


MODIS-based Modeling of Corn and Soybean Yields in the US

American Geophysical Union Fall Meeting - San Francisco - 13 December 2013



Furlough
Day # 3

Maryland Soybean
Field 10/3/2013



David M. Johnson
Geographer

United States Department of Agriculture
National Agricultural Statistics Service



National Agricultural Statistics Service (NASS)

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

NASS - Data and Statistics - Microsoft Internet Explorer

Address: http://www.nass.usda.gov/Data_and_Statistics/index.asp

United States Department of Agriculture
National Agricultural Statistics Service

The 2002 Census of Agriculture is the most comprehensive source of statistics portraying our nation's agriculture

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- Statistics by State

Select a State

Data and Statistics

Quick Stats (Agricultural Statistics Data Base)

NASS publishes U.S., state, and county level agricultural statistics for many commodities and data series. Quick Stats offers the ability to query by commodity, state(s) and year(s), providing the most up-to-date statistics including all revisions. The query dataset can be downloaded for easy use in your database or spreadsheet.

- Query our Quick Stats Data Base

Additional Crops County Resources

Maps of crops county estimates for acreage and yield are available from NASS as both CSV data files and maps.

County data from Quick Stats data is also available in pre-extracted data sets by year and by crop.

Census of Agriculture

To query Census of Agriculture data, choose from the Census years below. To view the Census publications, click here:

- Data Queries for 2002, select below:

Select a Census Query

- Data Queries for 1997, 1992, 1987

Interactive Data

NASS provides a variety of tools for interacting with our Census datasets.

- Interactive Statistical Maps
- Table Lens Application for 1997 Census Data

Last modified: 12/30/05

NASS Home | USDA.gov | FEDSTATS | Economics Statistics System (ESS) | Site Map
FOIA | Accessibility Statement | Privacy Policy | Non-Discrimination Statement | Information Quality | FirstGov | Web

2001 Wildlife Damage Survey

7.7 Percent of Crop Value Lost to Deer and Geese

Maryland farmers lost \$17.2 million of corn, soybeans and wheat to deer or geese during 2001, translates to Maryland farmers losing 7.7 percent of the crop value to deer and geese. Soybeans account for the greatest economic loss, totaling \$9.1 million, 11 percent. Corn losses were \$6.6 million, 5.8 percent and wheat \$1.5 million, 5.6 percent. Deer damage resulted in losses of \$13.6 million, 6.1 percent, while geese losses were \$3.6 million, 1.6 percent.

Production losses totaled 6.0 million bushels. Corn losses were 3.2 million bushels, soybean losses are 2.2 million bushels and wheat accounted for 0.6 million bushels. Production losses to deer were 4.7 million bushels and geese 1.3 million bushels.

In terms of yield, losses to deer were most severe in Central and Western Maryland, while geese damage greater on the Eastern Shore. Corn yield losses of 9.6 bushels per acre and 7.4 bushels per acre were reported in Central and Western Maryland, respectively. The Lower Eastern Shore reported the highest soybean loss of 6.1 bushels per acre.

Sixty-two percent of farms reported deer or geese damage to one or more crops. Damage was reported on 47 percent of farms raising corn, 58 percent of farms growing soybeans and 27 percent of farms with wheat.

Maryland 2001 Crop Loss from Deer

Region	Crop	Acre	Harvested Yield (bushels)	Average Yield Loss (bushels)	Production Loss (bu)	Economic Loss (\$)
Western Maryland	Corn	9,500	114.4	7.4	40,100	83
	Soybeans	300	36.7	3.3	1,200	24
	Wheat	200	45.2	2.3	460	1
Central Maryland	Corn	114,200	98.4	9.6	1,100,200	2,478
	Soybeans	92,200	34.2	3.3	360,260	1,478
	Wheat	38,300	63.3	3.3	126,390	318

USDA NEWS RELEASE

NATIONAL AGRICULTURAL STATISTICS SERVICE
United States Department of Agriculture - Washington, DC 20250
Ag Statistics Hotline: (800) 727-9540 • www.nass.usda.gov

Contact: Ellen Dougherty, (202) 690-8122
Jeff Geuder, (202) 720-2127

USDA FORECASTS RECORD-SETTING CORN CROP FOR 2007

Washington, Aug. 10, 2007 – U.S. history in 2007, according to the National Agricultural Statistics Service, is projected to reach 13.1 billion bushels, 10.6 percent above the 2006 record.

Based on conditions as of August 10, 2007, the Service projects a record corn crop of 13.1 billion bushels, up 3.7 bushels from last year's record of 12.7 billion bushels, behind the 160.4 bushels per acre record set in 2006 on 81 million acres of corn for grain in the United States.

WISCONSIN AGRICULTURAL STATISTICS SERVICE
P.O. Box 8934 Madison, WI 53708-8934
In cooperation with WI Department of Agriculture, Trade and Consumer Protection

2002 Dairy Producer Opinion Survey

November 2002

Wisconsin Milk Production to Recover

Milk production is expected to increase in Wisconsin during the next five years according to a survey conducted by the Wisconsin Agricultural Statistics Service. This statewide survey of producers asked for plans with the assumption that milk prices for the next five years will be at the same level as the past five years. The survey was conducted during May and June 2002.

