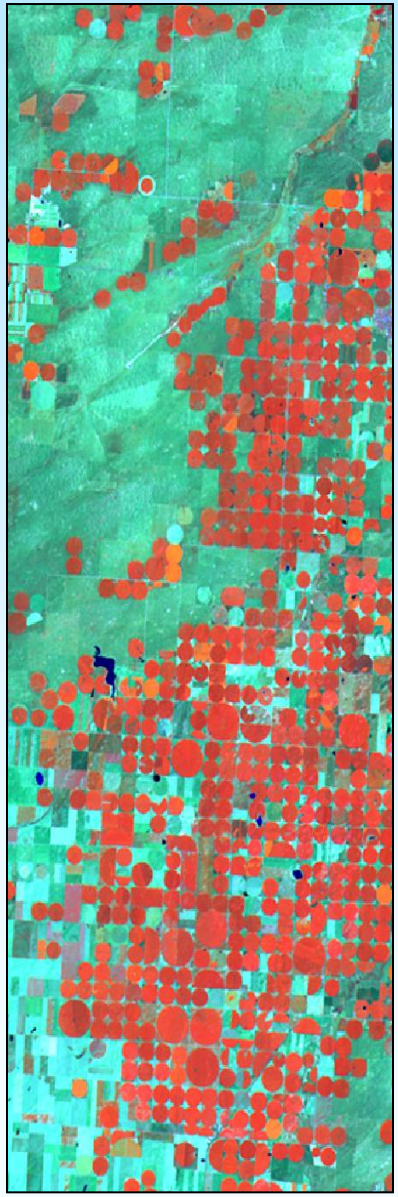
Single Crop Planting Intensity and Crop Rotation Assessment

Goal: To determine the specific counties with high percentages of single crop planting intensity and derive the predominant crop rotation patterns in Nebraska, Iowa and Illinois

Corn

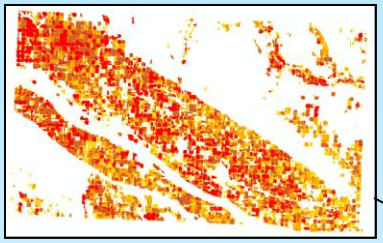
Soybeans

Single Crop Planting Intensity Methodology

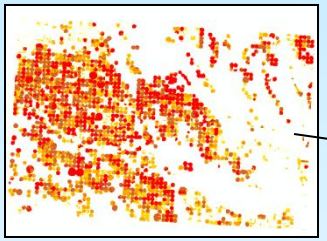


1. Inputs include: Cropland Data Layers (CDLs) for 2004-2008
2. CDLs are recoded such that crop under evaluation =1
3. The recoded CDL's are added together using the ERDAS Imagine Modeler
4. The output is the Crop Intensity Image which is ready for evaluation

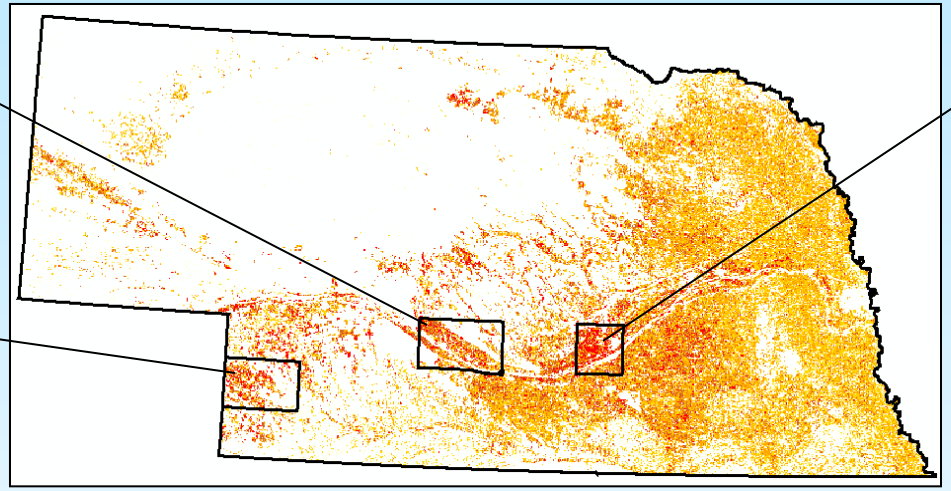
Corn Planting Intensity in Nebraska
2004 - 2008

