Satellite Remote Sensing Imagery Quality and Timeliness: Considerations for Use in Regional Estimation of Crop Production

USDA United States Department of Agriculture
National Agricultural Statistics Service

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BLS Data Quality Workshop, December 1, 2017
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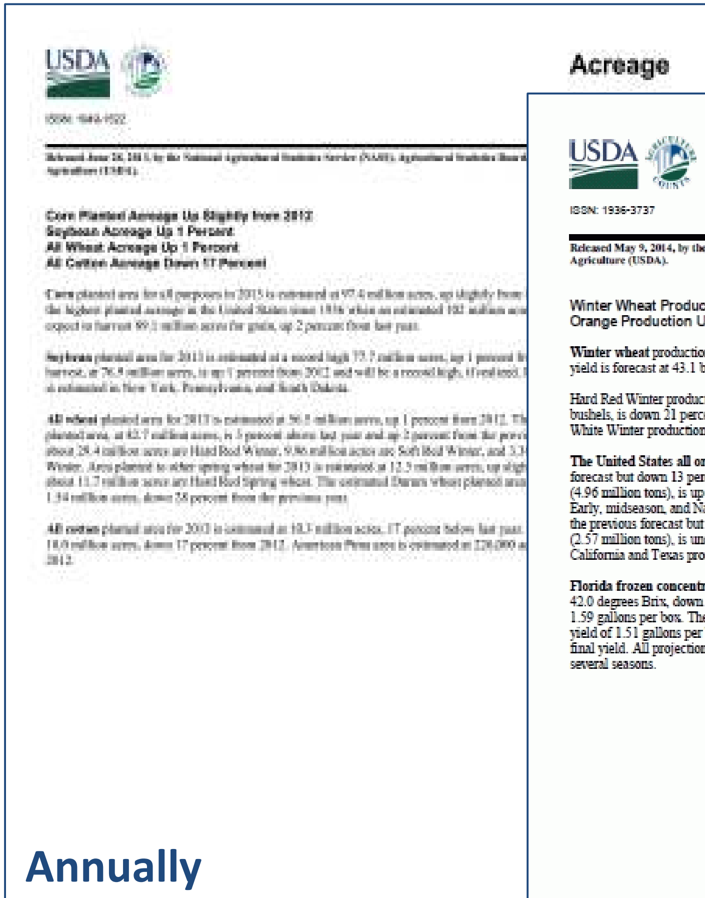
Most popular crop reports from NASS



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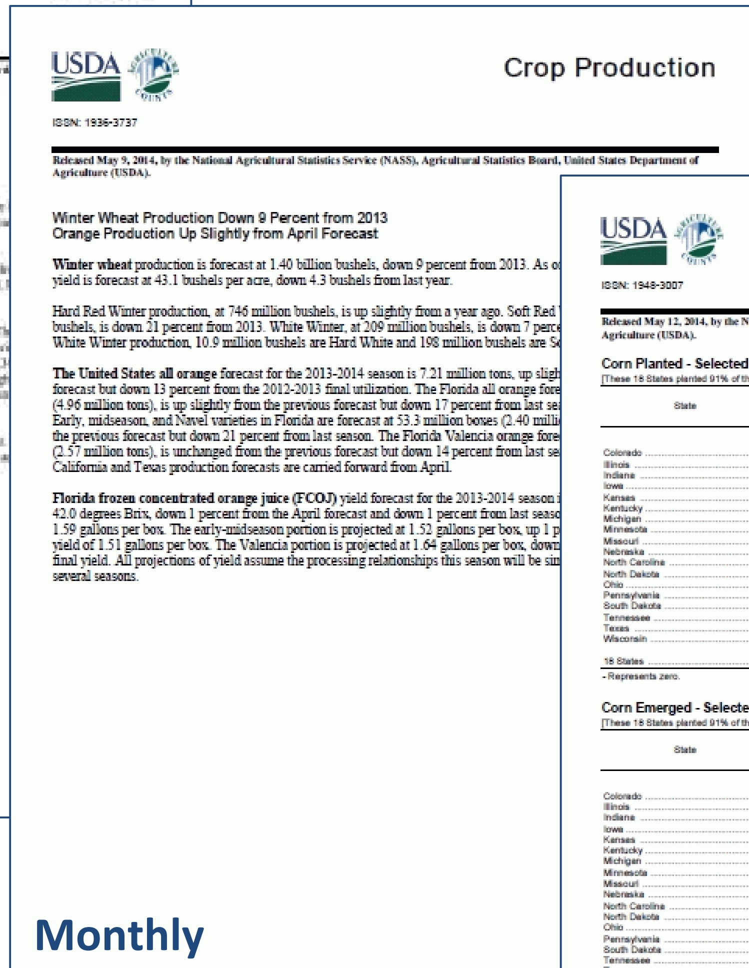

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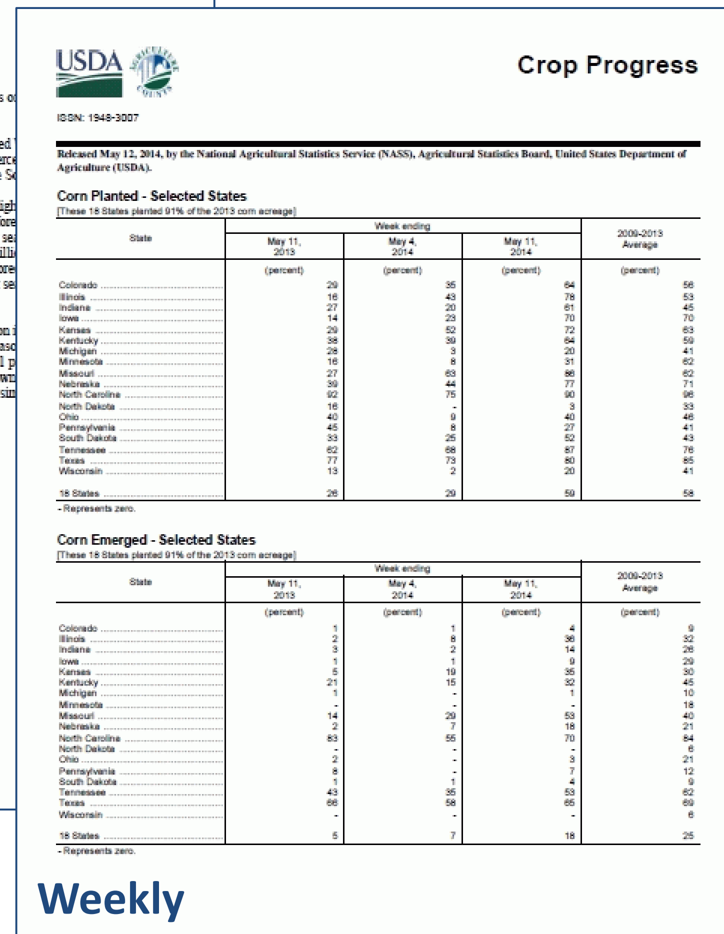

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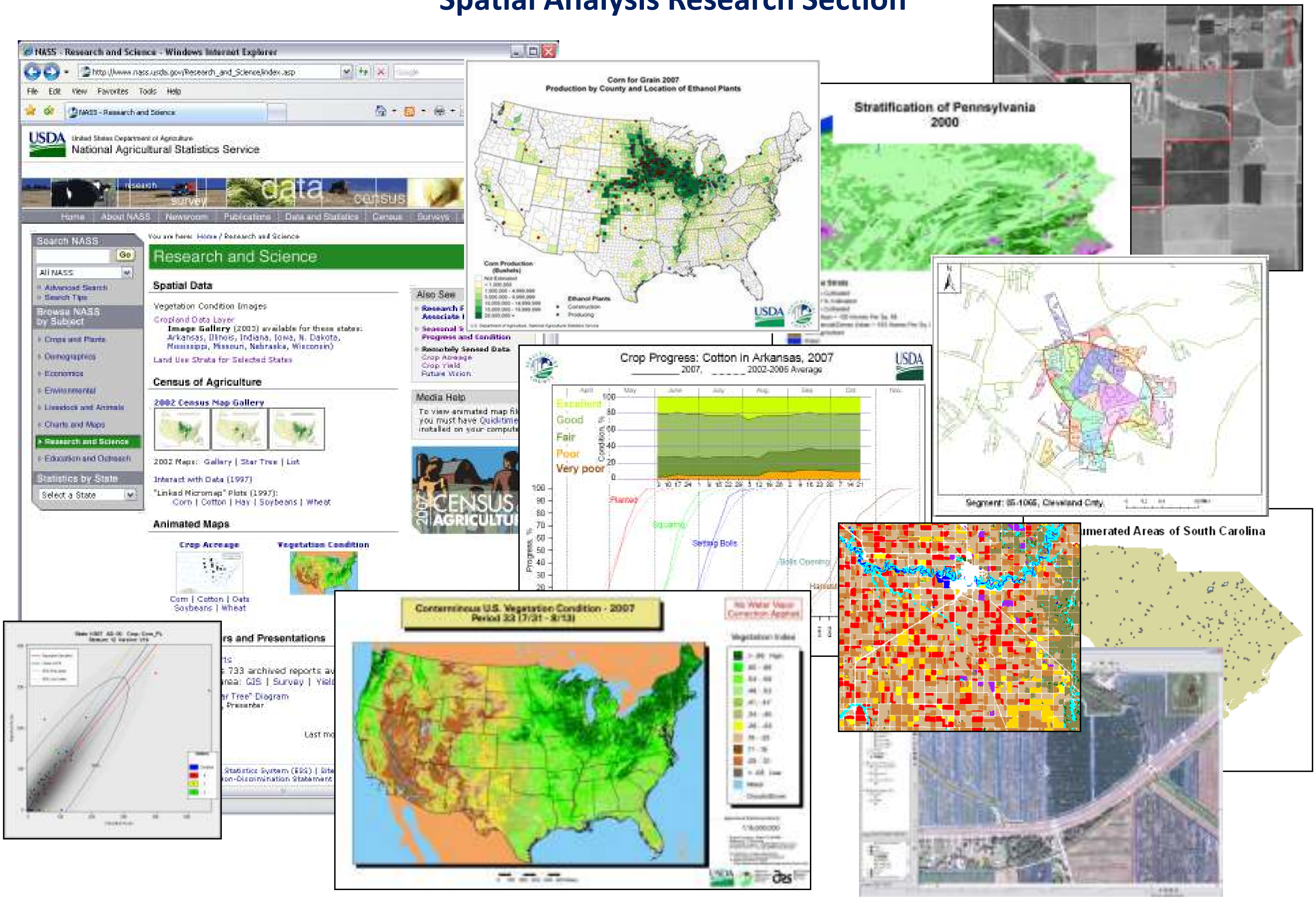
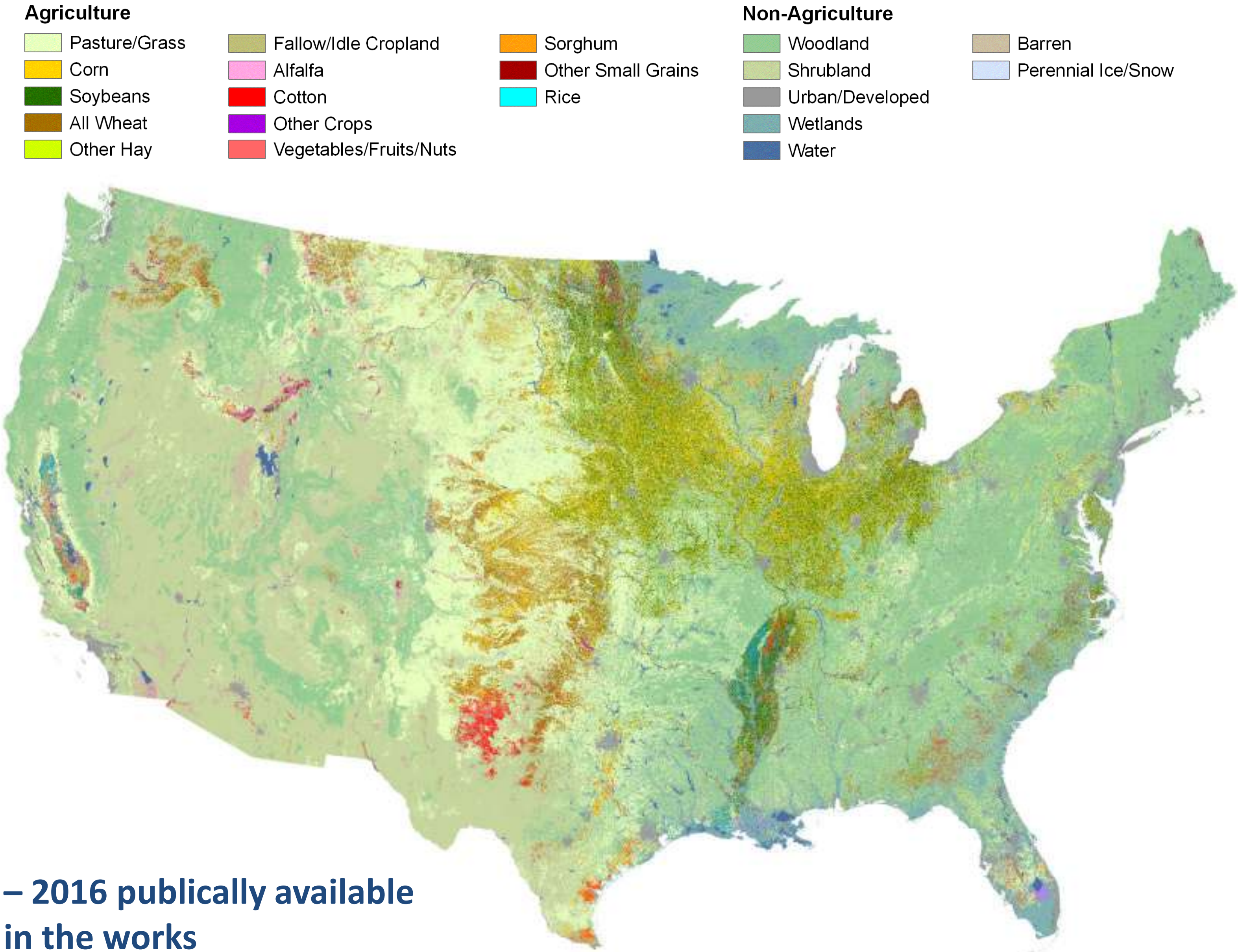
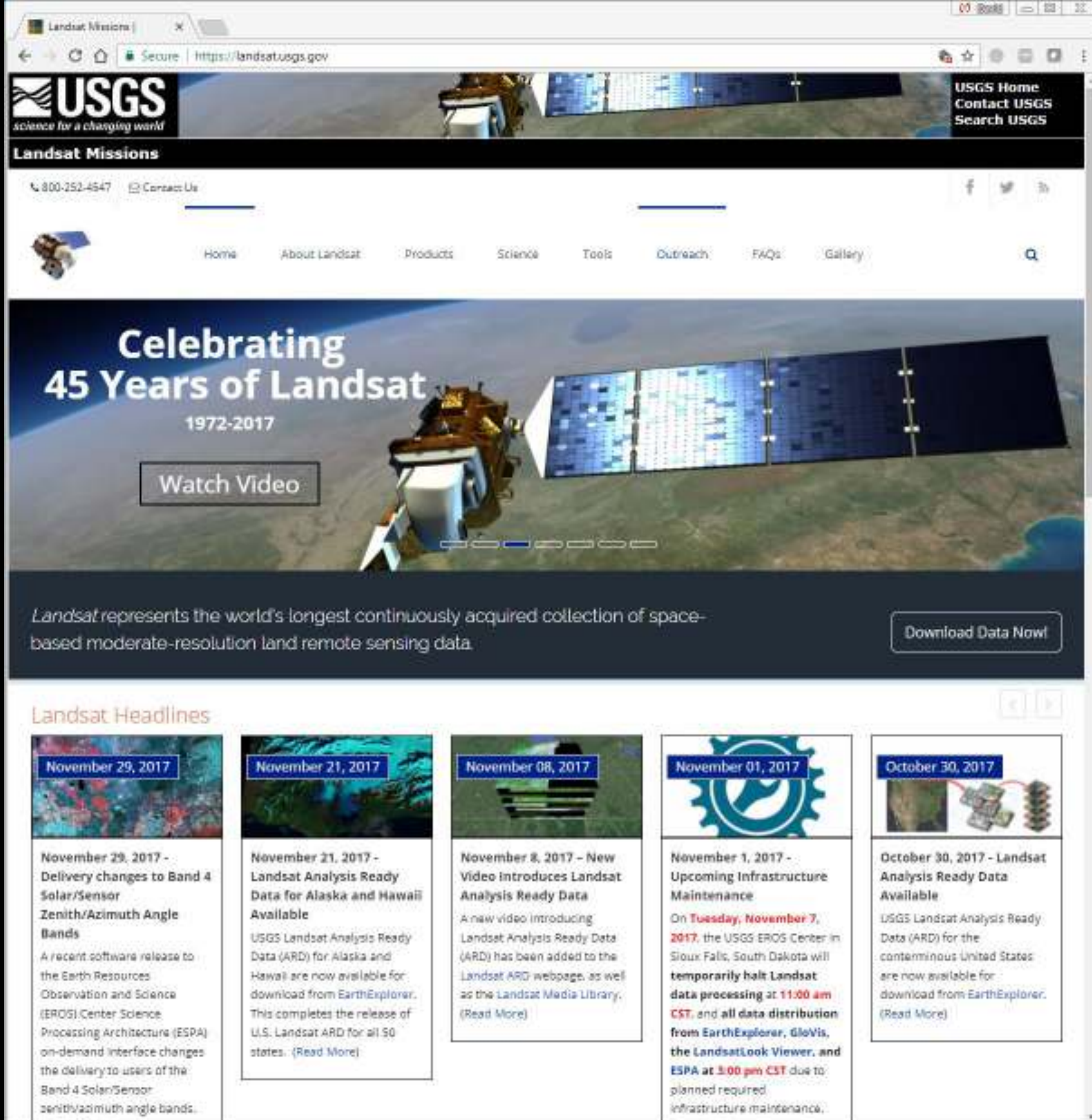


Land cover mapping - Cropland Data Layer (CDL)