Based on the survey, 60 percent of producers expect to keep the same herd size, 20 percent intend to increase herd size, and 20 percent intend to discontinue milking by 2007. Actual results will depend on future milk prices, input prices, financing availability, crop yields, and other factors.

The number of herds projected for 2007 shows that the diversity of small to large herds will continue. The most prevalent herd size will remain at 50 to 99 cows.

National Agricultural Statistics Service 2002 Census of Agriculture

United States | All data items are from Chapter 2 - Table 1, Area Summary Highlights: 2002
Selected crops harvested - Land in orchards (acres)

State: United States - County Level | Data Item: Selected crops harvested - Land in orchards (acres)

United States Total: 5,330,439
State Total:
County Total:
County Total:

Download data as CSV | XML | PDF

Help | Print | Return to

Legend

Scale: National

Zero or Data Withheld <= 20,000
20,001 to 40,000
40,001 to 60,000
60,001 to 80,000
80,001 to 100,000
100,001 >=

Color: Green

Source: USDA-NASS 2002 Census of Agriculture
© USDA-NASS 2005-2006

Navigate: Mouse-over a specific state/county to view the state/county level data. Right click to zoom (option-click for MAC users). Hold the Alt key and click-drag to pan. For additional assistance with this application, click here to view the support page.

All Milk Price, Wisconsin Annual Average, 1989 - 2002 \$/cwt

Wisconsin Dairy Herds by Herd Size

Milk cow herd size	May 2002 herds	May 2007 herds (projected) %	Change 2007/2002
1-29	2,800	1,440	-45
30-49	4,700	3,440	-27
50-99	7,400	5,600	-24
100-199	1,900	2,080	+9
200-499	700	600	-29
500+	200	440	+120
Total	17,500	19,900	+20

1/7/07 The May 2007 projection is based on farmers' opinions May-June 2002, with the assumption that milk prices for the next five years will be at the same level as the past five years.

Wisconsin Dairy Farmer Plans for May 2007 1/ by Herd Size

Milk cow herd size	Herds	Keep same herd size	Increase herd size	Discontinue milking
1-29	2,800	47	17	58
30-49	4,700	71	9	20
50-99	7,400	63	19	18
100-199	1,900	53	37	10
200-499	700	33	59	8
500+	200	22	78	0
Total	17,500	42	29	20

1/7/07 The May 2007 projection is based on farmers' opinions May-June 2002, with the assumption that milk prices for the next five years will be at the same level as the past five years.

Percent of Herds by Size Group 2007 Projection

1-29: 7.2%
30-49: 19.1%
50-99: 31.7%
100-199: 11.1%
200-499: 3.9%
500+: 1.8%

www.nass.usda.gov

NASS Research and Development Division

Geospatial Information Branch

NASS - Research and Science - Windows Internet Explorer

http://www.nass.usda.gov/Research_and_Science/index.asp

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USDA United States Department of Agriculture
National Agricultural Statistics Service

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Statistics by State

Select a State

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Research and Science

Spatial Data

Vegetation Condition Images

Cropland Data Layer

Image Gallery (2003) available for these states: Arkansas, Illinois, Indiana, Iowa, N. Dakota, Mississippi, Missouri, Nebraska, Wisconsin)

Land Use Strata for Selected States

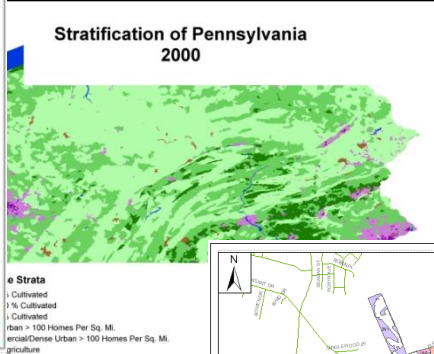
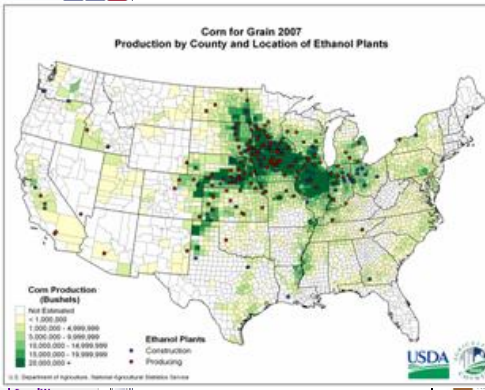
Census of Agriculture

2002 Census Map Gallery

2002 Maps: Gallery | Star Tree | List

Interact with Data (1997)