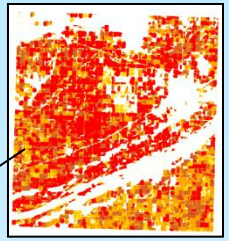


Dawson, NE

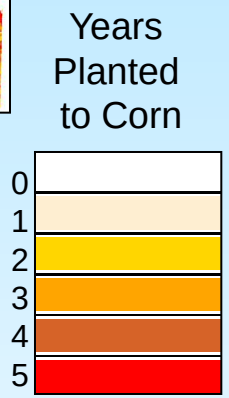


Chase, NE





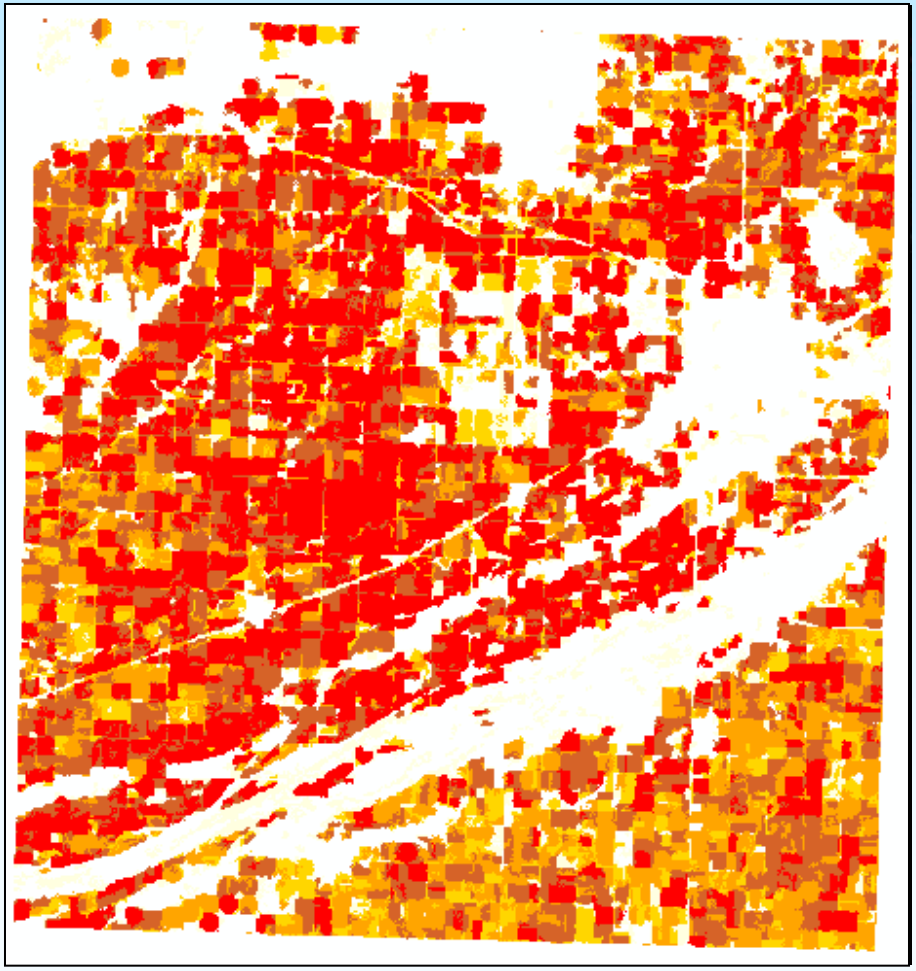
Hall, NE



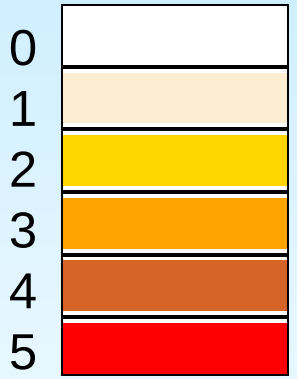
Hall County	Chase County	Dawson County	State Total
5 years in a row planted to corn: 43%	5 years in a row planted to corn: 28%	5 years in a row planted to corn: 21%	5 years in a row planted to corn: 7%
4 out of 5 years planted to corn: 22%	4 out of 5 years planted to corn: 21%	4 