*** 2008 – 2016 publically available**
*** 2017 in the works**
*** 2008 and 2009 being reprocessed from 56m to 30m**



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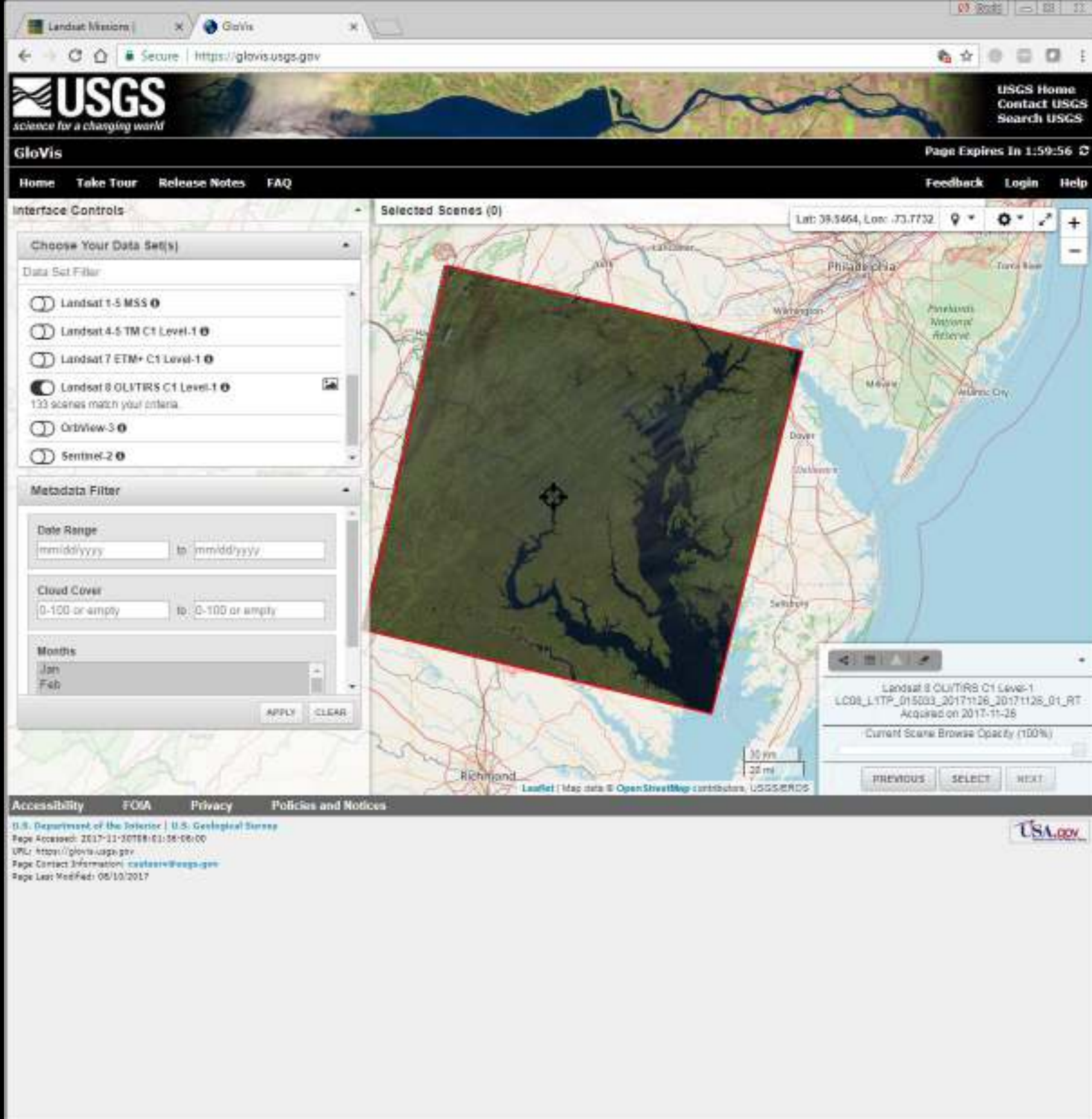
Landsat Headlines
November 29, 2017
November 29, 2017 - Delivery changes to Band 4 Solar/Sensor Zenith/Azimuth Angle Bands
A recent software release to the Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) on-demand interface changes the delivery to users of the Band 4 Solar/Sensor zenith/azimuth angle bands.
November 21, 2017
November 21, 2017 - Landsat Analysis Ready Data for Alaska and Hawaii Available
USGS Landsat Analysis Ready Data (ARD) for Alaska and Hawaii are now available for download from EarthExplorer. This completes the release of U.S. Landsat ARD for all 50 states. (Read More)
November 08, 2017
November 8, 2017 – New Video Introduces Landsat Analysis Ready Data
A new video introducing Landsat Analysis Ready Data (ARD) has been added to the Landsat ARD webpage, as well as the Landsat Media Library. (Read More)
November 01, 2017
November 1, 2017 - Upcoming Infrastructure Maintenance
On Tuesday, November 7, 2017, the USGS EROS Center in Sioux Falls, South Dakota will temporarily halt Landsat data processing at 11:00 am CST, and all data distribution from EarthExplorer, GloVis, the LandsatLook Viewer, and ESPA at 3:00 pm CST due to planned required infrastructure maintenance.
October 30, 2017
October 30, 2017 - Landsat Analysis Ready Data Available
USGS Landsat Analysis Ready Data (ARD) for the conterminous United States are now available for download from EarthExplorer. (Read More)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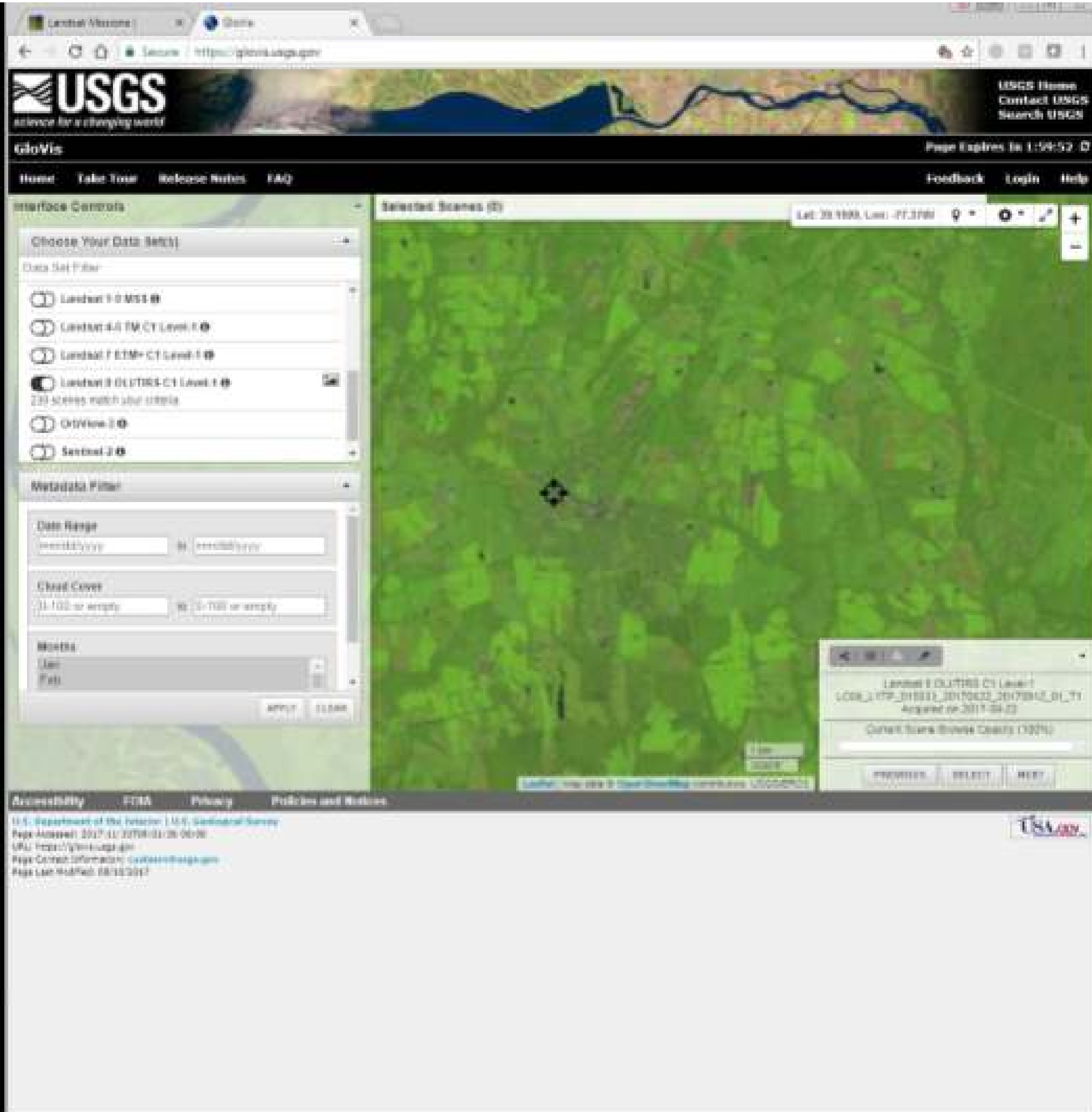
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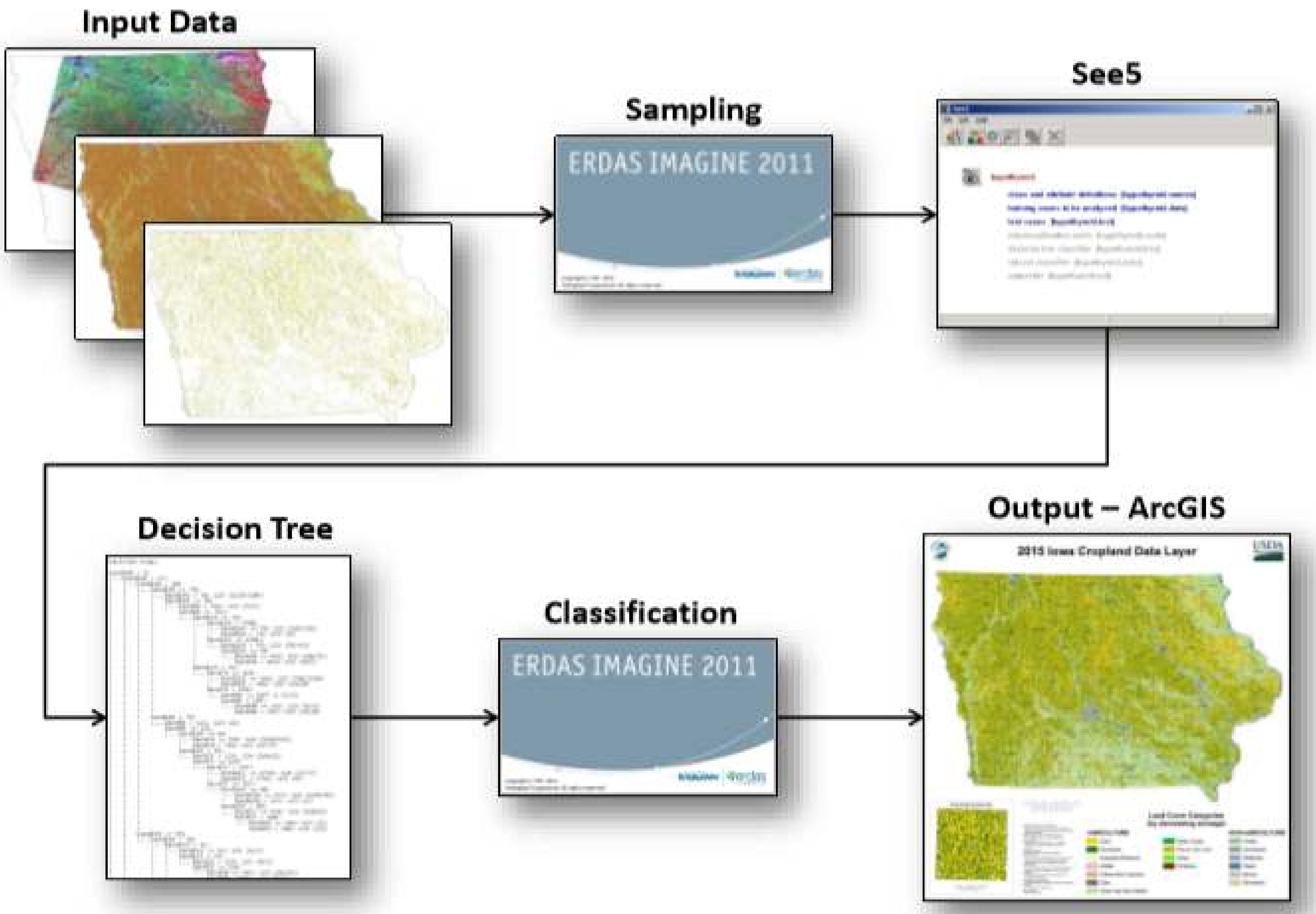
2017: June 16 – 22

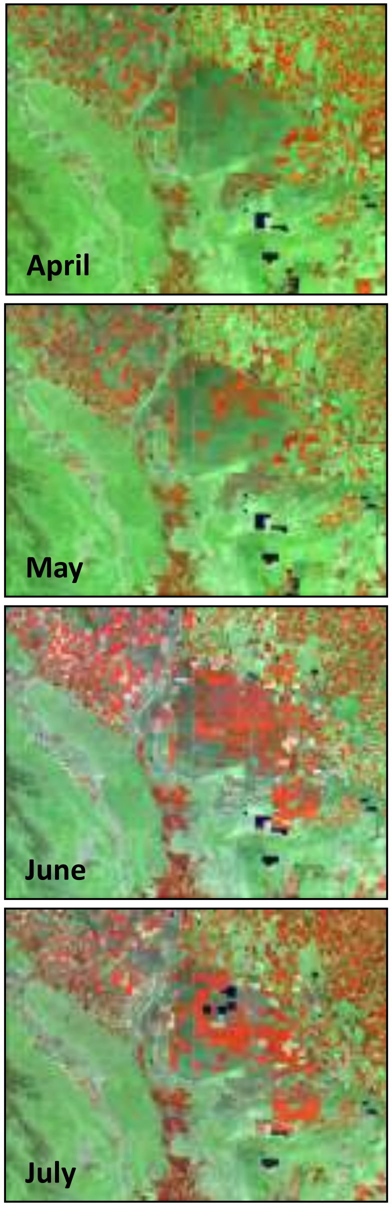
Available satellite imagery 2017: June 16 – 22

CDL Processing Flow

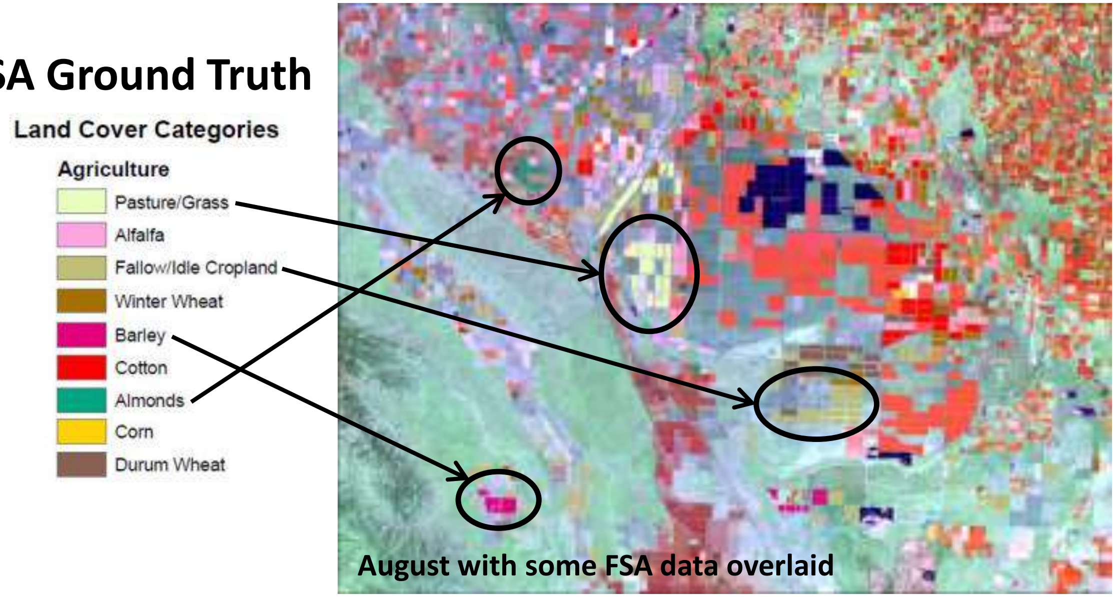


Classification

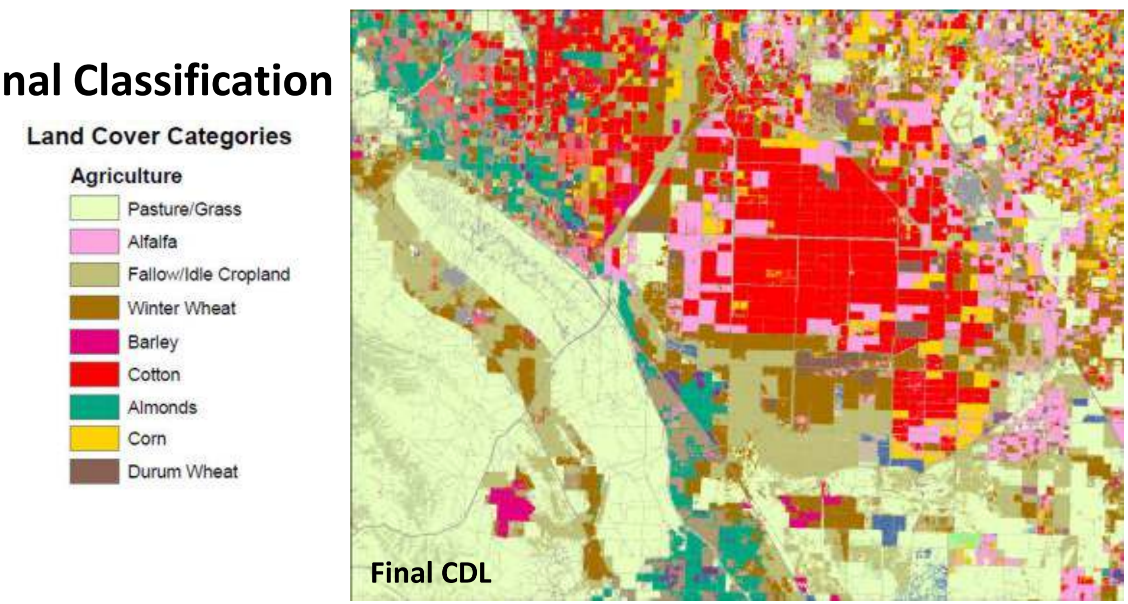
False Color IR Imagery



FSA Ground Truth



Final Classification



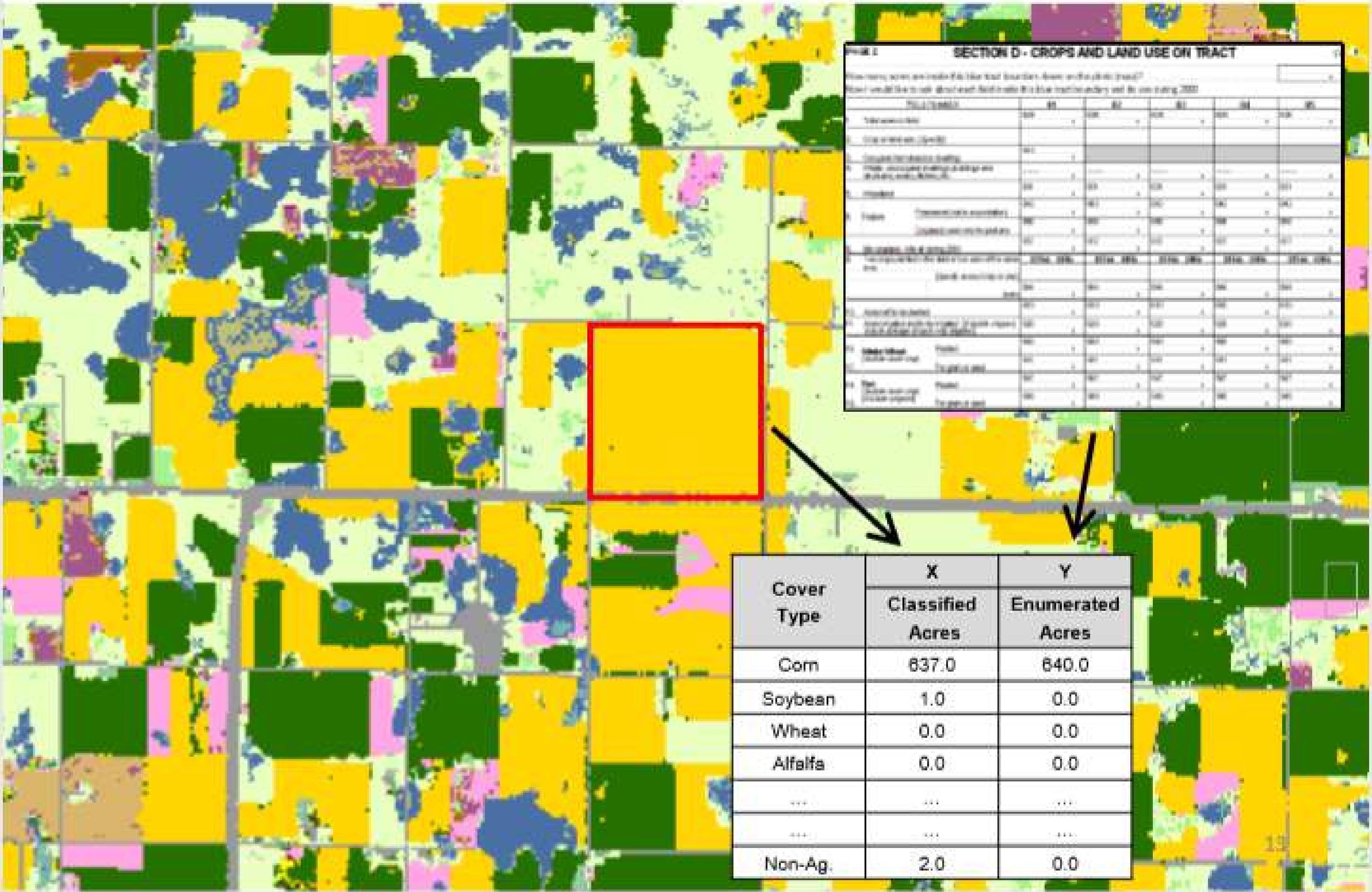
Accuracy Assessments

USDA, National Agricultural Statistics Service, 2014 Colorado Cropland Data Layer
STATEWIDE AGRICULTURAL ACCURACY REPORT

Crop-specific covers only	*Correct	Accuracy	Error	Kappa
OVERALL ACCURACY**	2,630,488	85.5%	14.5%	0.812

Cover Type	Attribute Code	*Correct Pixels	Producer's Accuracy	Omission Error	Kappa	User's Accuracy	Commission Error	Cond'l Kappa
Corn	1	419737	90.76%	9.24%	0.895	90.22%	9.78%	0.889
Sorghum	4	83214	62.32%	37.68%	0.611	64.72%	35.28%	0.635
Soybeans	5	1058	43.25%	56.75%	0.432	72.47%	27.53%	0.724
Sunflower	6	5760	39.64%	60.36%	0.395	70.61%	29.39%	0.705
Barley	21	7176	71.52%	28.48%	0.715	81.00%	19.00%	0.810
Winter Wheat	24	1100020	93.26%	6.74%	0.905	94.21%	5.79%	0.918
Millet	29	75109	67.86%	32.14%	0.671	76.85%	23.15%	0.762
Alfalfa	36	196153	89.75%	10.25%	0.891	85.60%	14.40%	0.848
Other Hay/Non Alfalfa	37	84626	63.33%	36.67%	0.624	85.92%	14.08%	0.854
Sugarbeets	41	4679	63.13%	36.87%	0.631	90.28%	9.72%	0.903
Dry Beans	42	9406	62.72%	37.28%	0.626	69.54%	30.46%	0.694
Potatoes	43	6104	89.74%	10.26%	0.897	93.79%	6.21%	0.938
Fallow/Idle Cropland	61	625989	88.08%	11.92%	0.855	89.23%	10.77%	0.869

Classified area vs June enumerated



Cover Type	X	Y
	Classified Acres	Enumerated Acres
Corn	637.0	640.0
Soybean	1.0	0.0
Wheat	0.0	0.0
Alfalfa	0.0	0.0
...	...	...
...	...	...
Non-Ag.	2.0	0.0