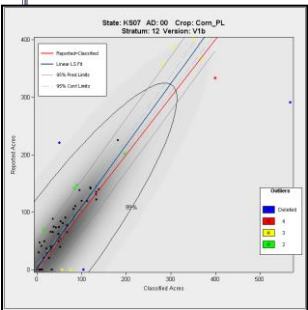
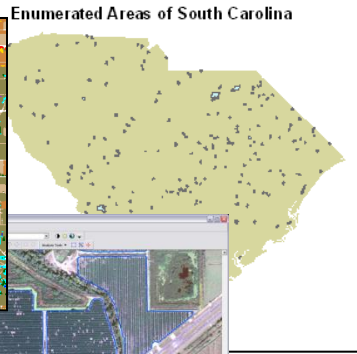
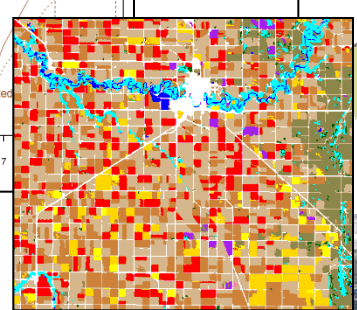
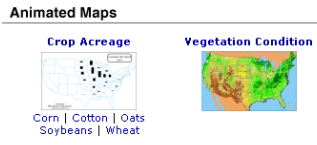
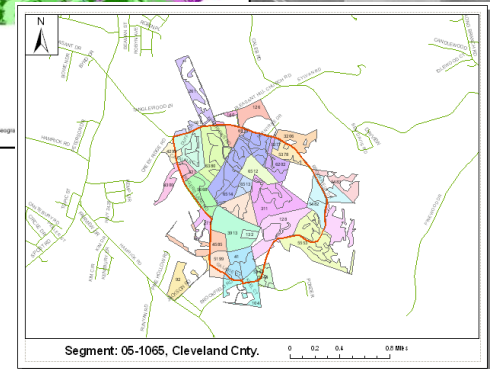
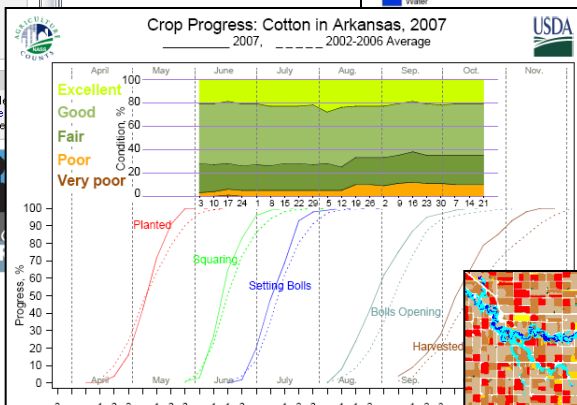
"Linked Micromap" Plots (1997):
Corn | Cotton | Hay | Soybeans | Wheat



- Also See
- Research Associate
 - Seasonal Progress and Condition
 - Remotely Sensed Data
 - Crop Acreage
 - Crop Yield
 - Future Vision

Media Help

To view animated map files you must have Quicktime installed on your computer.