out of 5 years planted to corn: 29%	4 out of 5 years planted to corn: 13%

Corn Planting Intensity, 2004 - 2008
Hall County, Nebraska

Hall County
5 years in a row planted to corn: **43%** (5% > than 2003-2007)
4 out of 5 years planted to corn: **22%** (2% < than 2003-2007)



Years Planted to Corn

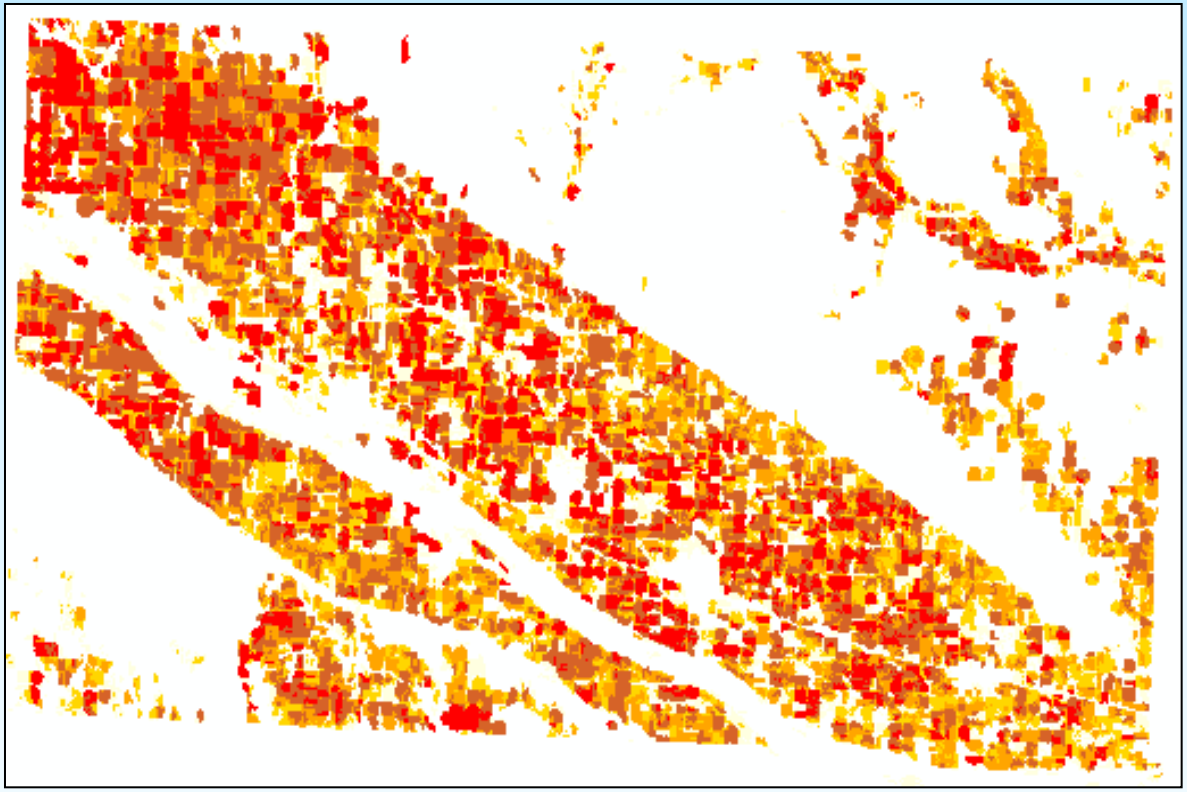


AWiFS 8/13/2007
Bands 3/4/2
Red/Green/Blue

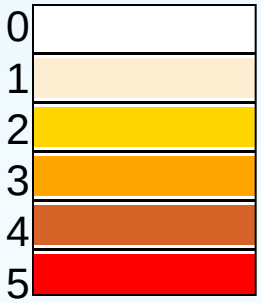
Percentages derived from total acreage in corn production