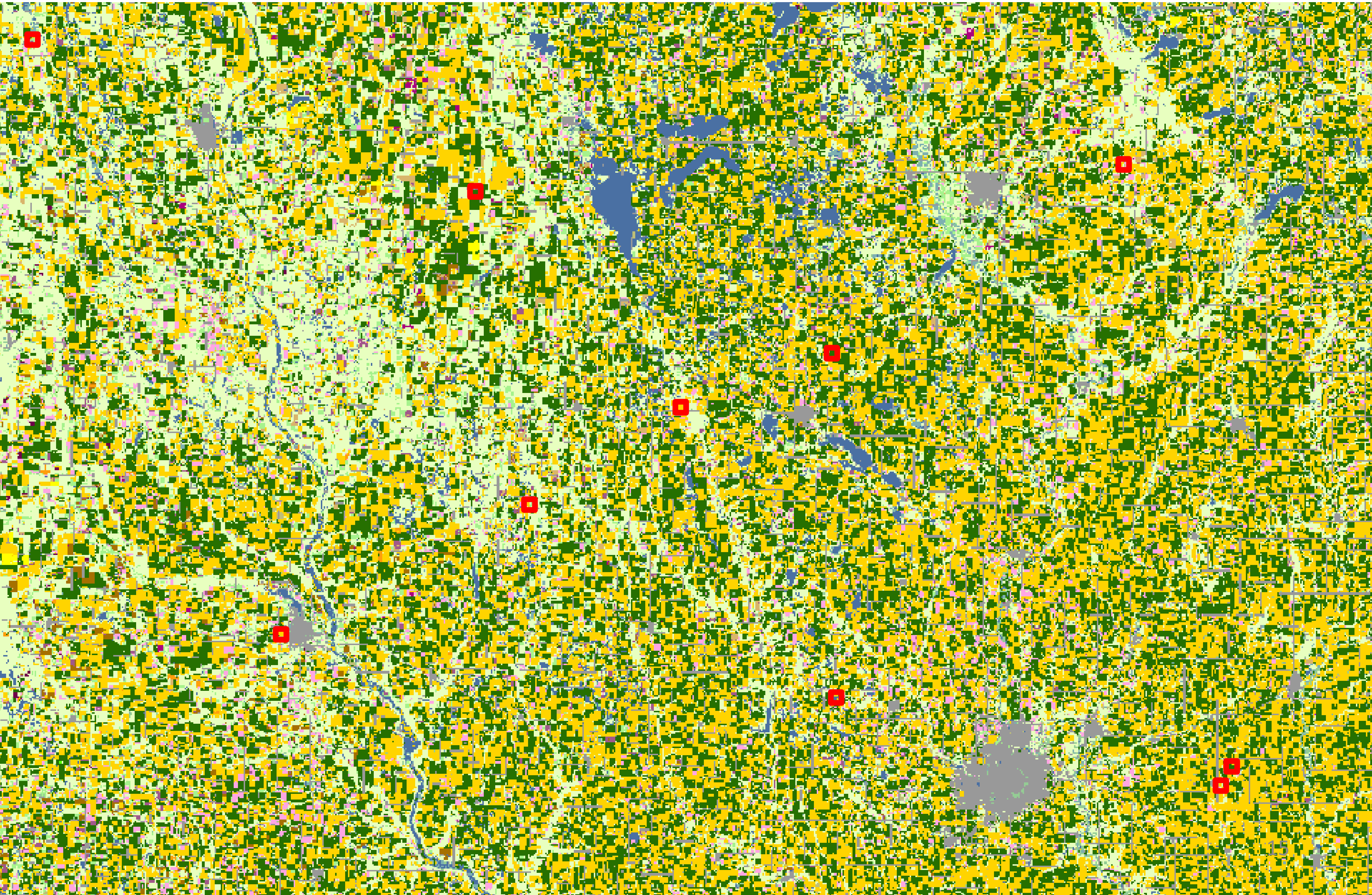
At three sites

Cover Type	X	Y
	Classified Acres	Enumerated Acres
Corn	176.0	190.0
Soybean	302.0	290.0
Wheat	0.0	0.0
Alfalfa	3.5	0.0
...	...	...
...	...	...
Non-Ag.	158.5	160.0

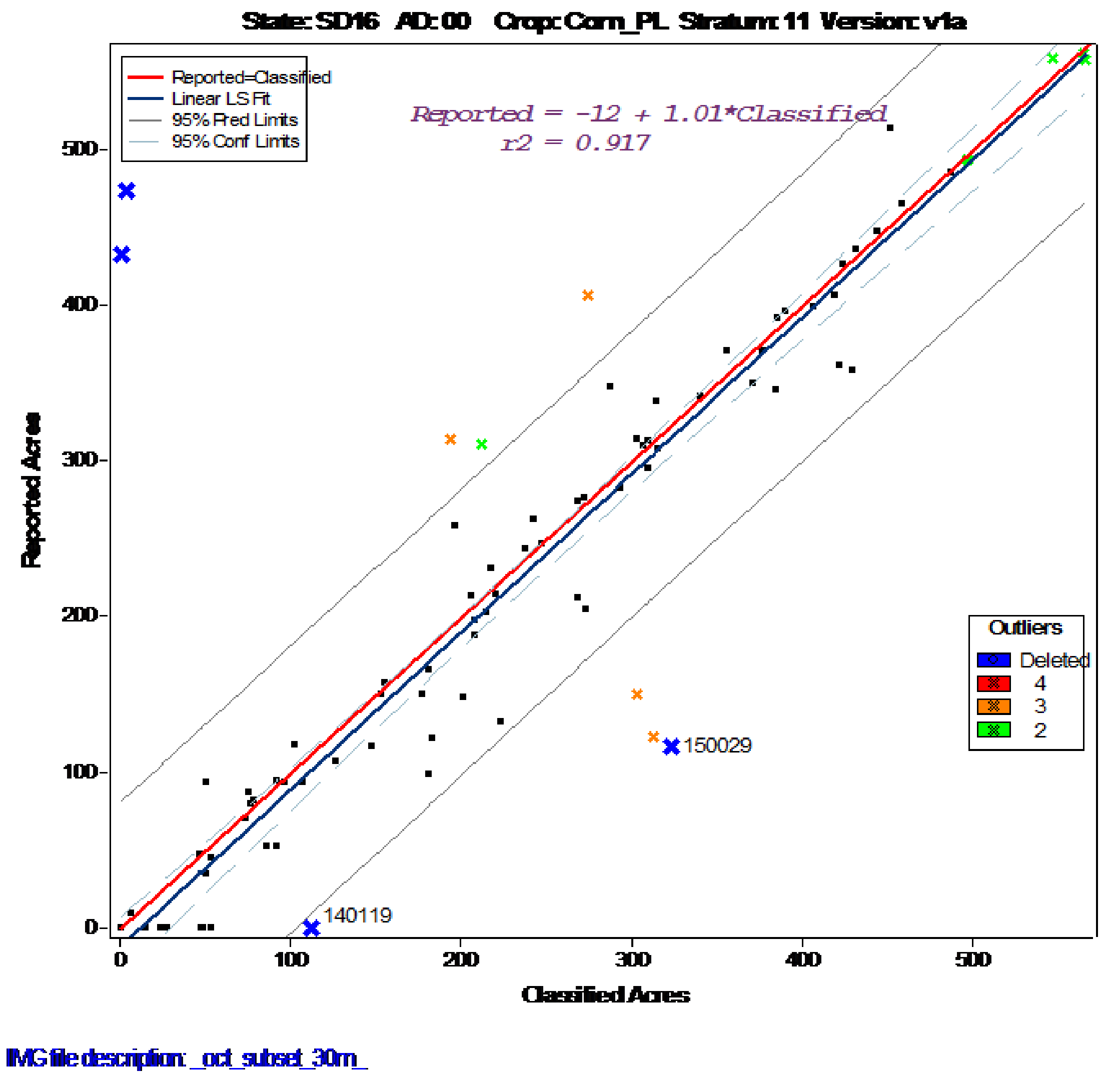
Cover Type	X	Y
	Classified Acres	Enumerated Acres
Corn	34.0	21.0
Soybean	177.0	155.0
Wheat	4.5	0.0
Alfalfa	2.5	0.0
...	...	...
...	...	...
Non-Ag.	422.0	464.0

Cover Type	X	Y
	Classified Acres	Enumerated Acres
Corn	637.0	640.0
Soybean	1.0	0.0
Wheat	0.0	0.0
Alfalfa	0.0	0.0
...	...	...
...	...	...
Non-Ag.	2.0	0.0

10 sites and so forth....

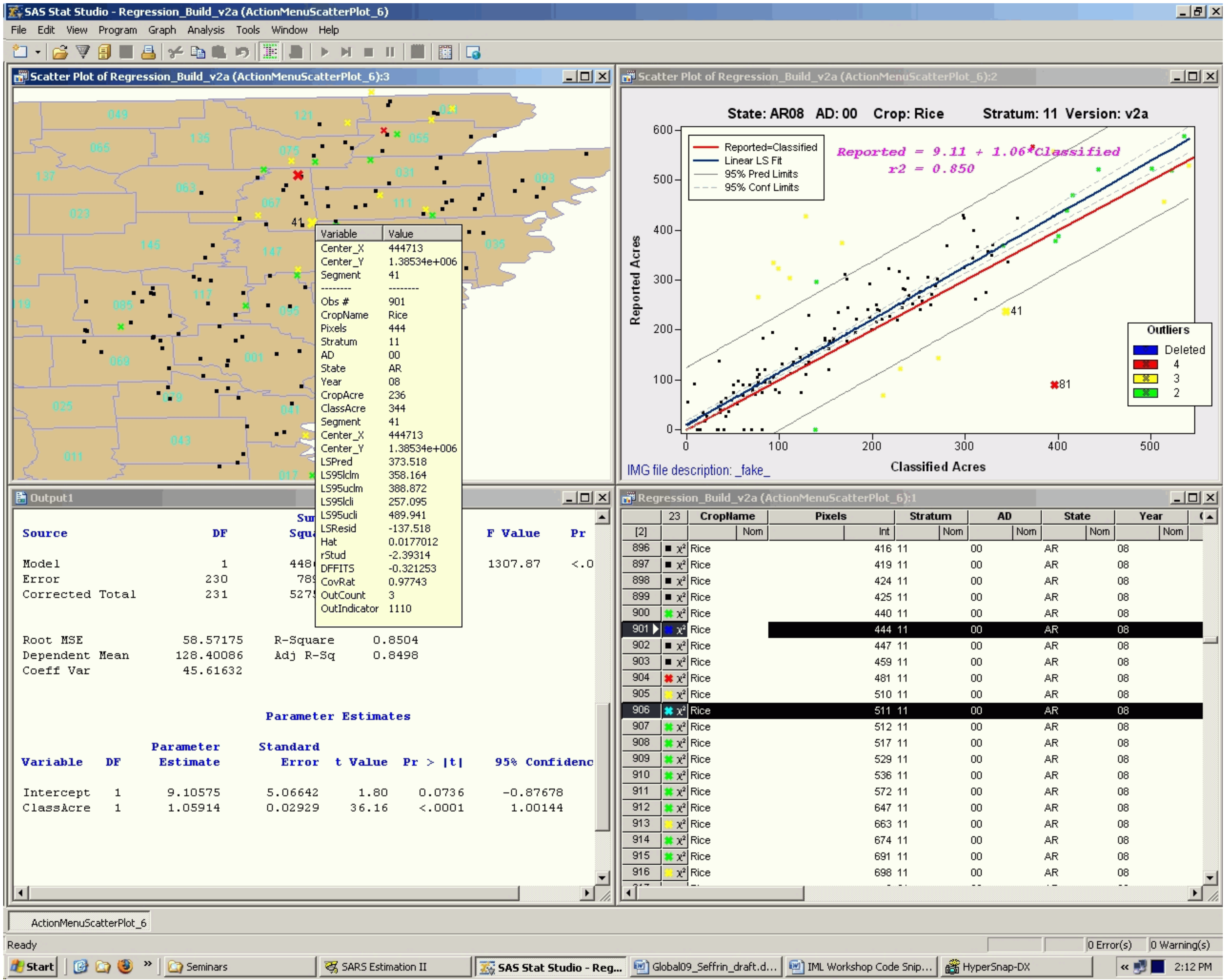


Acreage Regression Estimation

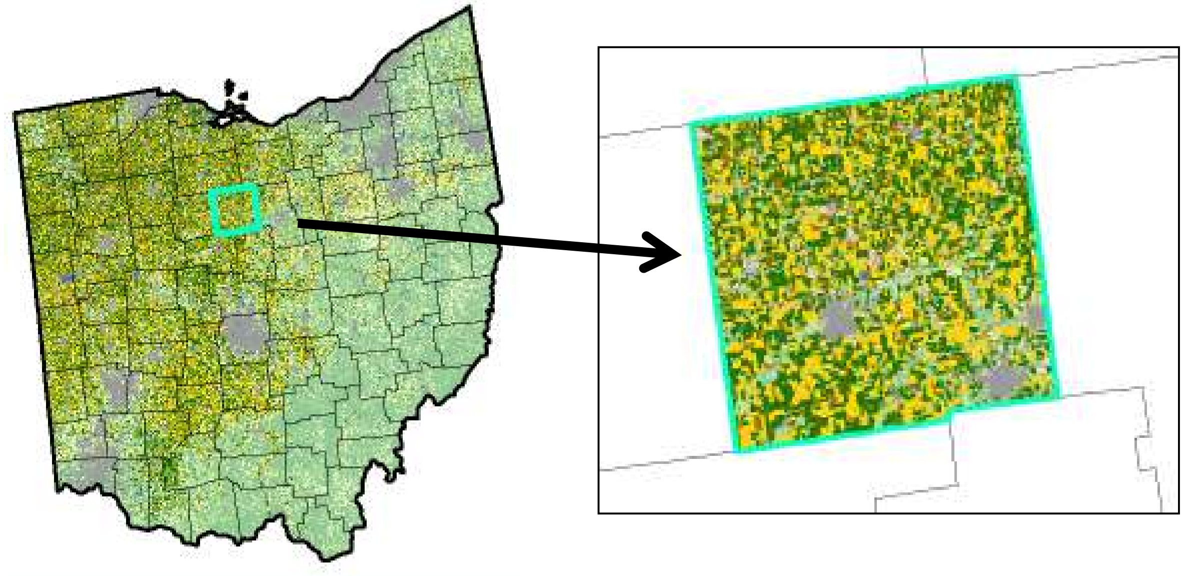


We don't just "pixel count" from CDL to estimate acreage

SAS-based Regression Estimate system



à la Bob Seffrin

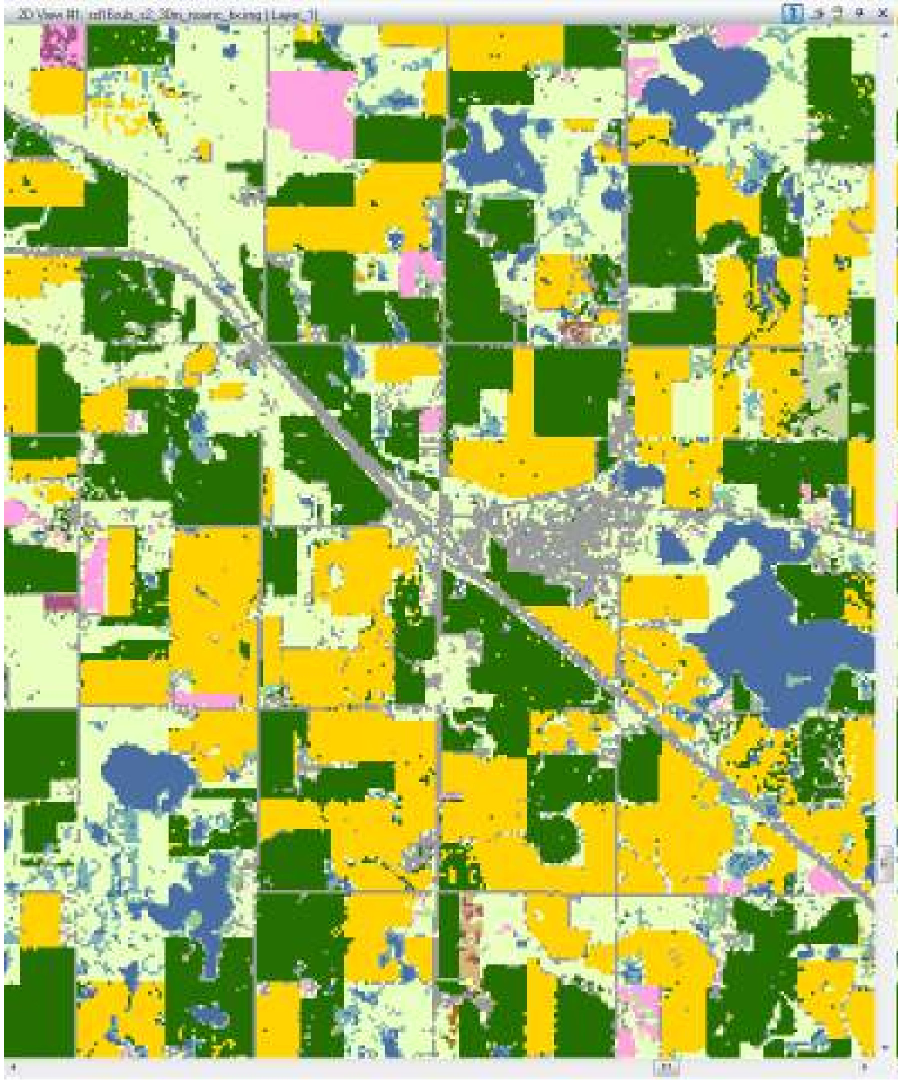


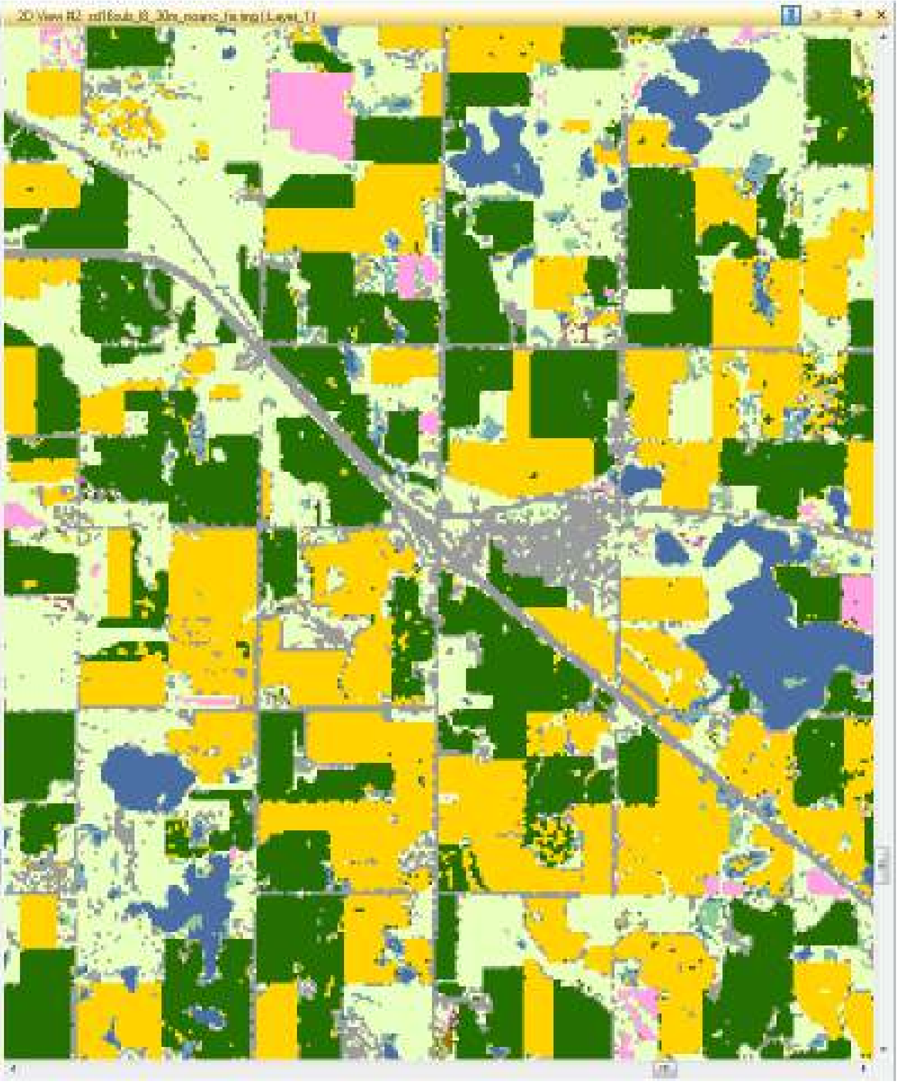
County Estimates

- Use Battese-Fuller estimator with nested design
- Apply state-strata level regression parameters
- Adjust intercept based on segments in county
- Ag Statistics Districts Est = Sum of County Estimates