ers and Presentations

733 archived reports available

Area: GIS | Survey | Yield

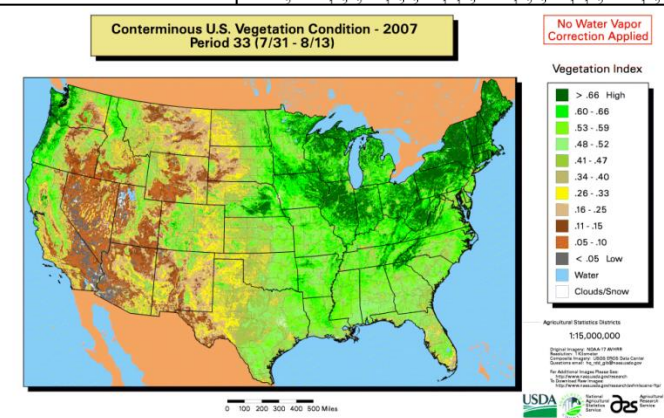
Star Tree" Diagram

Presenter

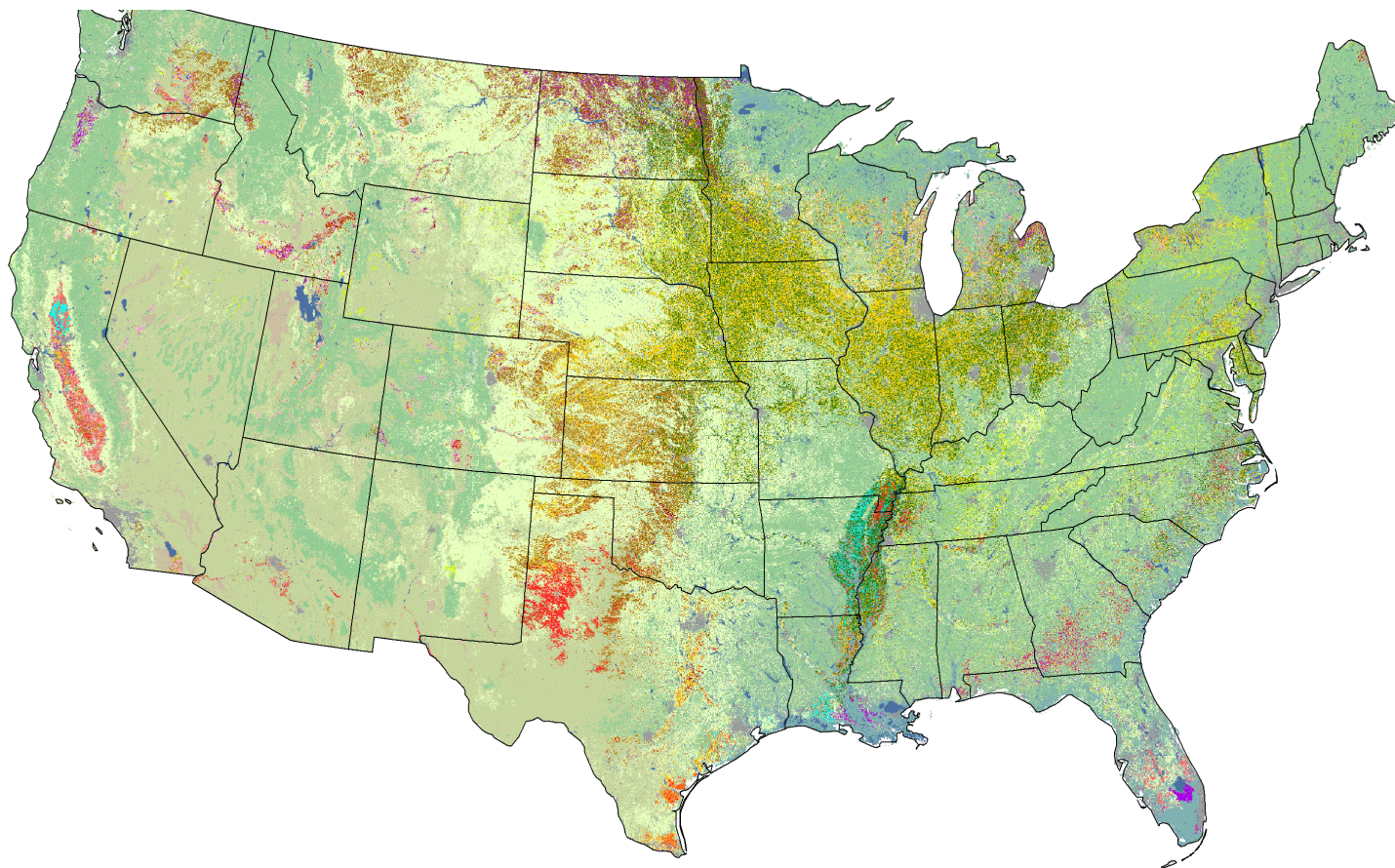
Last modified

Statistics System (ESS) | Site Map

Non-Discrimination Statement | In



Annually derived Cropland Data Layer (CDL)



Major Land Cover Categories

Agriculture

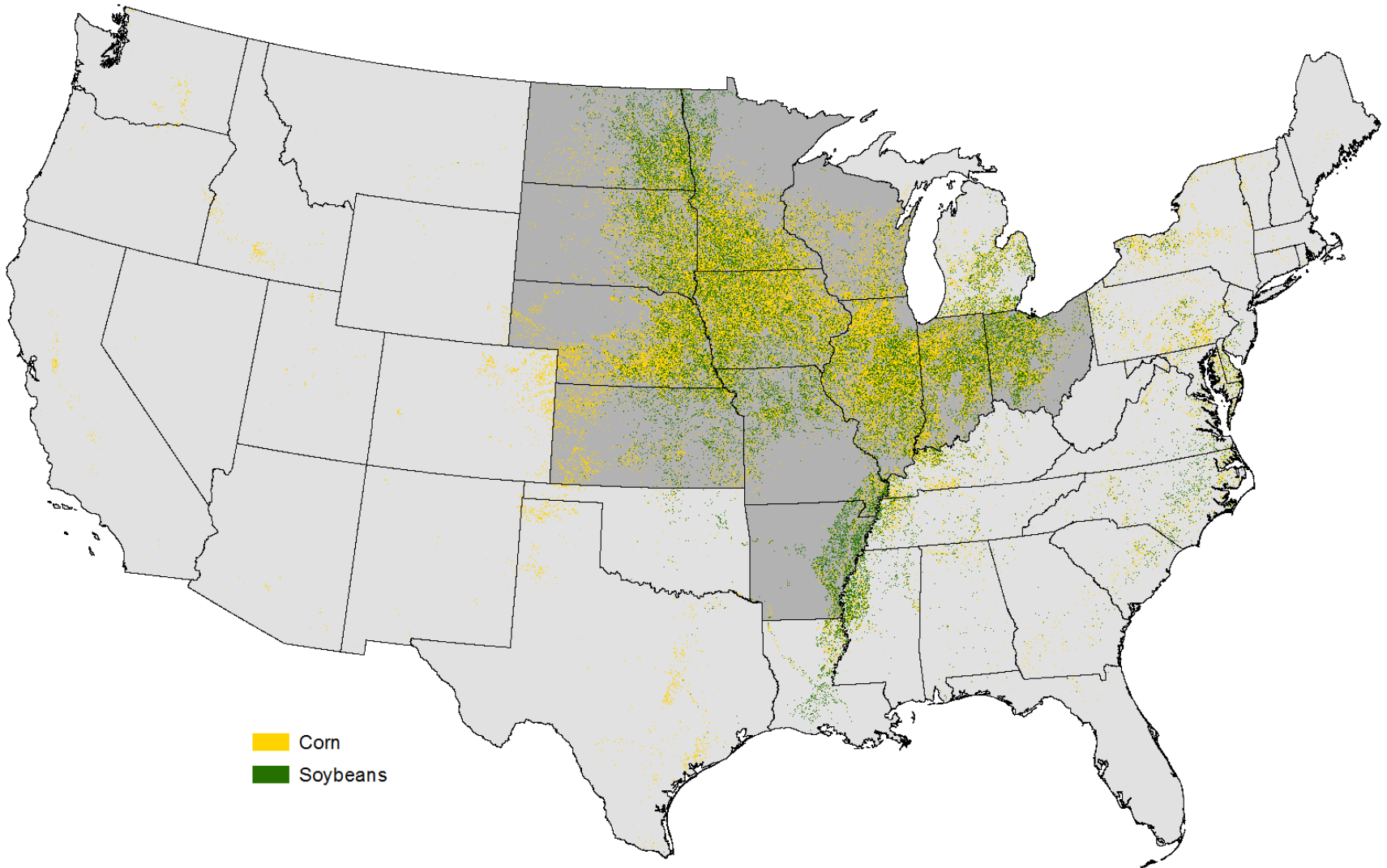
Pasture/Grass	Fallow/Idle Cropland	Sorghum
Corn	Alfalfa	Other Small Grains
Soybeans	Cotton	Rice
All Wheat	Other Crops	
Other Hay	Vegetables/Fruits/Nuts	