Corn Planting Intensity, 2004 - 2008
Dawson County, Nebraska

Dawson County
5 years in a row planted to corn: **21%** (1% > than 2003-2007)
4 out of 5 years planted to corn: **29%** (1% > than 2003-2007)

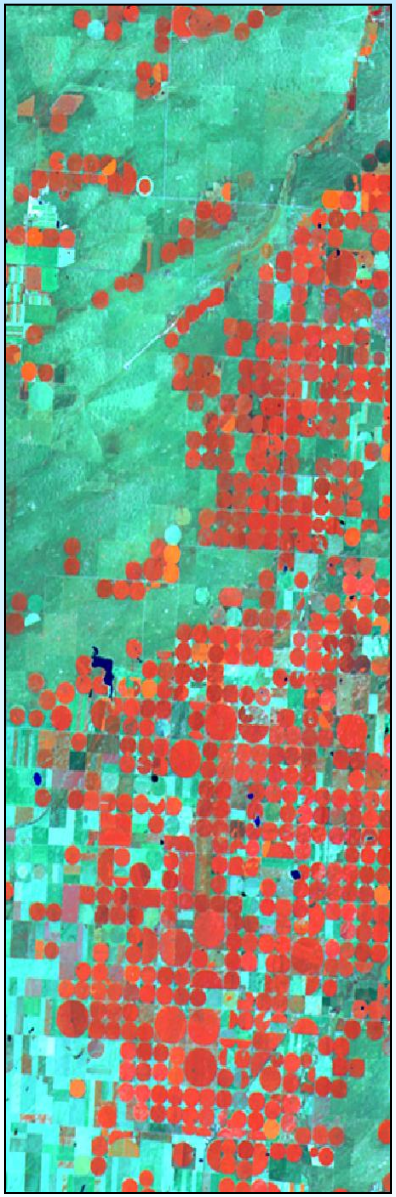


Years Planted to Corn



Percentages derived from total acreage in corn production

AWiFS 8/13/2007
Bands 3/4/2
Red/Green/Blue



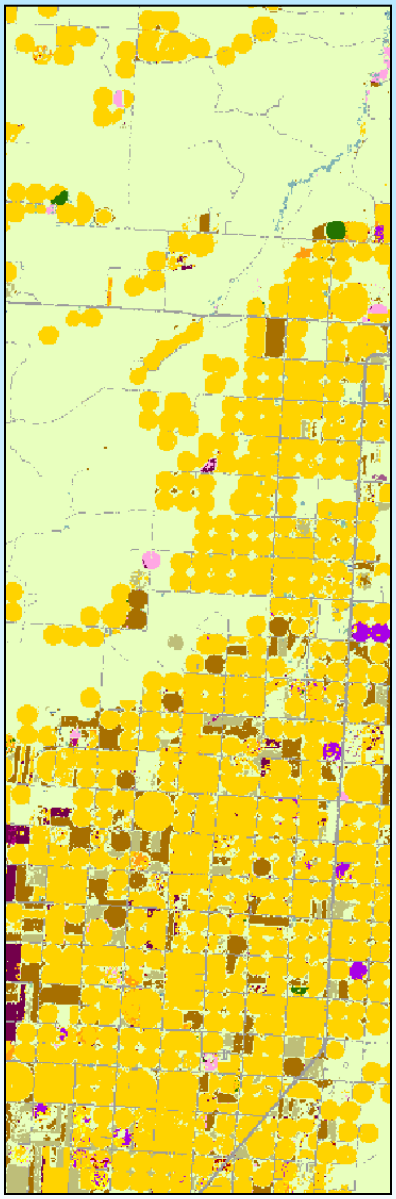
Crop Rotation Methodology

1. Inputs include: Cropland Data Layers (CDLs) for 2004 - 2008

2. CDLs are recoded to
   2008: Corn: 1, Soy: 2, Other: 3
   2007: Corn: 10, Soy: 20, Other: 30
   2006: Corn: 100, Soy: 200, Other: 300
   2005: Corn: 1,000, Soy: 2,000, Other: 3,000
   2004: Corn: 10,000, Soybeans: 20,000, Other: 30,000

3. The recoded CDLs are added together using the ERDAS Imagine Modeler

4. The output is the Crop Rotation Image which is ready for evaluation



Crop Rotation Results
Nebraska

Crop Rotation Patterns (Corn and Soybean) 04- 08
As Percentage of
Total Cultivated Cropland

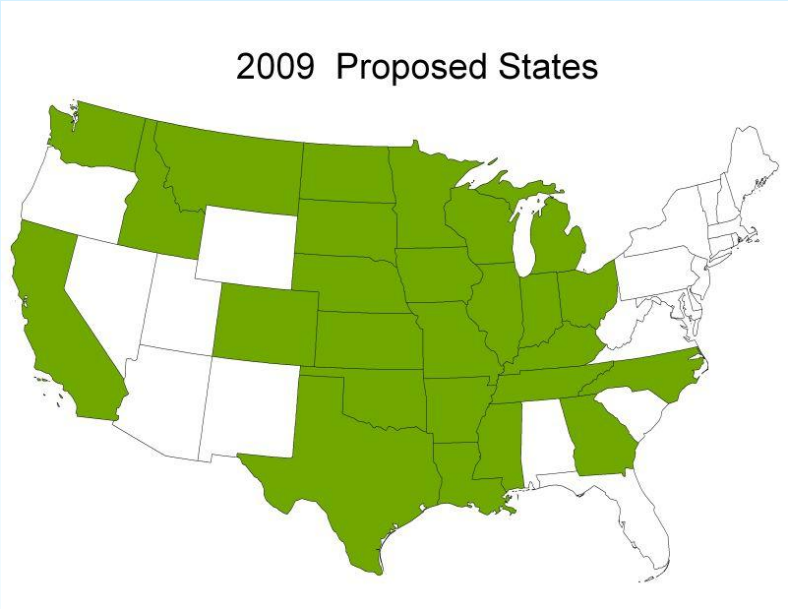
Corn (04), Soy (05), Corn (06), Soy (07), Corn (08)	**10.1%**
Soy (04), Corn (05), Soy (06), Corn (07), Soy (08)	**9.3%**
Corn (04), Corn (05), Corn (06), Corn (07), Corn (08) (.3% < than 2003-2007)	**7.5%**
Additional acreage into corn production (07):	**309,688 acres**
Additional acreage into corn production (08):	**503,221 acres**

Total Cultivated Cropland derived from NASS' Nebraska 2008 CDL

Cropland Data Layer Summary

- **Operational Program since 2007**
  - Early delivery of estimates, 2008 and 2009
    - Winter Wheat – June
    - Corn and Soybeans – August & October
    - Small Grains – September
  - Provides measureable statistical error
  - Results considered for setting national acreage estimate

- **Components**
  - AWiFS/MODIS/Landsat TM
  - Farm Service Agency
    - Common Land Unit (training/testing)
  - Commercial Software
  - June Agricultural Survey
    - Regression estimator



- **Distribution**
  - datagateway.nrcs.usda.gov
  - http://www.nass.usda.gov/Research_and_Science/

Thank You

Claire Boryan, Rick Mueller, Mike Craig, Dave Johnson, Bob Seffrin, Patrick Willis, Larry Beard, Zhengwei Yang and Lee Ebinger

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