Classification comparison #1

30m Sentinel-2a | **30m Landsat 8**

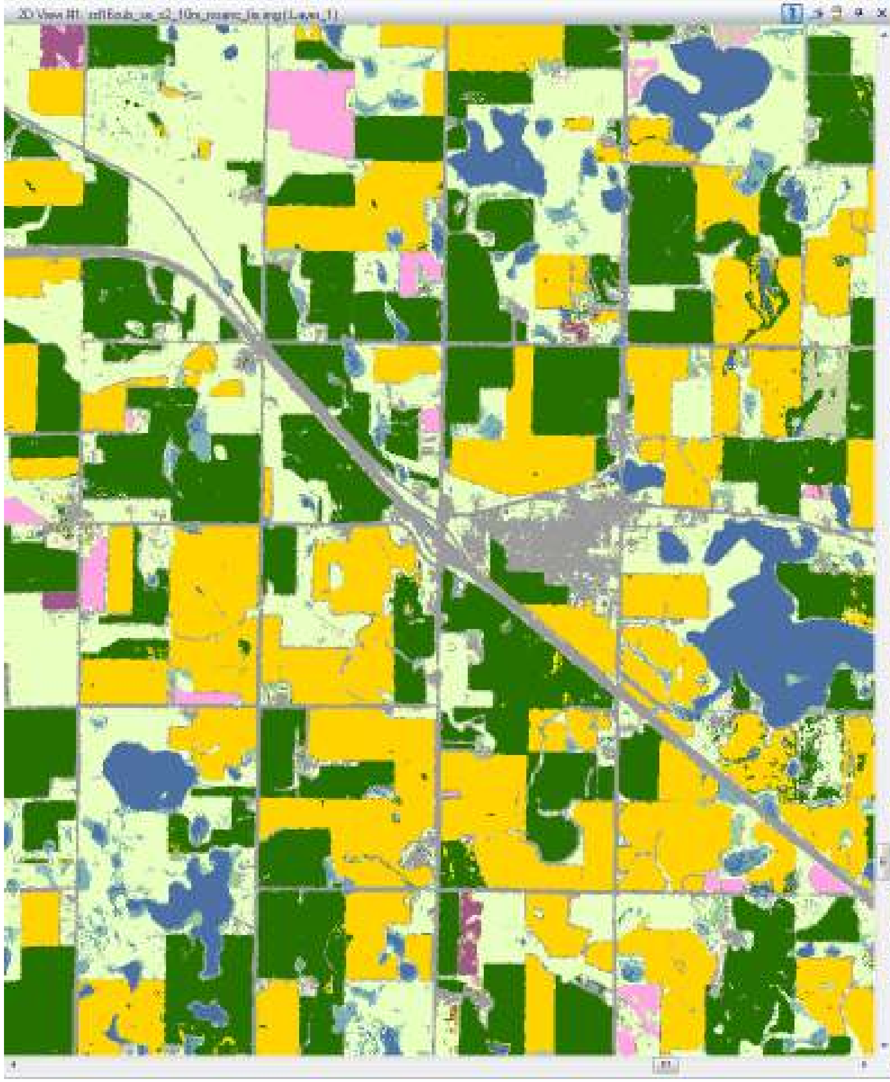
93.9 

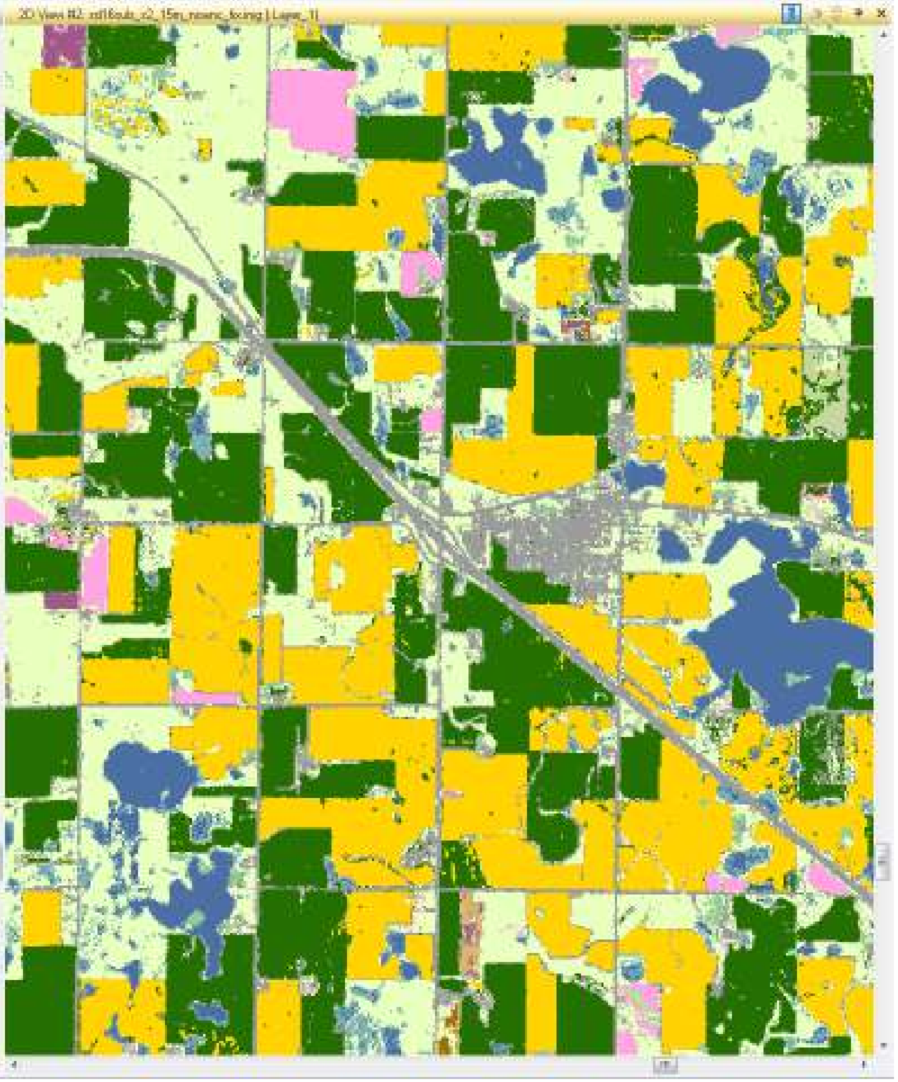
 93.8

Classification comparison #2

10m Sentinel-2a | **15m Sentinel-2a**

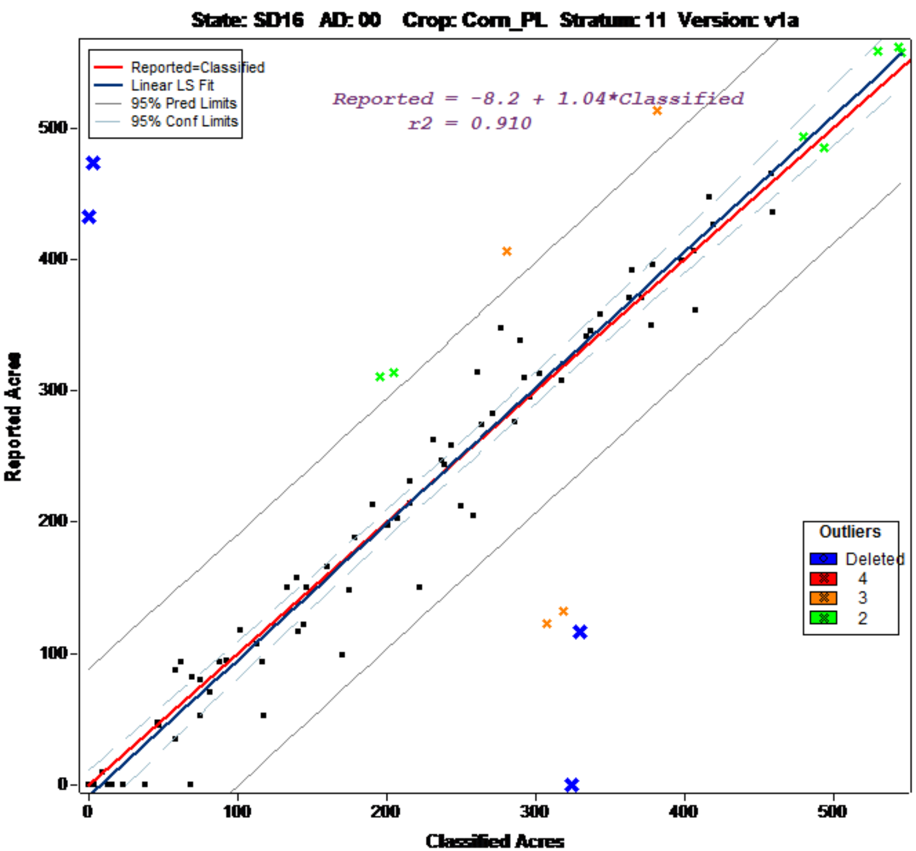
94.2



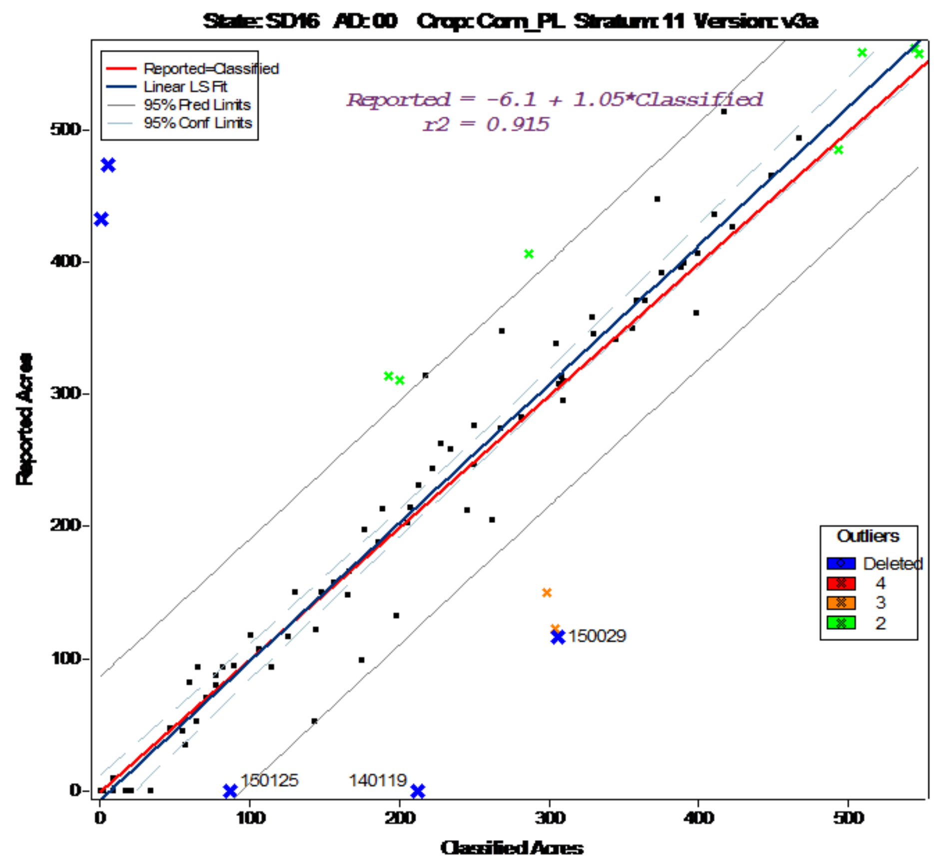


94.0

60m vs 15m regression analysis - corn

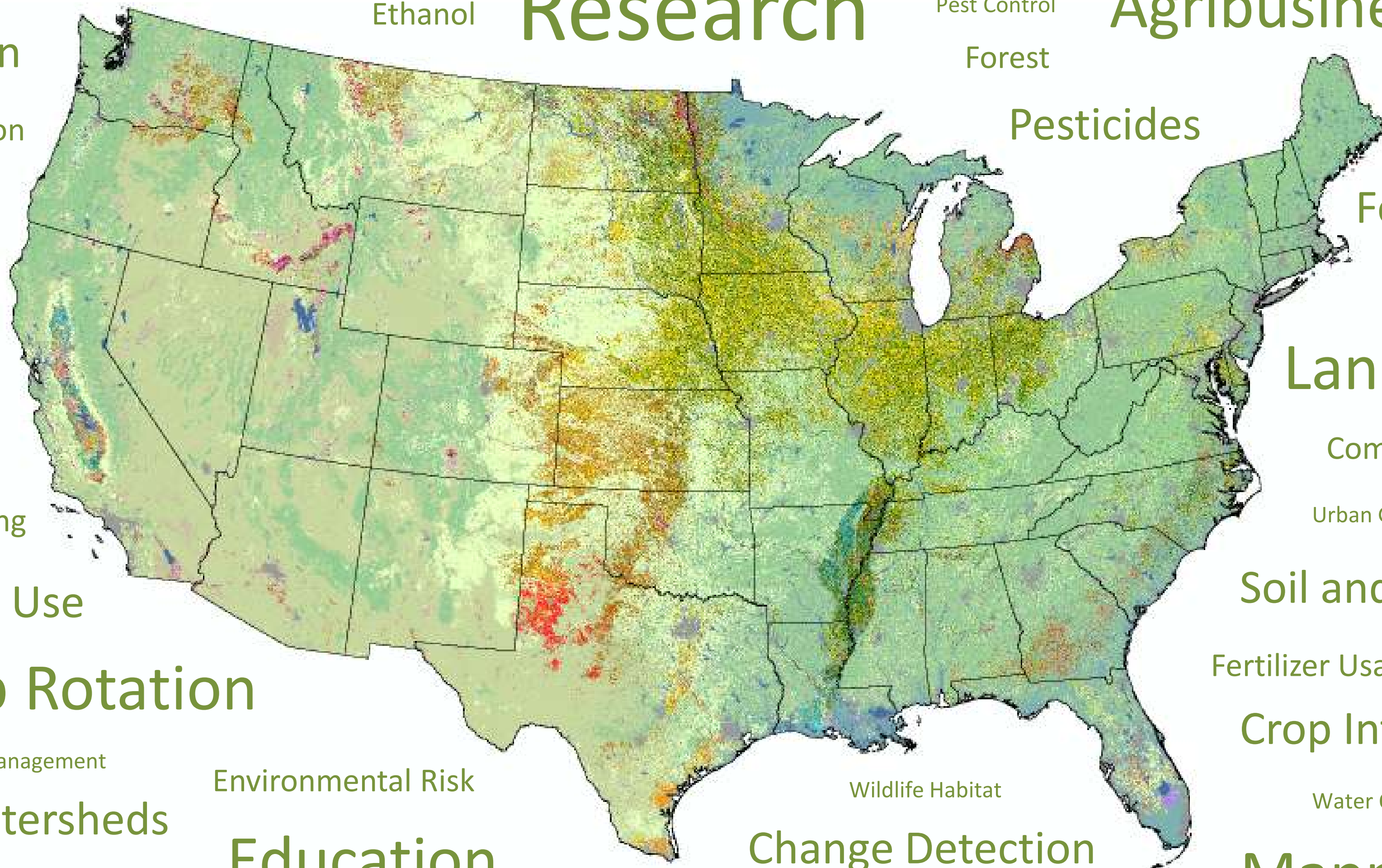


IMG file description: _60m_fix_



VIG file description: _sub_s2_15m_noan

CDL Applications



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Crop Protection


YIELD
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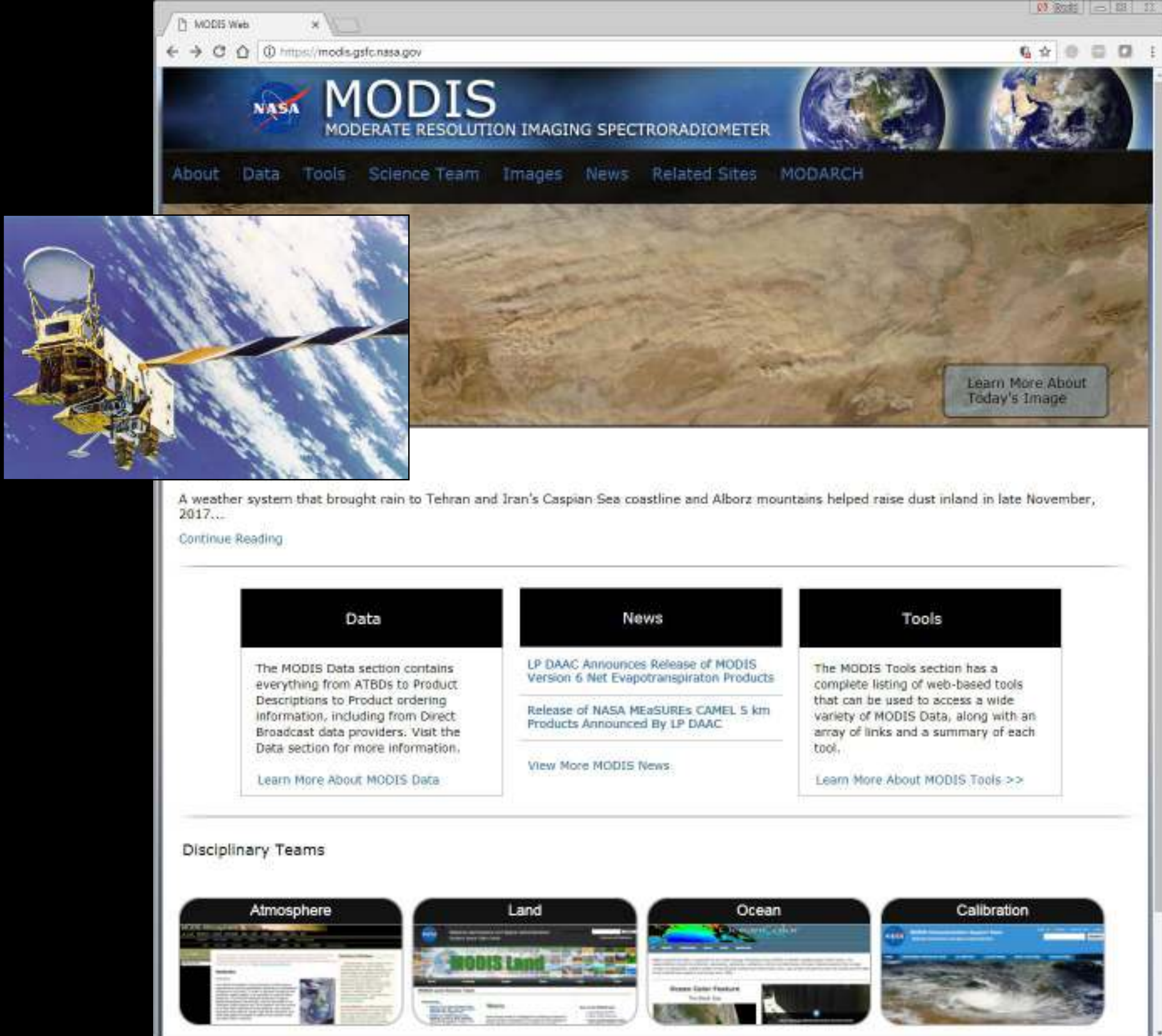
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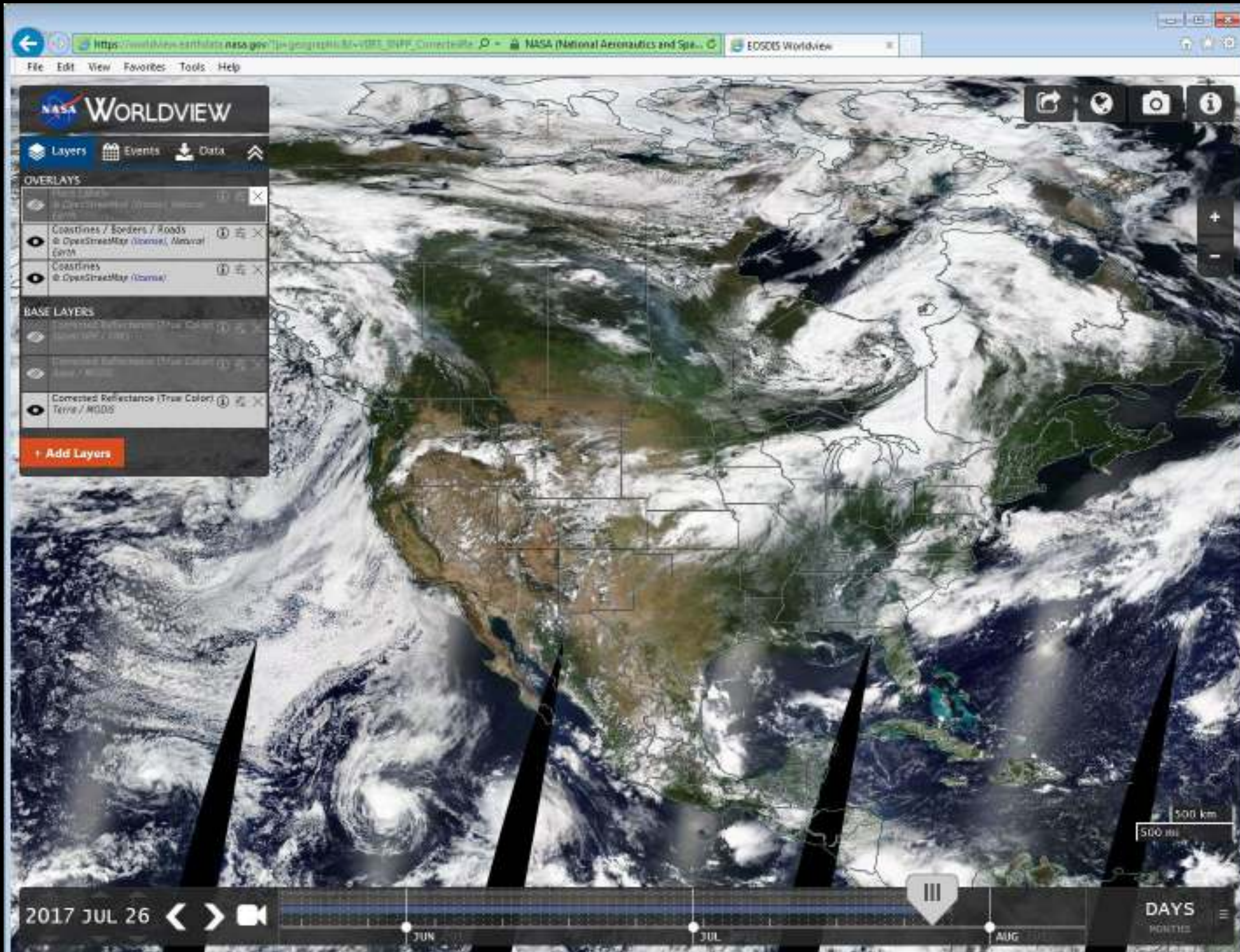
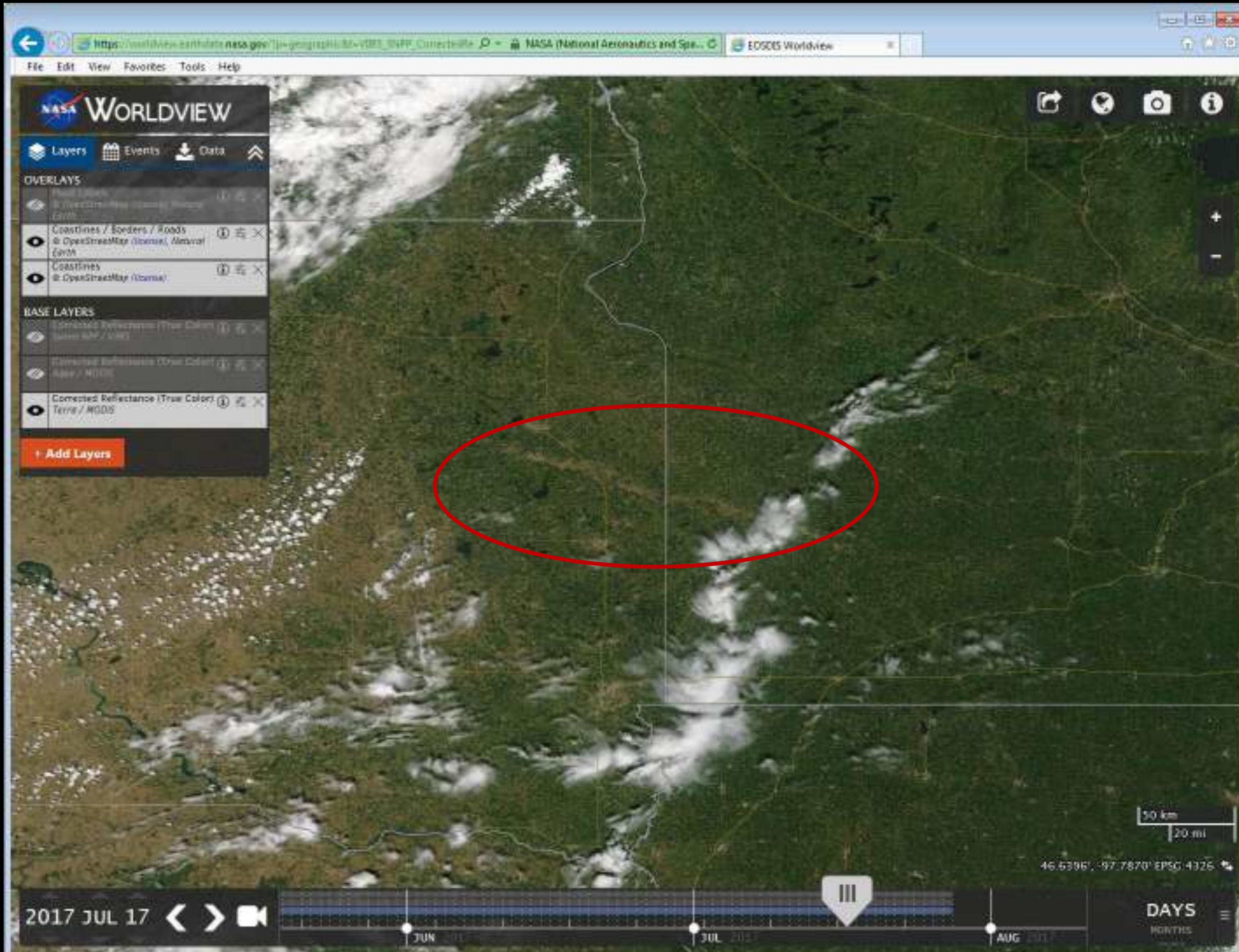