Non-Agriculture

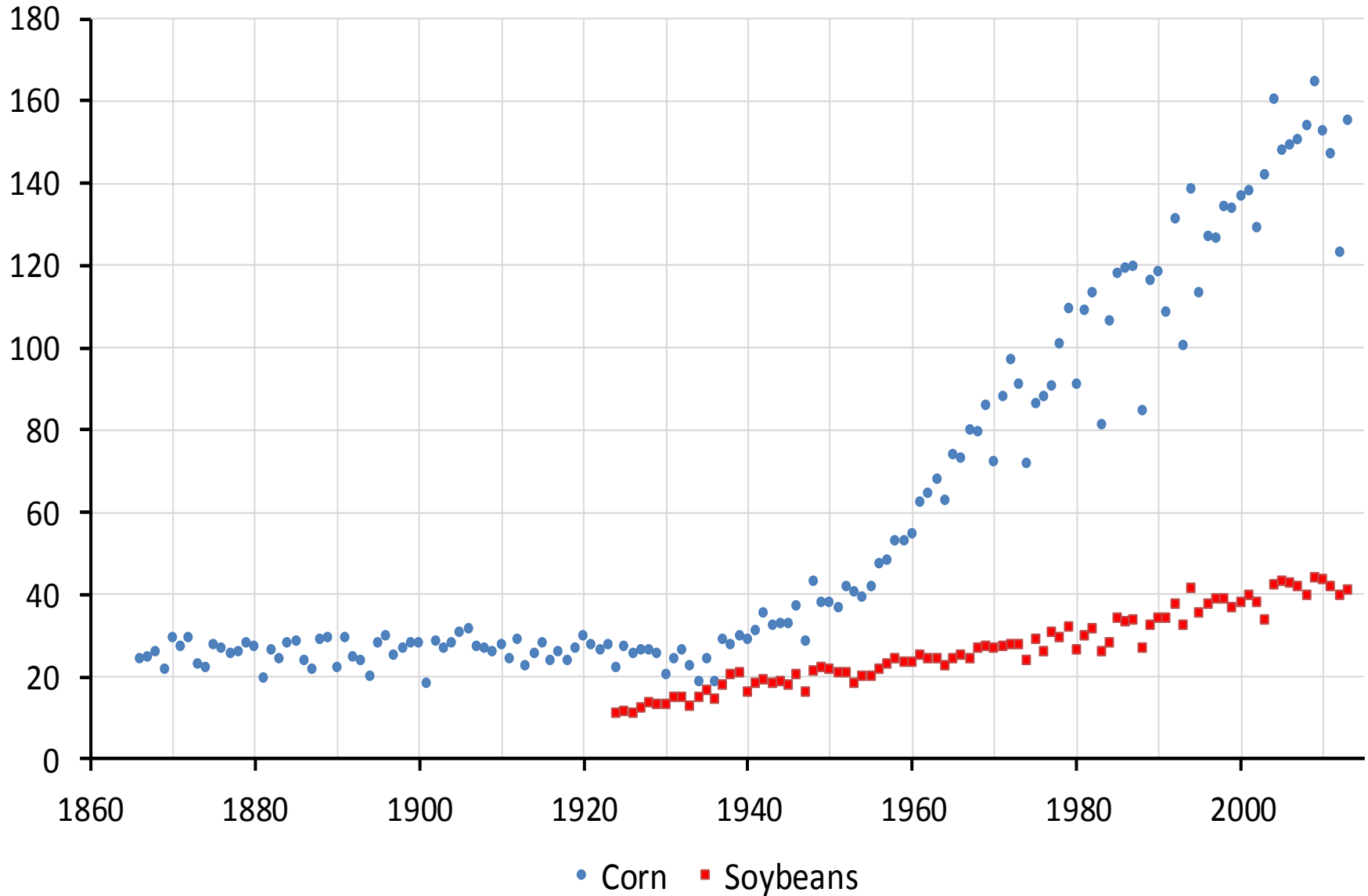
Woodland	Barren
Shrubland	Perennial Ice/Snow
Urban/Developed	
Wetlands	
Water	