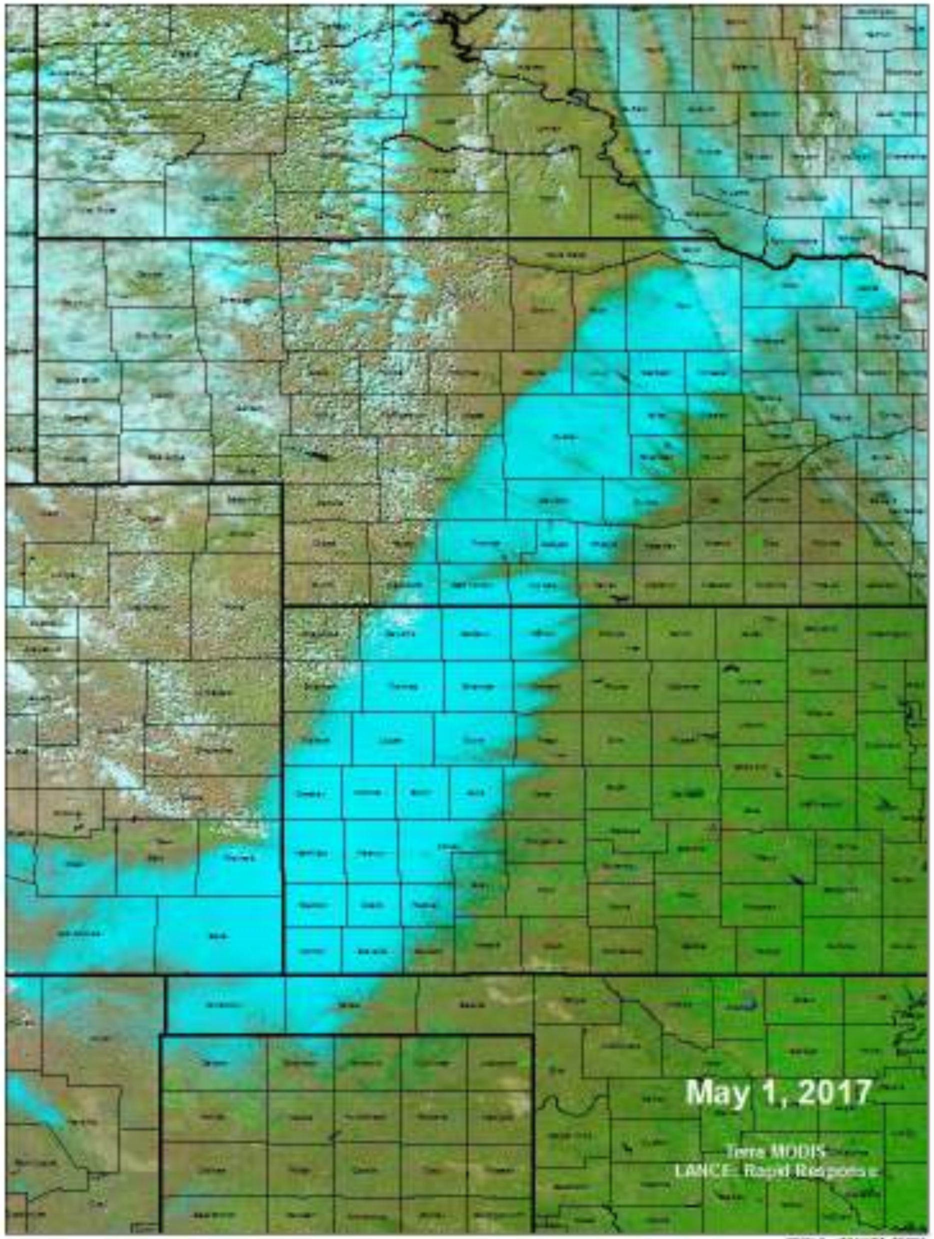
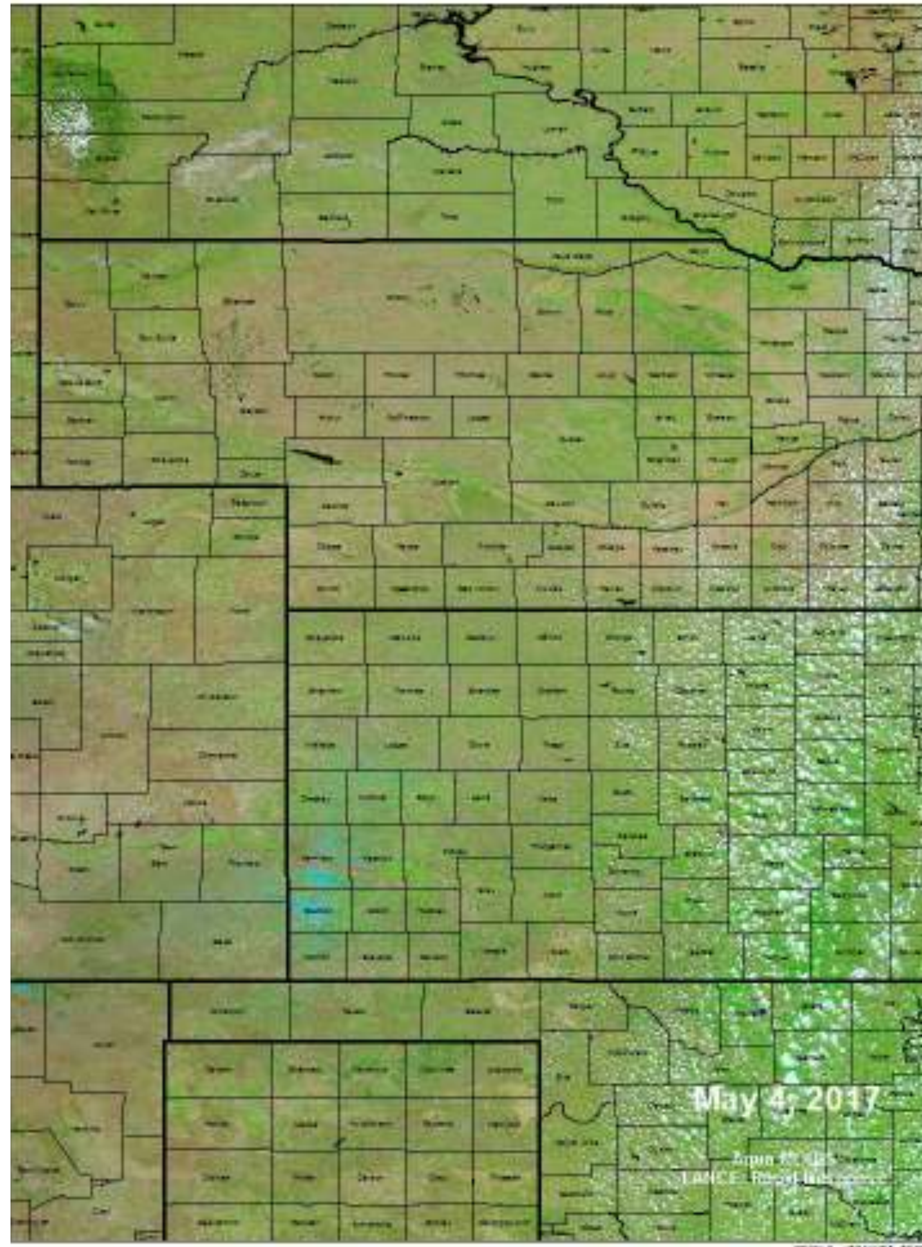


Hail example

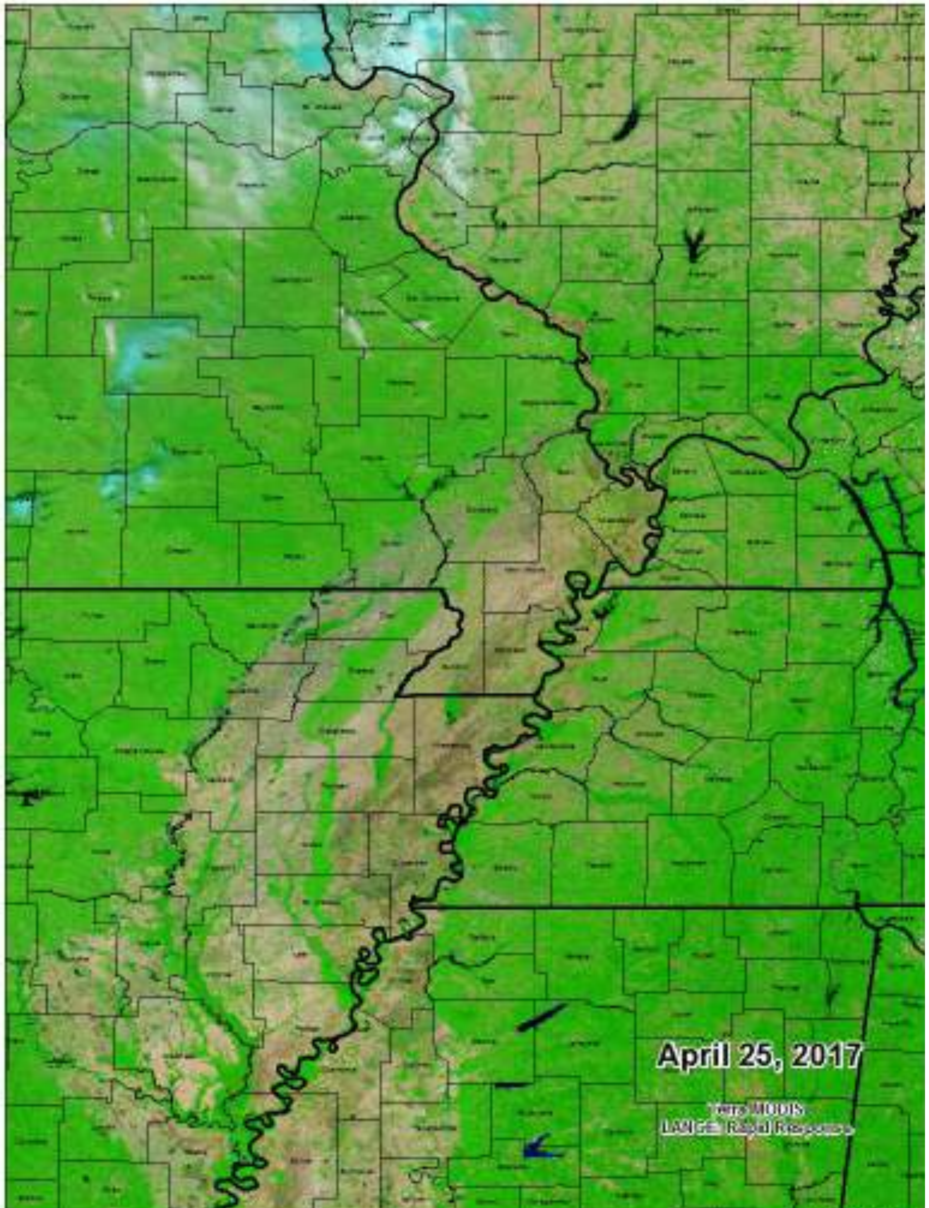


MODIS Imagery - Snow event

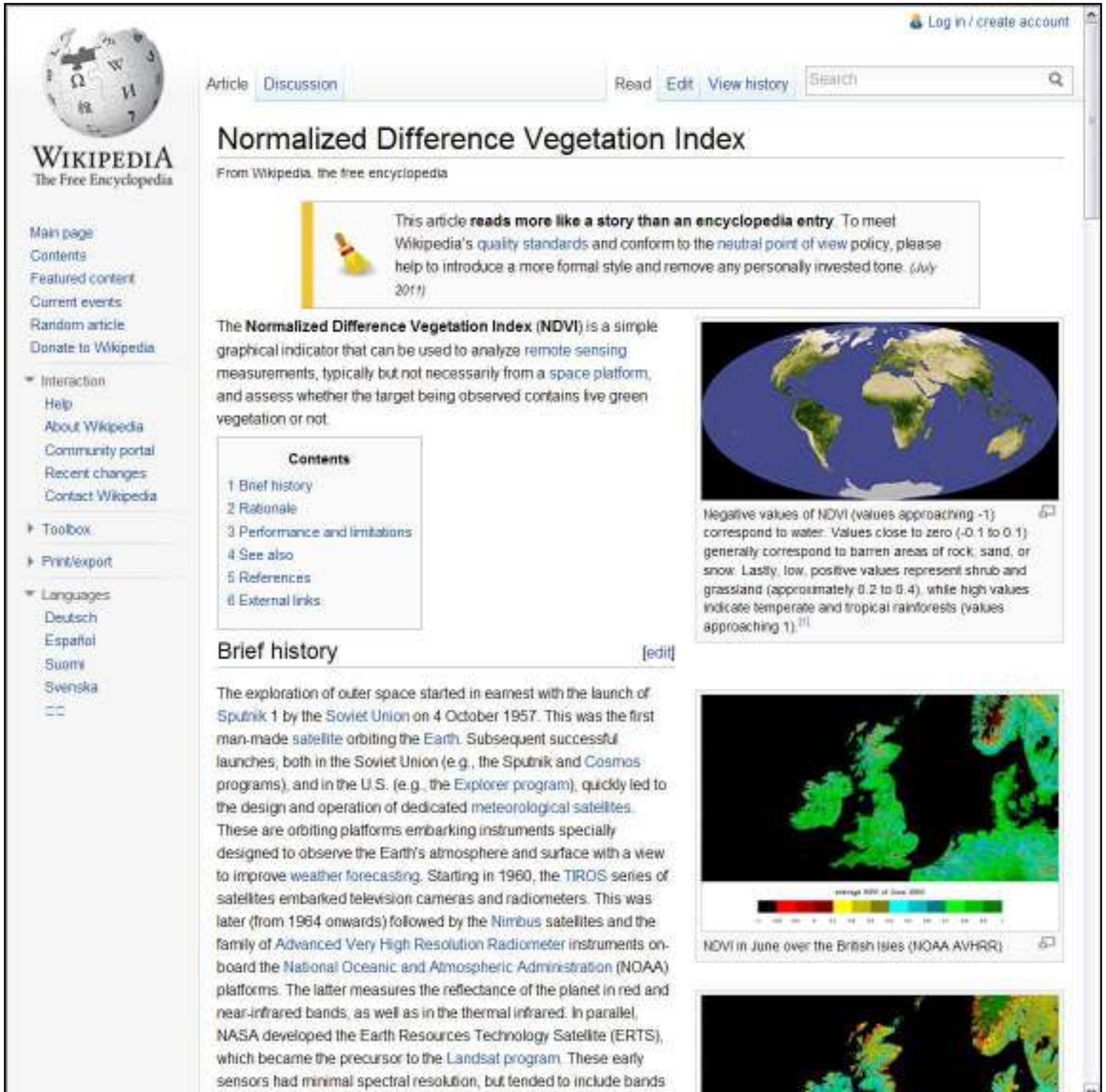




MODIS Imagery - Flood event



Calculation and use of NDVI



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Normalized Difference Vegetation Index

From Wikipedia, the free encyclopedia

This article **reads more like a story than an encyclopedia entry**. To meet Wikipedia's quality standards and conform to the neutral point of view policy, please help to introduce a more formal style and remove any personally invested tone. *(July 2011)*

The **Normalized Difference Vegetation Index (NDVI)** is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not.

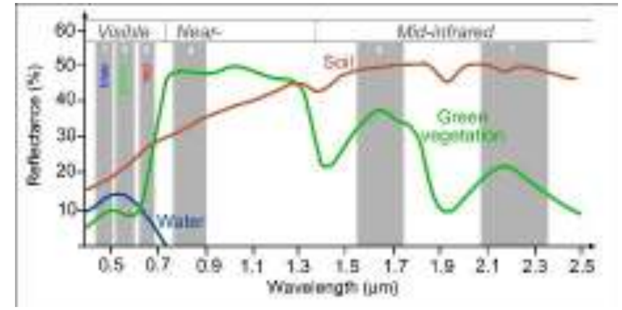
Contents

Negative values of NDVI (values approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Lastly, low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1).[1]

Brief history [edit]

The exploration of outer space started in earnest with the launch of Sputnik 1 by the Soviet Union on 4 October 1957. This was the first man-made satellite orbiting the Earth. Subsequent successful launches, both in the Soviet Union (e.g., the Sputnik and Cosmos programs), and in the U.S. (e.g., the Explorer program), quickly led to the design and operation of dedicated meteorological satellites. These are orbiting platforms embarking instruments specially designed to observe the Earth's atmosphere and surface with a view to improve weather forecasting. Starting in 1960, the TIROS series of satellites embarked television cameras and radiometers. This was later (from 1964 onwards) followed by the Nimbus satellites and the family of Advanced Very High Resolution Radiometer instruments on-board the National Oceanic and Atmospheric Administration (NOAA) platforms. The latter measures the reflectance of the planet in red and near-infrared bands, as well as in the thermal infrared. In parallel, NASA developed the Earth Resources Technology Satellite (ERTS), which became the precursor to the Landsat program. These early sensors had minimal spectral resolution, but tended to include bands

NDVI in June over the British Isles (NOAA AVHRR)



$$\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}$$

NIR = near-infrared band

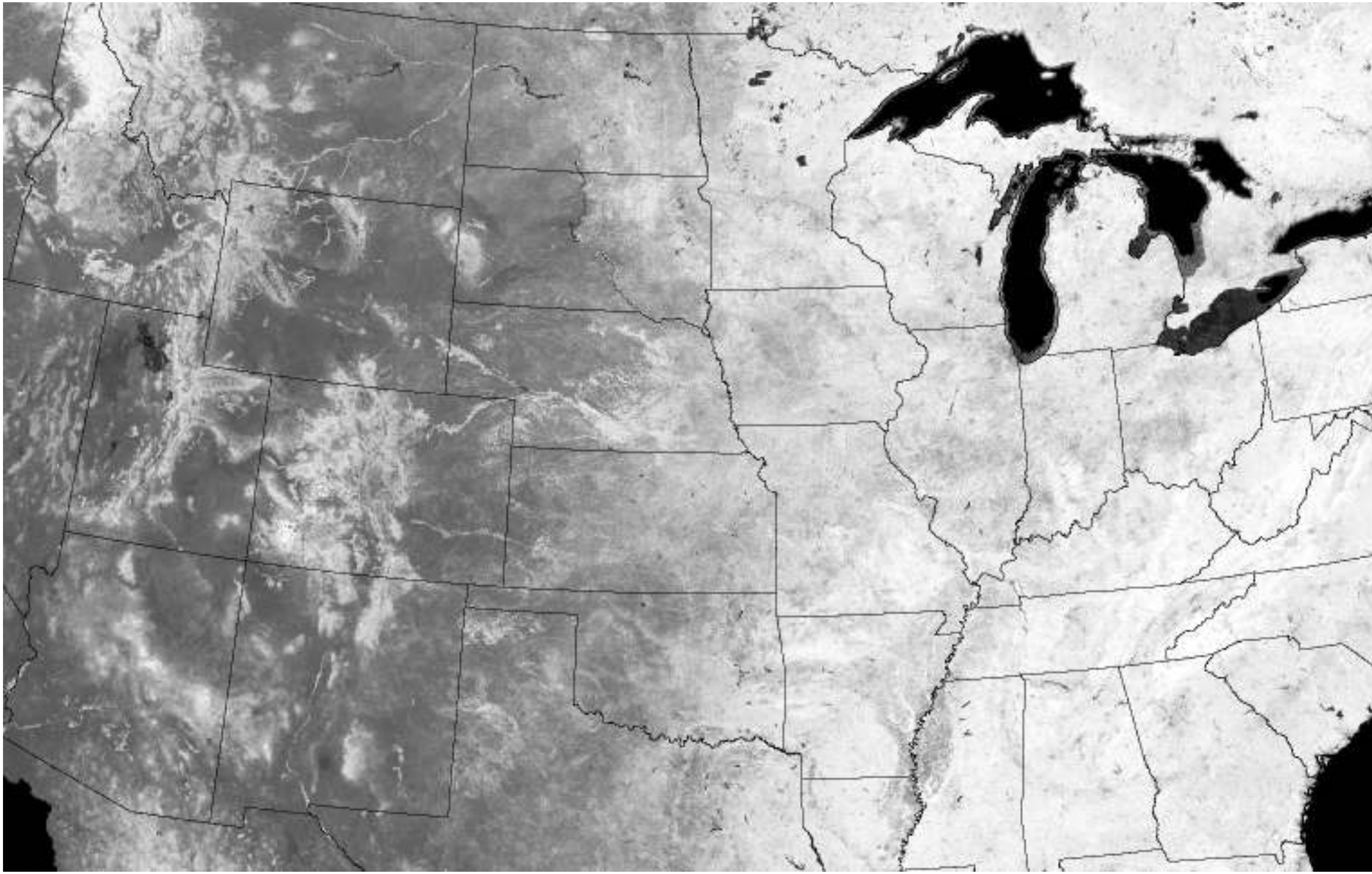
VIS = visible band

Ranges from -1.0 to 1.0

NDVI is a related to:

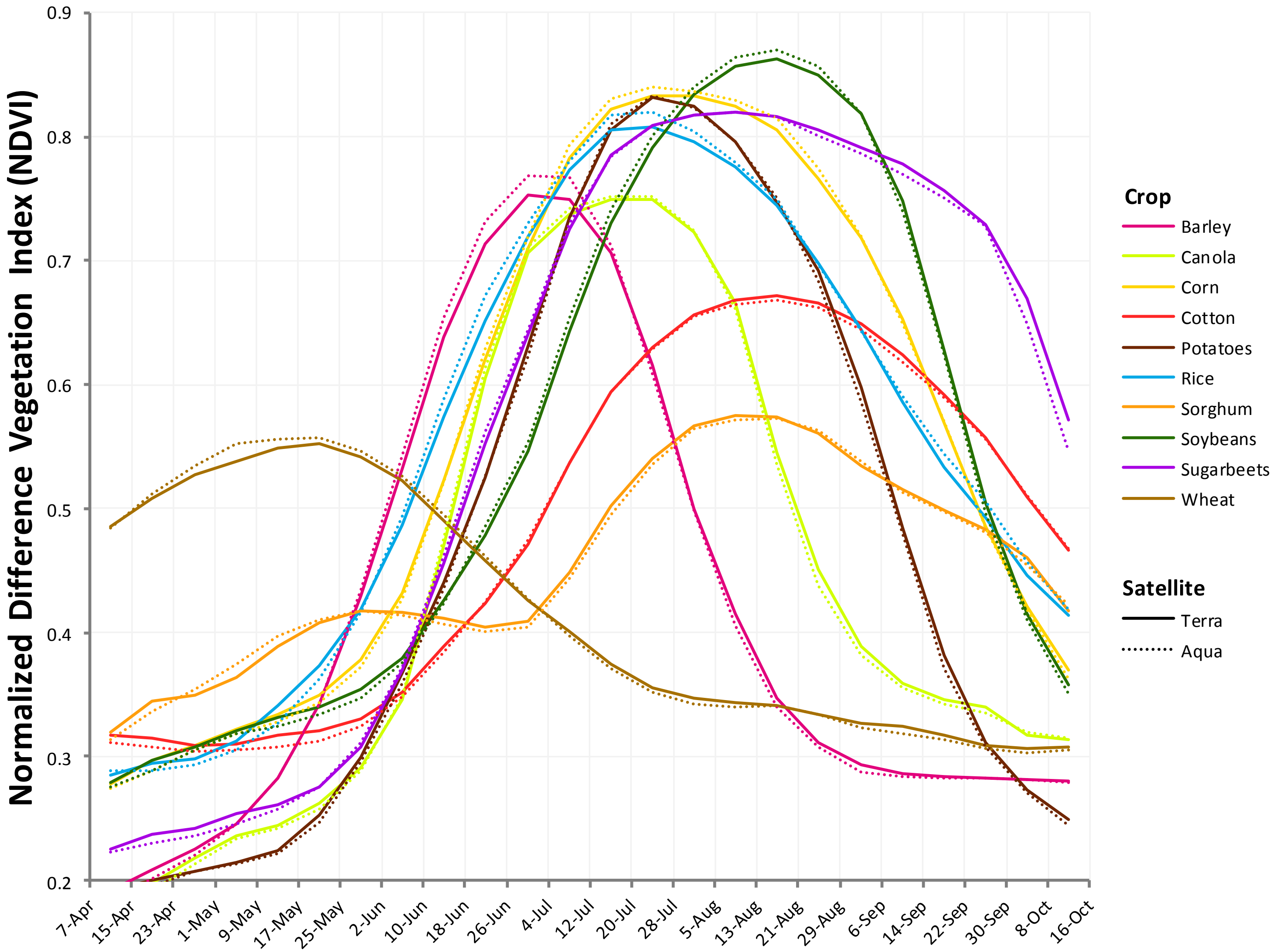
- Plant health
- Chlorophyll content
- “Greenness”
- Amount of Biomass
- Vegetation vigor
- **Yield!**

MODIS NDVI 8-day composite imagery example



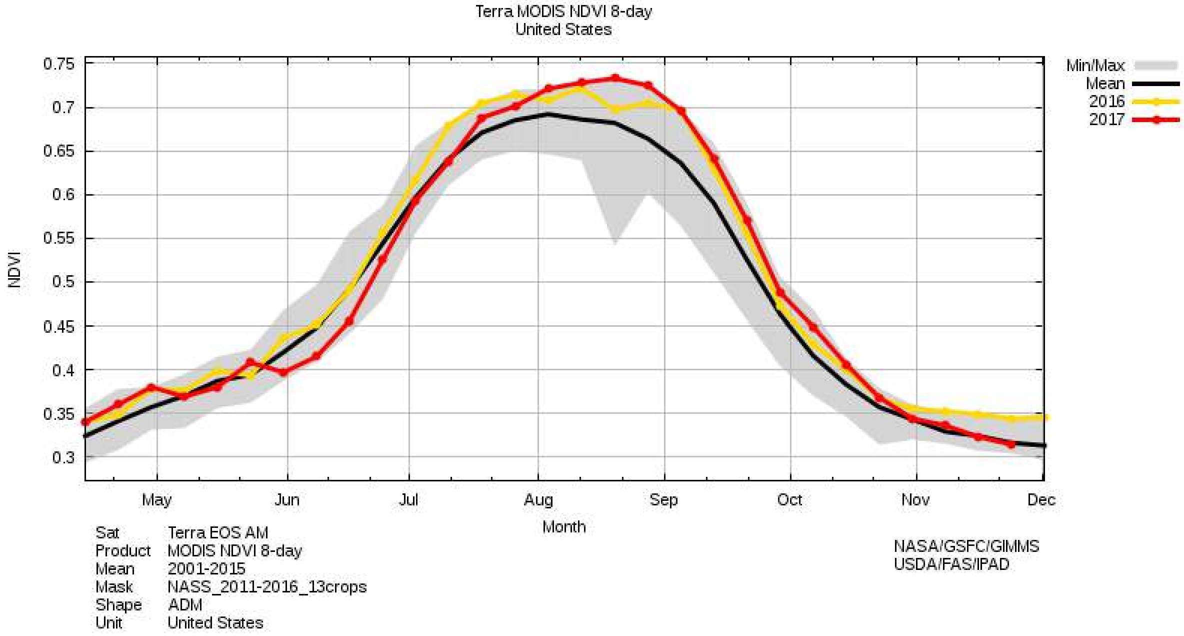
Lighter shades, greater NDVI

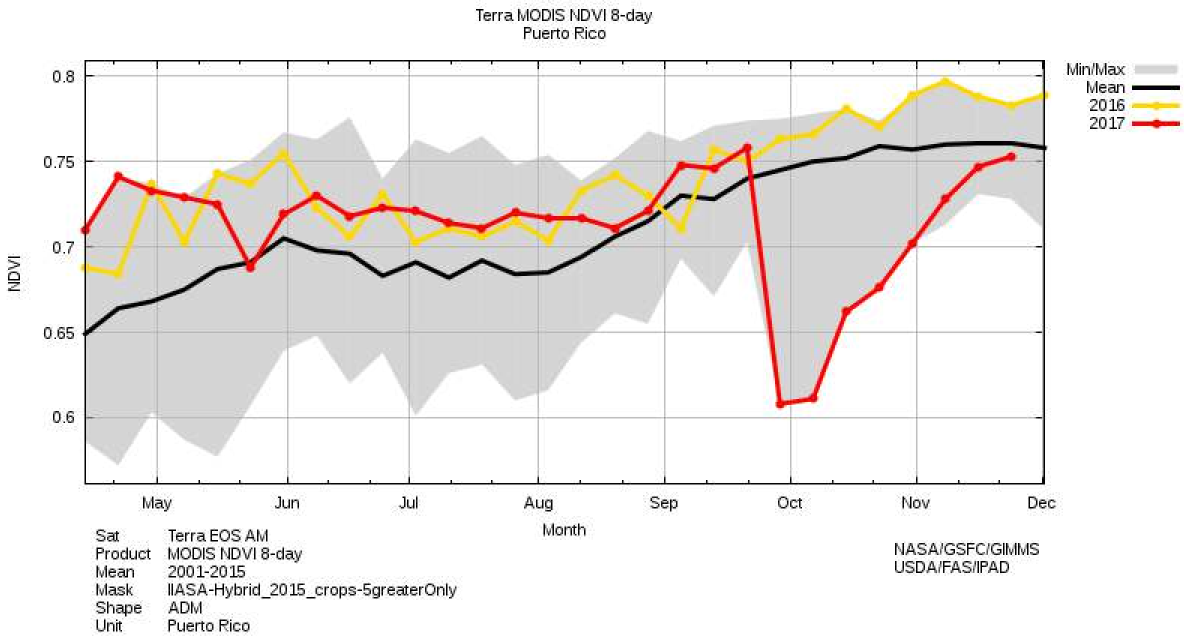
Average NDVI phenologies over United States



Signals isolated using crop specific masks

Real-time tracking of NDVI





NASS recent efforts on remote sensing of crop yields

Premise

- Positive relationship between crop yield and biomass – plant vigor - "greenness" - NDVI
- Negative relationship between crop yield and land surface temperature

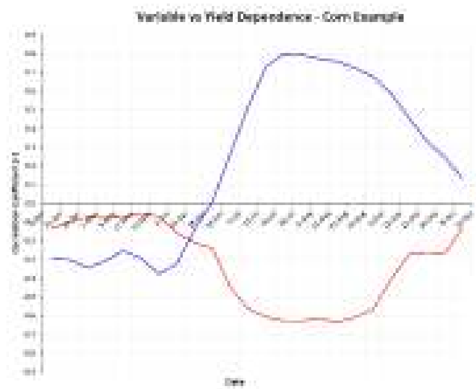
Utilize time-series MODIS satellite data to obtain biomass and temperature estimates throughout the growing season

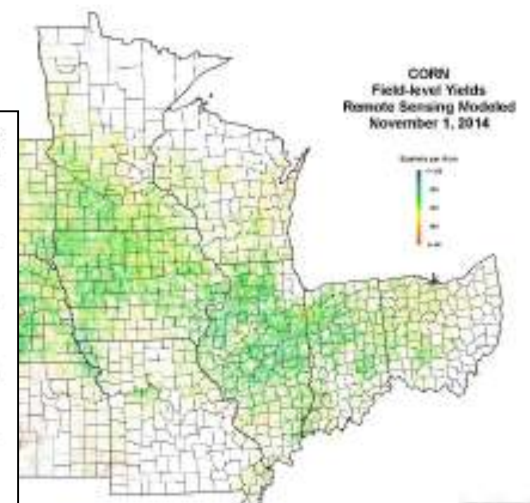
- Use Cropland Data Layer to isolate known crop areas
- Then use them in an empirically-based prediction model based on historical imagery and NASS county-level yield statistics

Run model at National, State, and County levels

- Integrating over season approach
- Using decision trees (Rulequest Cubist)
- Corn and Soybeans operational currently

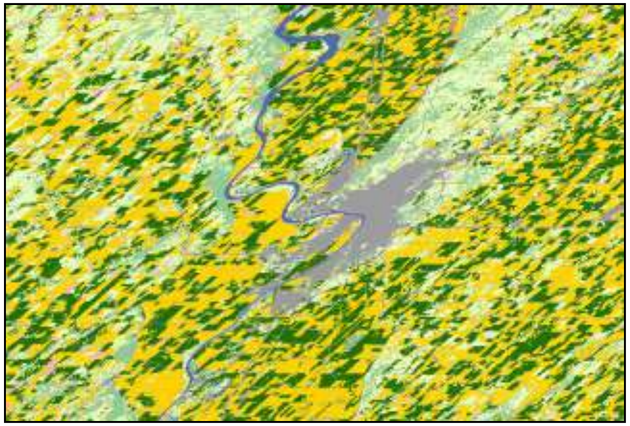
Perform within crop season at monthly intervals



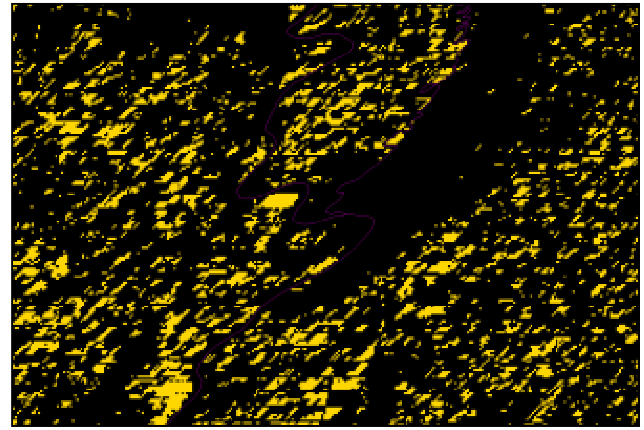


Must be timely, accurate, and useful

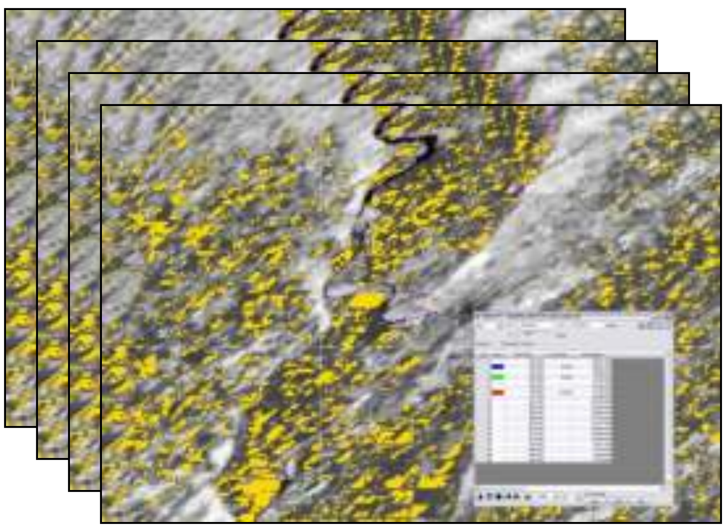
Intersecting of crop "mask" with time-series of MODIS data

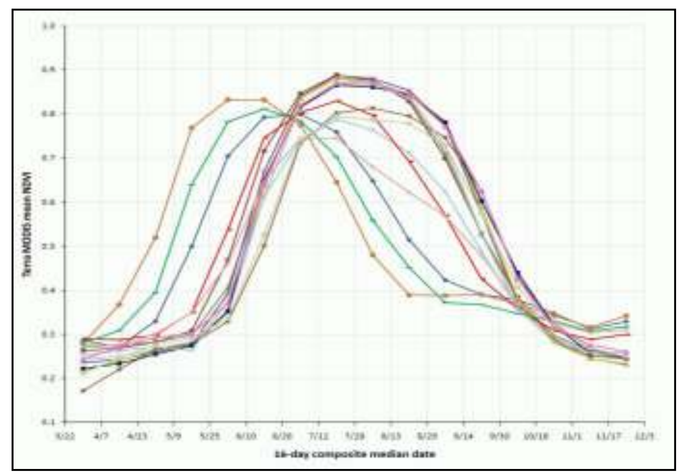


CDL



Isolate crop of interest





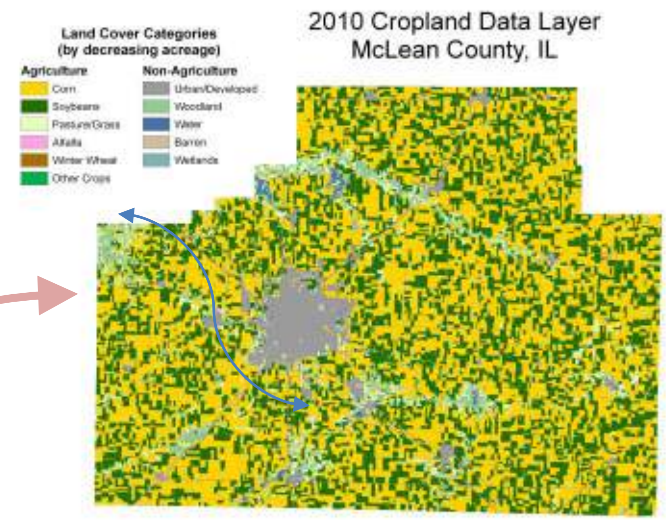
Intersect crop mask with MODIS time series and then spatially average those pixels