Freely available over Internet via “Cropscape”

Region with the bulk of corn and soybean production



United States Yield (bushels/acre)



NASS Crop Production reports

Corn Area Planted for All Purposes and Harvested for Grain, Yield, and Production – States and United States: 2009-2011 (continued)

State	Yield per acre			Production		
	2009 (bushels)	2010 (bushels)	2011 (bushels)	2009 (1,000 bushels)	2010 (1,000 bushels)	2011 (1,000 bushels)
Alabama	108.0	116.0	114.0	27,000		
Arizona	175.0	210.0		3,500		
Arkansas	148.0	150.0	142.0	60,680		
California	180.0	195.0	185.0	28,800		
Colorado	153.0	151.0	133.0	151,470		
Connecticut	(NA)	(NA)	(NA)	(NA)		
Delaware	145.0	115.0	130.0	23,635		
Florida	100.0	105.0	100.0	3,700		
Georgia	140.0	145.0	158.0	51,800		
Idaho	180.0	180.0	185.0	14,400		
Illinois	174.0	157.0		2,053,200		
Indiana	171.0	157.0	146.0	933,660		
Iowa	182.0	165.0	172.0	2,420,600		
Kansas	155.0	125.0	107.0	598,300		
Kentucky	165.0	124.0	139.0	189,750		
Louisiana	132.0	140.0	135.0	80,520		
Maine ¹	(NA)	(NA)	(NA)	(NA)		
Maryland	145.0	106.0	109.0	61,625		
Massachusetts ¹	(NA)	(NA)	(NA)	(NA)		
Michigan	148.0	150.0	153.0	309,320		
Minnesota	174.0	177.0	156.0	1,244,100		
Mississippi	126.0	136.0	128.0	87,570		
Missouri	153.0	123.0	114.0	446,760		
Montana	152.0	135.0	130.0	3,952		
Nebraska	178.0	166.0	160.0	1,575,300		
Nevada	(NA)	(NA)	(NA)	(NA)		
New Hampshire	(NA)	(NA)	(NA)	(NA)		
New Jersey	143.0	114.0	123.0	10,010		
New Mexico	185.0	180.0	180.0	9,250		
New York	134.0	150.0	133.0	79,730		
North Carolina	117.0	91.0	84.0	93,600		
North Dakota	115.0	132.0	105.0	200,100		
Ohio	174.0	163.0	158.0	546,360		
Oklahoma	105.0	130.0	90.0	33,600		
Oregon	215.0	200.0	215.0	6,890		
Pennsylvania	143.0	128.0	111.0	131,560		
Rhode Island	(NA)	(NA)	(NA)	(NA)		
South Carolina	111.0	91.0	65.0	35,520		
South Dakota	151.0	135.0	132.0	706,690		
Tennessee	148.0	117.0	131.0	87,320		
Texas	130.0	145.0	93.0	254,800		
Utah	155.0	172.0	164.0	2,635		
Vermont ¹	(NA)	(NA)	(NA)	(NA)		
Virginia	131.0	67.0	118.0	43,230		
Washington	215.0	205.0	225.0	22,575		
West Virginia	125.0	90.0	114.0	3,790		
Wisconsin	153.0	162.0	156.0	448,290		
Wyoming	140.0	121.0	130.0	6,300		
United States	164.7	152.8	147.2	13,091,862		

(NA) Not available
¹ Area harvested for grain not estimated.

Crop Production 2011 Summary (January 2012)
USDA, National Agricultural Statistics Service



ISSN: 1936-3737

Released August 11, 2011, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA).

Planted Acreage Update

Survey respondents who reported acreage as not yet planted in Minnesota, Montana, North Dakota, and South Dakota during the survey conducted in preparation for the *Acreage* report, released June 30, 2011 were re-contacted in July to determine how many of those acres were planted or still intended to be planted. Acreage estimates in this report reflect this updated information.