County-level time-series database has been built

2006 -> present

Every eight day "window" through the growing season

- Observed average value of NDVI
- Observed average value of LST

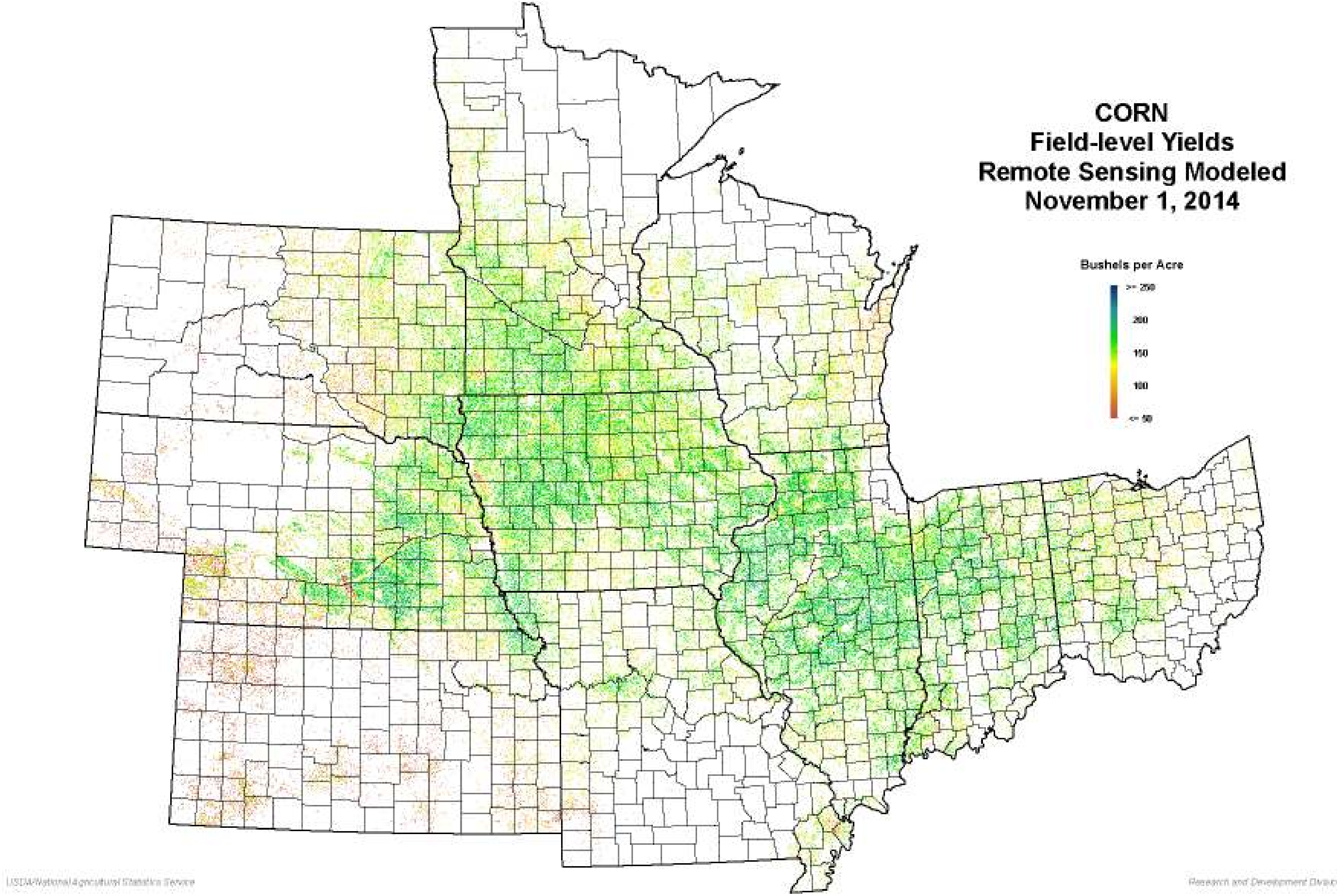


For every county we also know

- NASS published yield

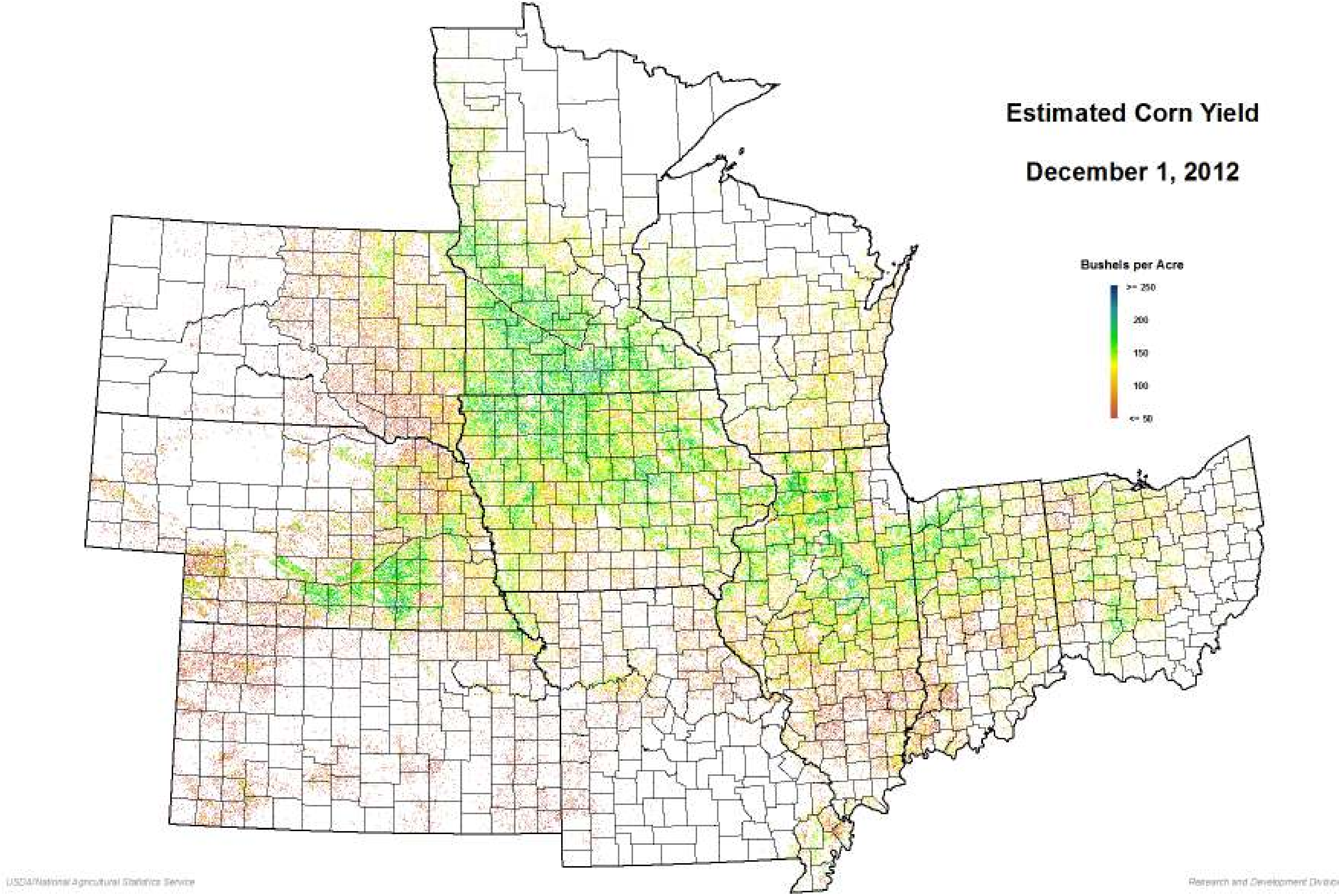
state	county	year	yield	NDVI	DLST	23-Apr	1-May	9-May	17-May	25-May	2-Jun	10-Jun	18-Jun	26-Jun	4-Jul	12-Jul	20-Ju
17	93	2010	168.6			2980.673	3264.547	3862.318	3866.409	3990.153	5893.765	7558.422	8108.906	8559.559	8826.817	8930.85	8935.61
17	95	2010	159.9			2992.195	2977.046	3203.401	3377.778	3848.078	5771.909	7450.655	8012.679	8310.476	8537.081	8645.006	8702.09
17	97	2010	?			3337.864	3836.186	5403.508	4459.949	4311.525	5635.508	7575.966	7776.288	8082.441	8575.966	8689.22	8524.83
17	99	2010	162.9			2844.2	2971.099	3332.757	3486.144	3937.887	6032.626	8059.657	8344.285	8565.456	8784.721	8903.283	8939.18
17	101	2010	156.9			3874.741	3988.952	4349.537	4930.498	5452.197	6205.825	7687.592	8022.794	8396.337	8589.467	8770.097	8827.56
17	103	2010	173.6			2782.144	2805.154	3018.966	3094.823	3512.443	5563.73	7306.284	8102.134	8554.694	8918.413	8949.941	8862.48
17	105	2010	166.6			2816.087	3007.861	3371.65	3608.025	3988.44	6100.426	8236.687	8503.526	8751.071	8872.207	8945.958	8805.10
17	107	2010	155.7			2706.578	2846.325	3249.914	3622.797	4402.778	6661.937	8254.186	8426.524	8515.872	8656.284	8755.741	8782.62
17	109	2010	141.8			3104.659	3240.878	3479.558	3558.215	4056.188	6151.458	7440.174	7913.743	8068.891	8437.704	8697.558	8783.25
17	111	2010	171.4			3079.982	3283.63	3659.725	3626.941	3909.787	5483.311	7163.395	8116.372	8578.756	8844.542	8908.066	8886.72
17	113	2010	169.5			2727.7	2899.42	3316.302	3573.485	4053.523	6484.888	8304.741	8585.89	8846.408	8960.349	8953.985	8860.08
17	115	2010	[illegible]			2791.229	2943.968	3442.016	3862.389	4880.537	7264.473	8749.776	8793.049	8769.201	8787.036	8828.984	8797.02
17	117	2010	146.9			3213.265	3342.063	3617.414	4030.15	4799.472	6474.308	8021.675	8511.256	8646.314	8885.395	8920.521	9010.37
17	119	2010	166.3			3282.816	3405.388	3712.914	4087.371	4860.512	6581.844	8129.837	8410.098	8587.161	8826.583	8879.477	8854.28
17	121	2010	149.7			3524.353	3534.901	3931.625	4260.018	4856.34	6251.207	7828.069	8242.445	8450.967	8601.465	8853.656	8952.45
17	123	2010	163.3			2748.186	2881.69	3261.708	3448.857	3851.546	5647.397	7541.326	8205.306	8567.037	8799.09	8891.405	8904.80

Map Output



Normal year

Map Output

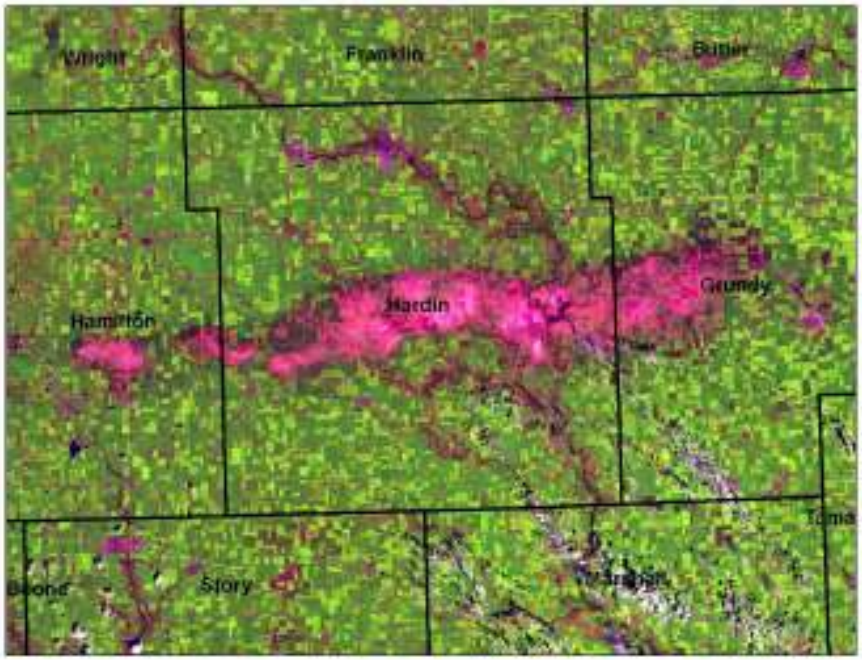


Drought year

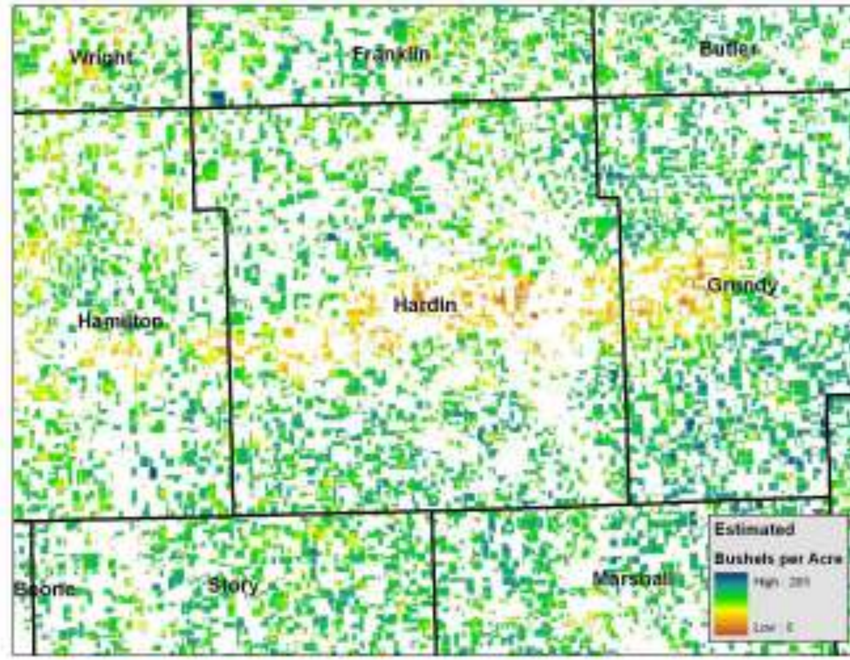
Johnson, 2014

Localized example of yield map variability

Scene of a large hailstorm



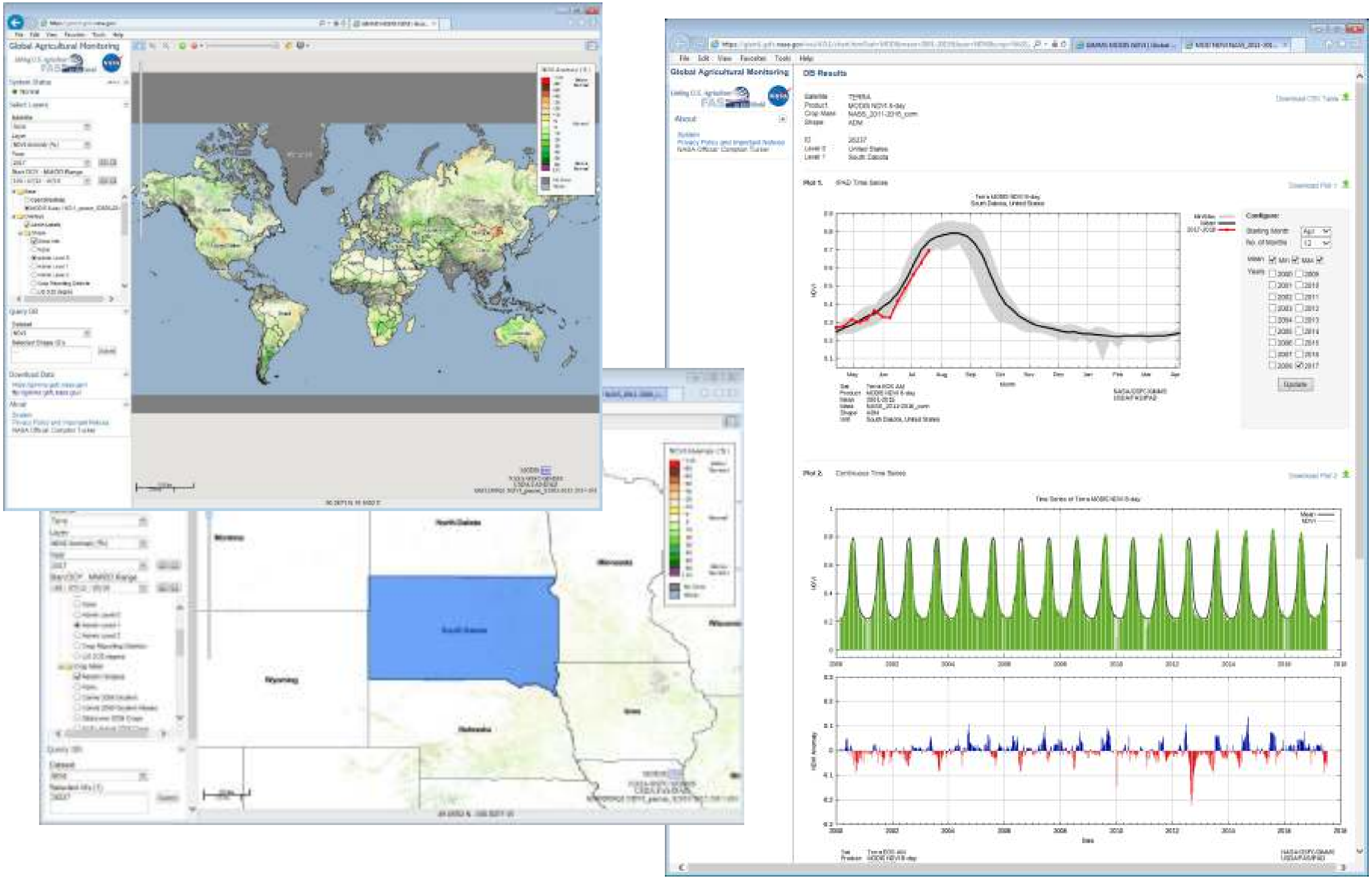
Landsat image



Modeled yields from MODIS

USDA Foreign Agricultural Service/NASA GLAM

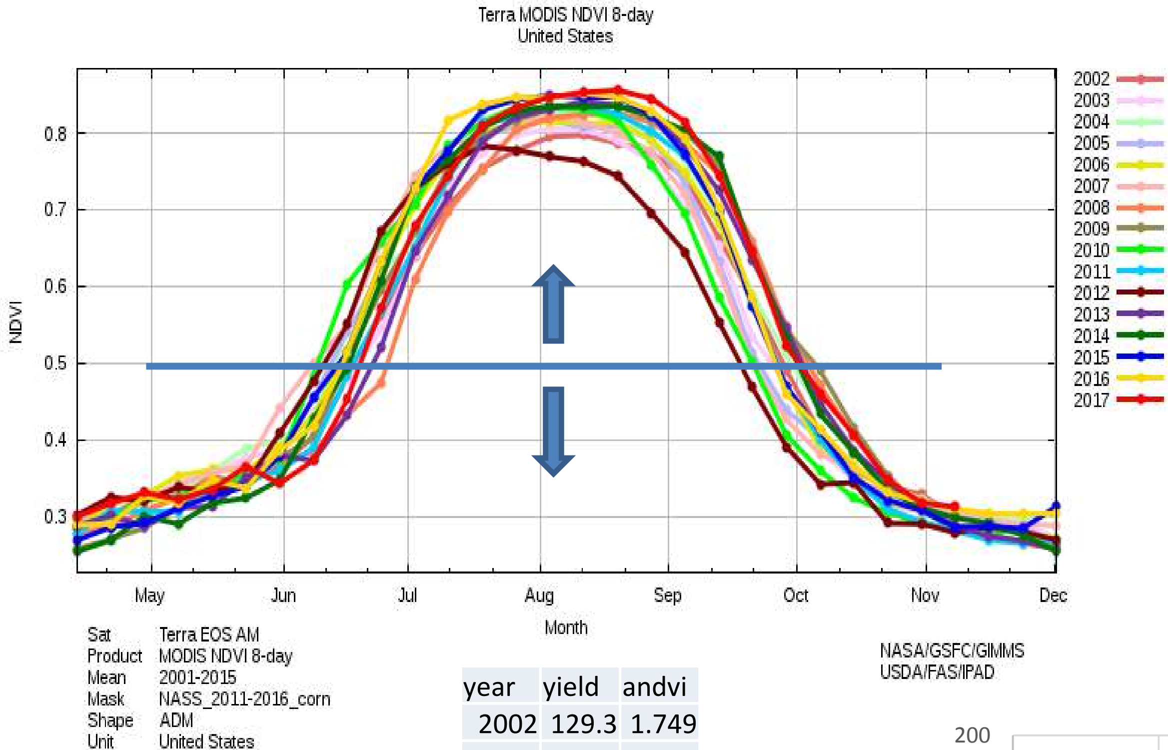
https://glam1.gsfc.nasa.gov/



Highly already customized tool for time series analysis and display

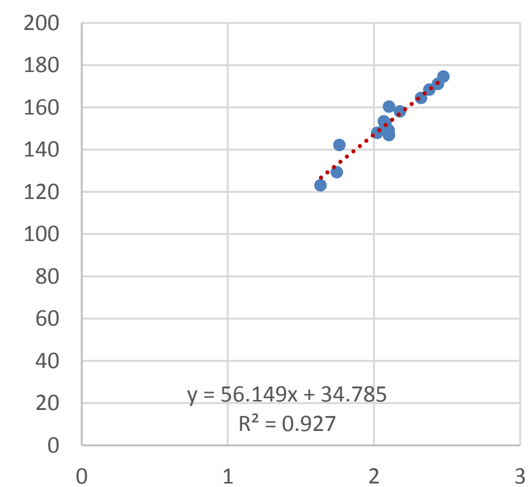
Also, shifting to a simpler model construction

Find Optimal Threshold Value

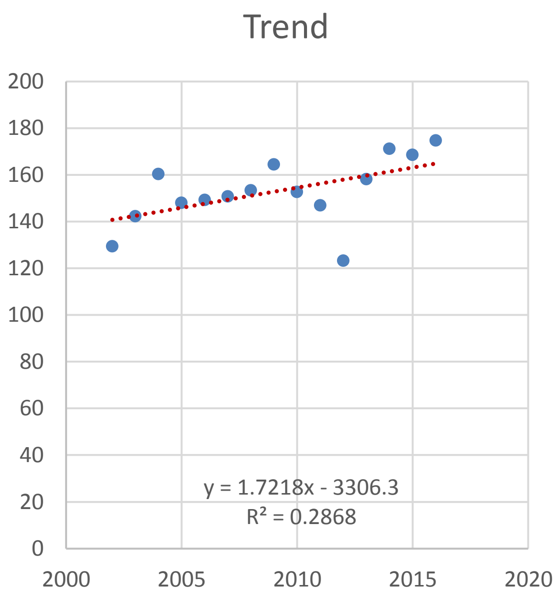


Calculate area under the curve, over a threshold and relate to past years.