- Corn Production Up 4 Percent from 2010**
- Soybean Production Down 8 Percent from 2010**
- Cotton Production Down 9 Percent from 2010**
- All Wheat Production Down 1 Percent from July Forecast**

Corn production is forecast at 12.9 billion bushels, up 4 percent from 2010. If realized, this will be the third largest production total on record for the United States. Based on conditions as of August 1, yields are expected to average 153.0 bushels per acre, up 0.2 bushel from 2010, and the fourth highest yield on record. Acreage planted for all purposes is estimated at 92.3 million acres, unchanged from the June estimate. Area harvested for grain is forecast at 84.4 million acres, down less than 1 percent from June but up 4 percent from 2010.

Soybean production is forecast at 3.06 billion bushels, down 8 percent from last year. Based on August 1 conditions, yields are expected to average 41.4 bushels per acre, down 2.1 bushels from last year. Area for harvest in the United States is forecast at 73.8 million acres, down less than 1 percent from June and down 4 percent from 2010. Planted area for the Nation is estimated at 75.0 million acres, down fractionally from June.

All cotton production is forecast at 16.6 million 480-pound bales, down 9 percent from last year's 18.1 million bales. Yield is expected to average 822 pounds per harvested acre, up 10 pounds from last year. Upland cotton production is forecast at 15.8 million 480-pound bales, down 10 percent from 2010. American Pima production is forecast at 737,200 bales, up 46 percent from last year. Producers expect to harvest 9.67 million acres of all cotton, down 10 percent from 2010. This harvested total includes 9.38 million acres of Upland cotton and 287,500 acres of Pima cotton.

All wheat production, at 2.08 billion bushels, is down 1 percent from the July forecast and down 6 percent from 2010. Based on August 1 conditions, the United States yield is forecast at 45.2 bushels per acre, up 0.6 bushel from last month but down 1.2 bushels from last year.

Crop Production



United States
Department of
Agriculture

National
Agricultural
Statistics
Service



ISSN: 1057-7822

Crop Production 2011 Summary

January 2012



Published no later
than the 12th of
each month.



Yields results primarily derived from two surveys

Agricultural Yield

- Farmer reported survey data of expected crop yields.
- Data obtained throughout the growing season.
- Conducted in all states except Alaska and Hawaii.
- Sample size in the 1000s per state.
- Farm operator contacts are selected from the March Crops/Stocks survey (small grains) and the June Crops/Stocks survey (late season crops and tobacco).
- Primarily telephone based.



Objective yield

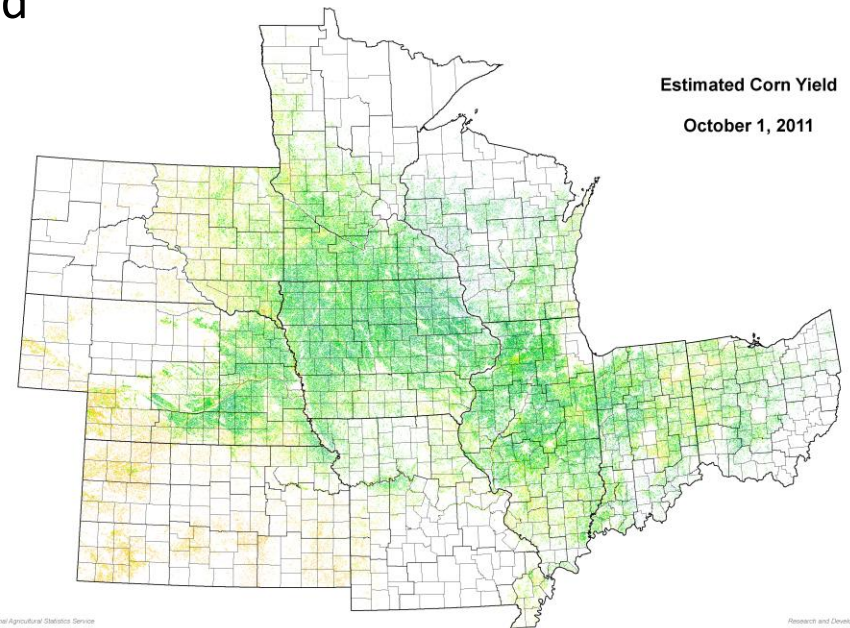
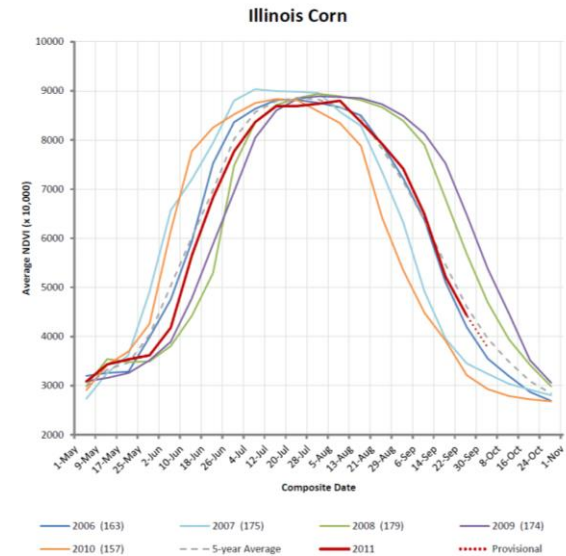
- Corn, Cotton, Soybeans, Wheat, Potatoes.
- Only done in states where the commodities are primarily found.
- Samples selected from areas found in June Area Survey (“Acreage”).
- Performed at 100s of sample sites per state.
- Biophysical plant/seed measurements obtained.
- Each plot revisited a few times per season.