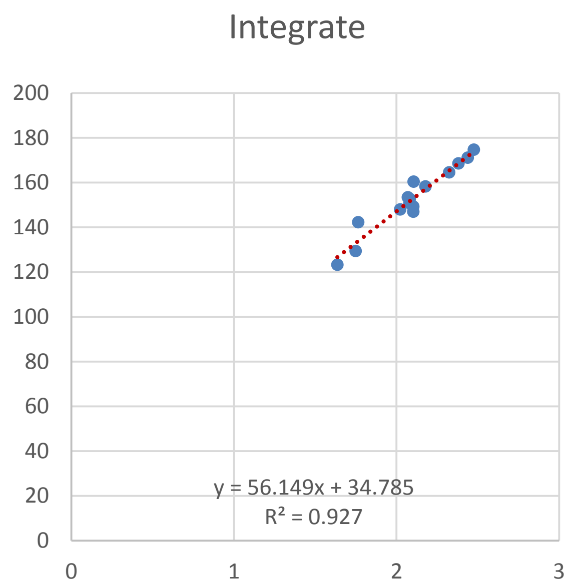
year	yield	andvi
2002	129.3	1.749
2003	142.2	1.765
2004	160.3	2.106
2005	147.9	2.024
2006	149.1	2.104
2007	150.7	2.08
2008	153.3	2.07
2009	164.4	2.324
2010	152.6	2.082
2011	146.8	2.105
2012	123.1	1.637
2013	158.1	2.179
2014	171	2.44
2015	168.4	2.382
2016	174.6	2.477



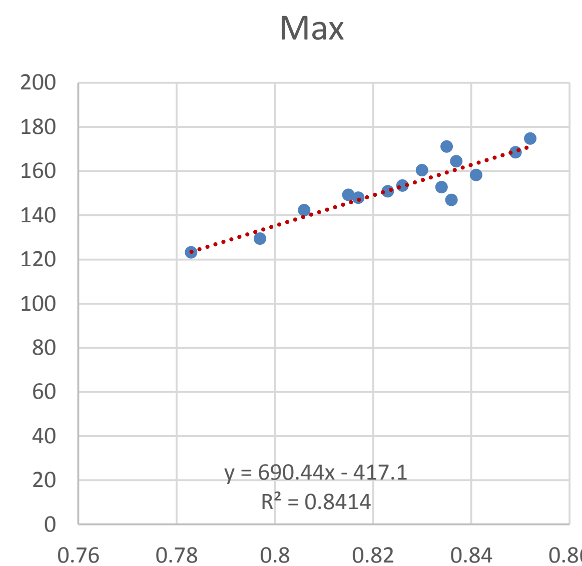
USA national-level simplistic corn yield model



Standard Error	12.5996

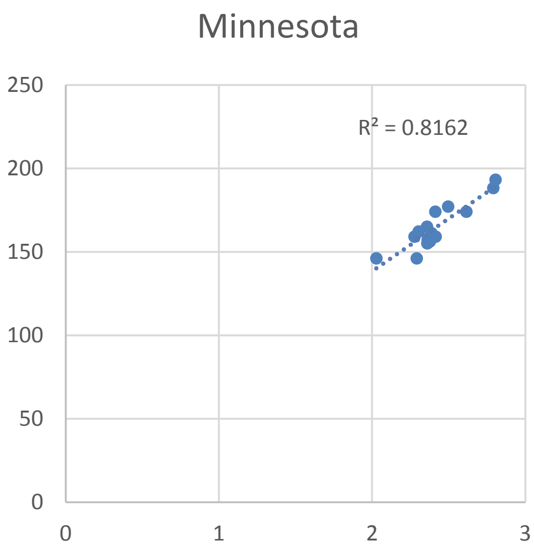


Standard Error	4.0309

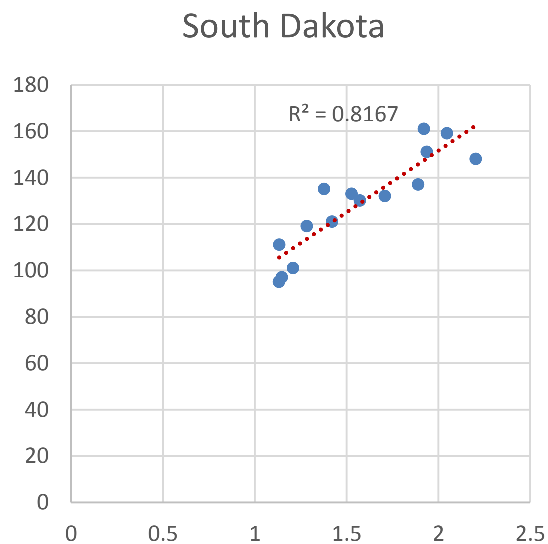


Standard Error	5.9422

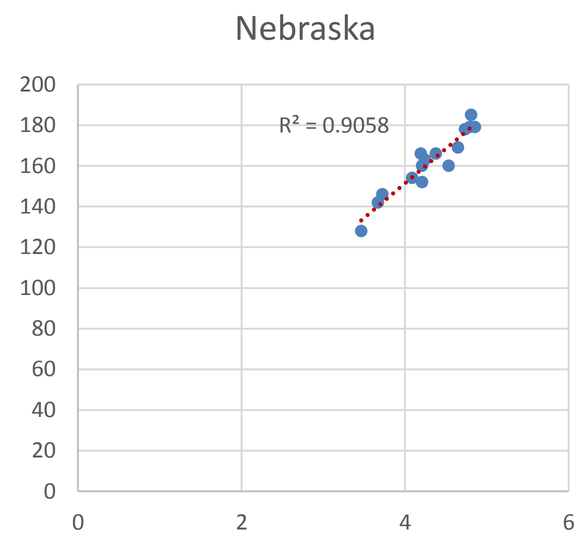
State-level simplistic yield modeling



Standard Error	6.1590

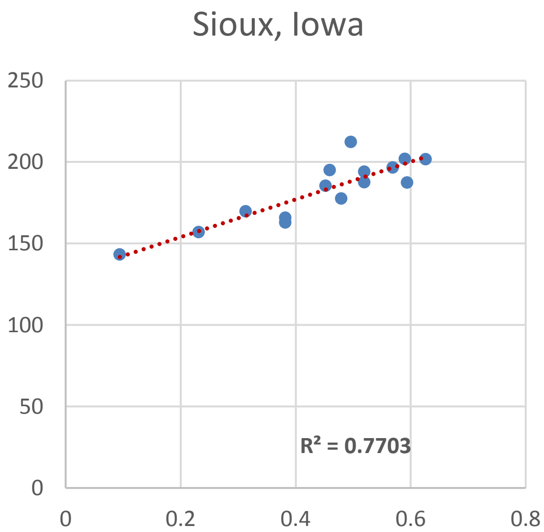


Standard Error	9.4601

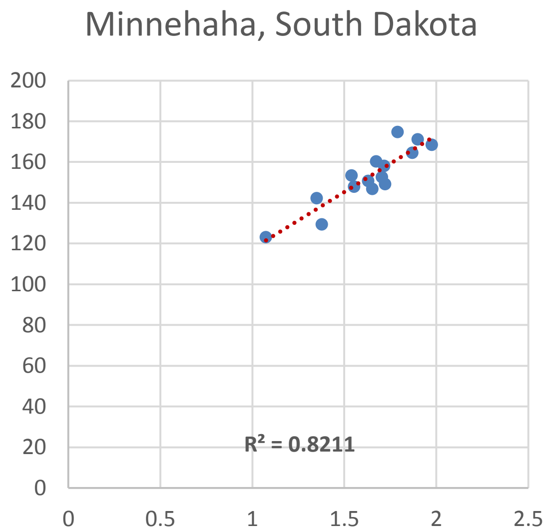


Standard Error	4.9836

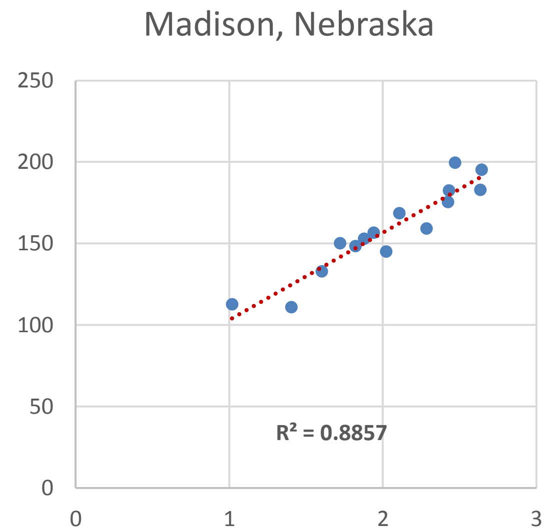
County-level simplistic yield modeling



Standard Error	10.41041

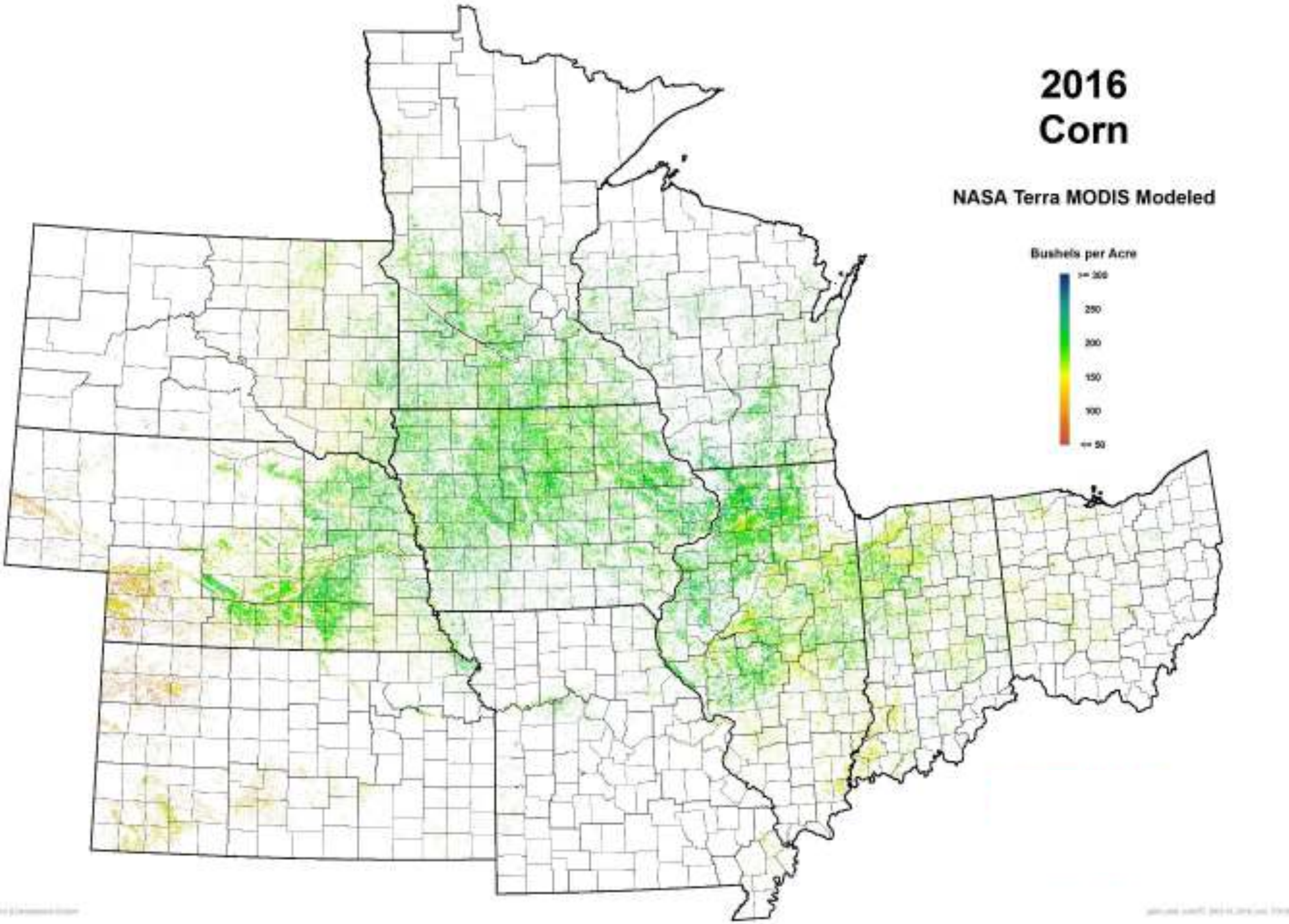


Standard Error	6.31143

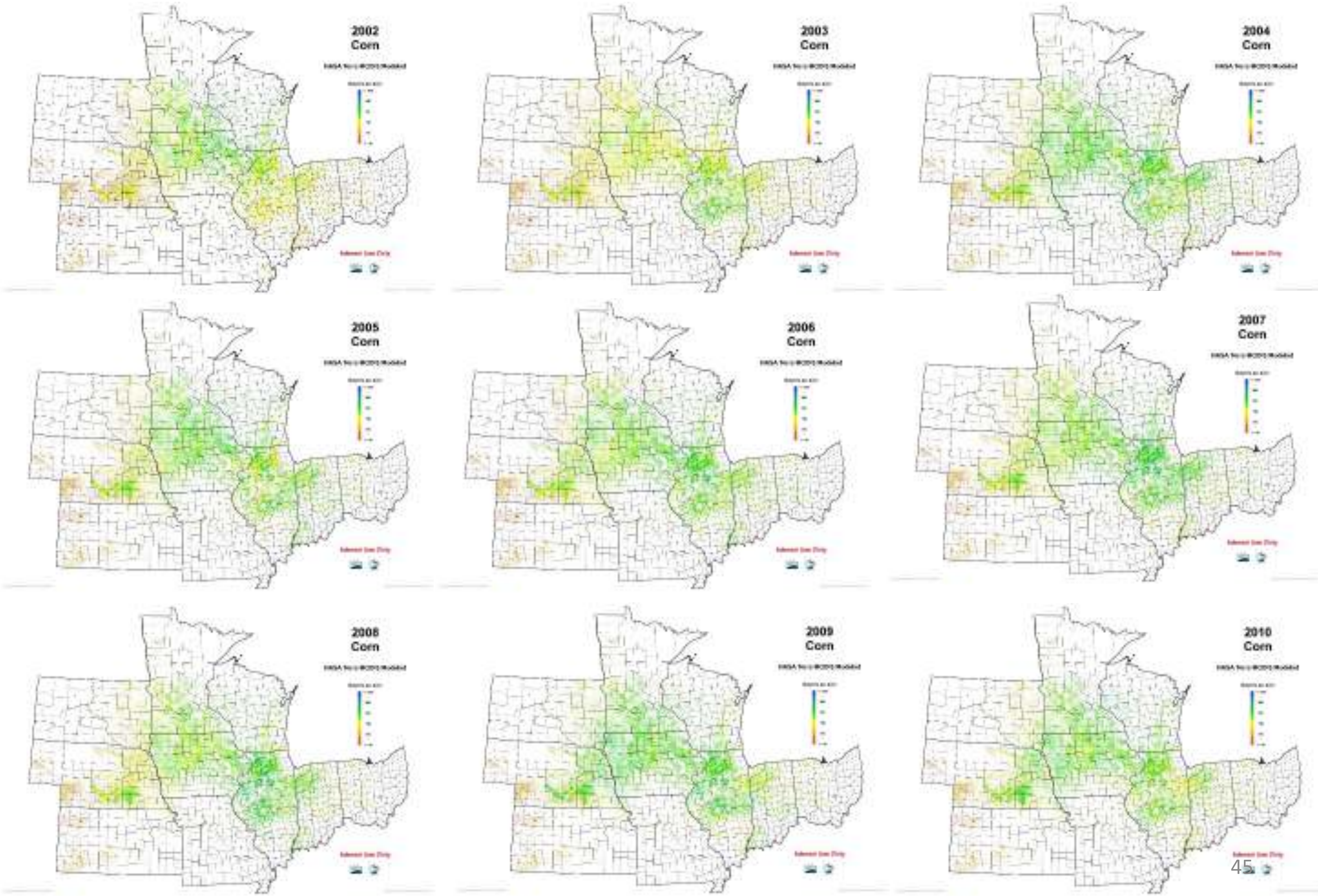


Standard Error	9.377654

Map output still possible



And easy to create time series…

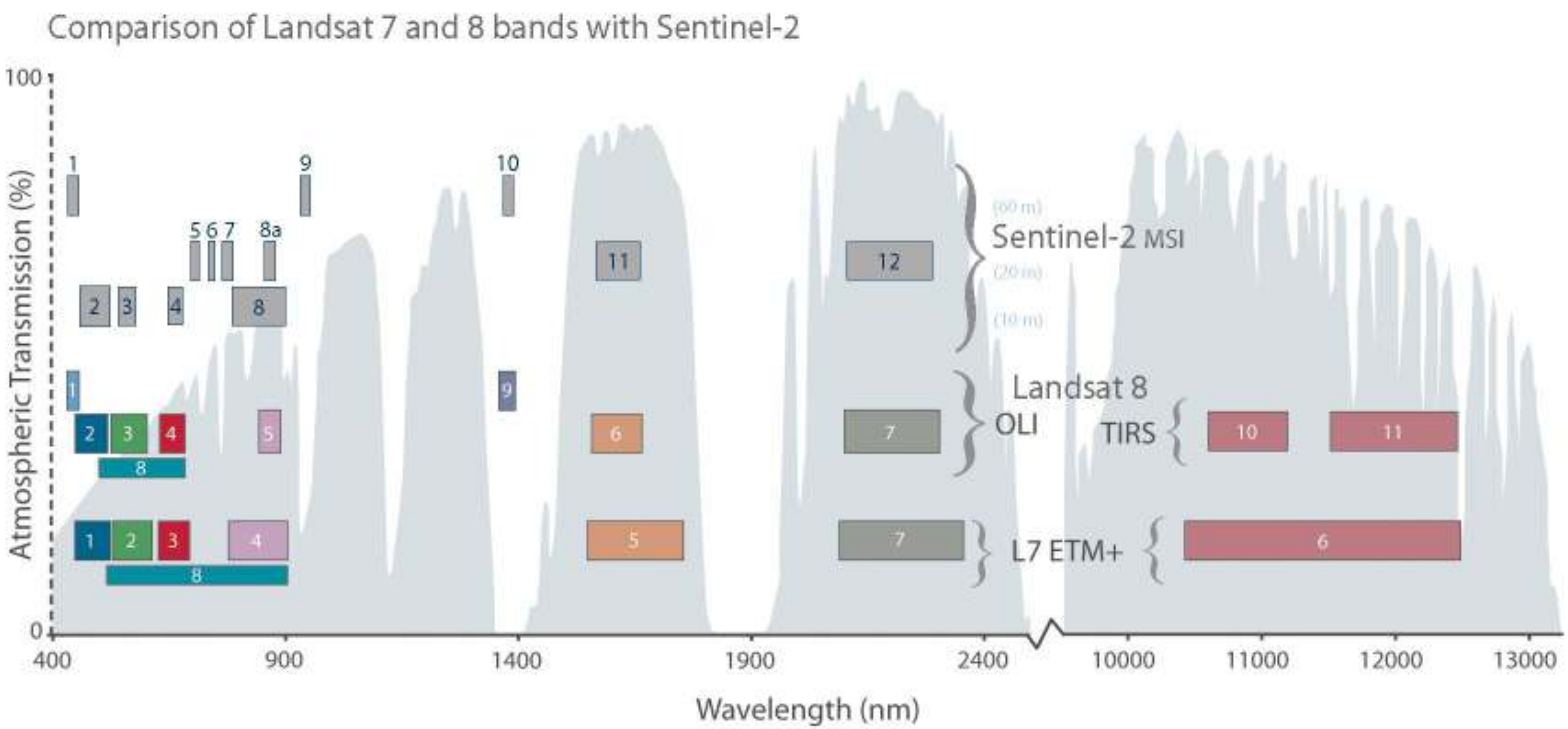


Summary of Remote Sensing for Crop Production Estimation

- **Strengths**
  - Good areal coverage
  - Solid temporal coverage
  - Many free data sources
  - Better sensors on the way
  - Little data latency
  - Fine spatial detail
  - Simple statistical models seem to be as good as complicated ones
  - Cheap computing and analytics has been a boon
- **Weaknesses**
  - Computationally intensive
  - Integrative skill set required
  - Calibration of datasets always ongoing
  - Measurement uncertainties difficult to quantify
  - A variety of noise sources are present
  - No long-term history
  - *In situ* validation lacking
  - Past utility was oversold

David M. Johnson, Geographer
BLS Data Quality Workshop, December 1, 2017
dave.johnson@nass.usda.gov

Sentinel-2 vs Landsat 7 & 8 spectral bands



Acreage estimate for a crop in stratum *h*

$$\hat{y}_h = N_h[\bar{y}_h + b_h(\bar{X}_h - \bar{x}_h)]$$

$N_h = Number\ of\ frame\ units(segments\ in\ frame)$

$\bar{y}_h = \boldsymbol{sample}\ mean\ per\ segment\ of\ reported\ acres\ of\ crop\ cover$

$b_h = Slope\ of\ the\ regression\ of\ acres\ in\ segment\ on\ pixel(acres)$

$\bar{X}_h = \boldsymbol{population}\ mean\ pixels(acres)in\ segment$

$\bar{x}_h = \boldsymbol{sample}\ mean\ pixels(acres)in\ segment$

Estimate of county total for a crop, stratum

$$\hat{T}_{(BF)hc.} = N_{hc}\left[\hat{\beta}_{0h} + \hat{\beta}_{1h}\bar{x}_{hc} + \delta_{hc}\bar{u}_{hc.}\right]$$

$$\bar{u}_{hc.} = \bar{y}_{hc.} - \hat{\beta}_{0h} - \hat{\beta}_{1h}\bar{x}_{hc.}$$ (residual)

1) if σ^2_{within} = 0, use $\delta = 1$,
2) if $\sigma^2_{between}$ = 0, use $\delta = 0$,
3) if < 2 segments use $\delta = 0$,
4) if σ^2_{within} = 1.0, use $\delta = 0$,
5) otherwise use $\delta = \gamma$