Remote Sensing for Yield Estimation

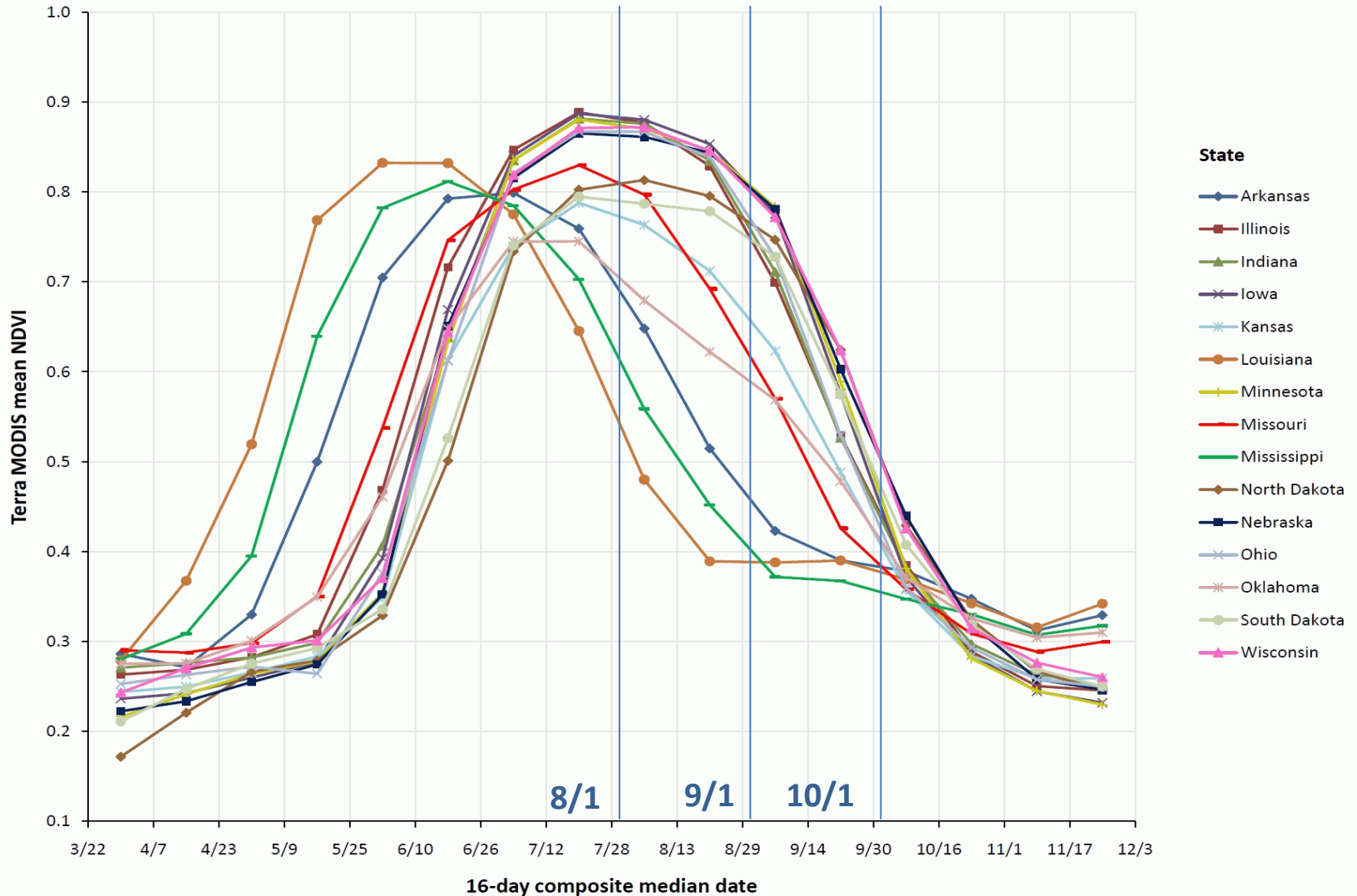
A third method...

- Premise
 - There is a known relationship between crop
 - Biomass, vigor, “greenness”, NDVI
 - and
 - Crop yield
 - Also temperature and rainfall too.
- Utilize MODIS data to obtain biomass and temperature variables
- Utilize Nexrad Ground radar to estimate precipitation
- Produce for national, state, ASD, and county
 - Corn and soybeans only
 - “Speculative” region only
 - i.e. Corn Belt
- Be independent of other methods

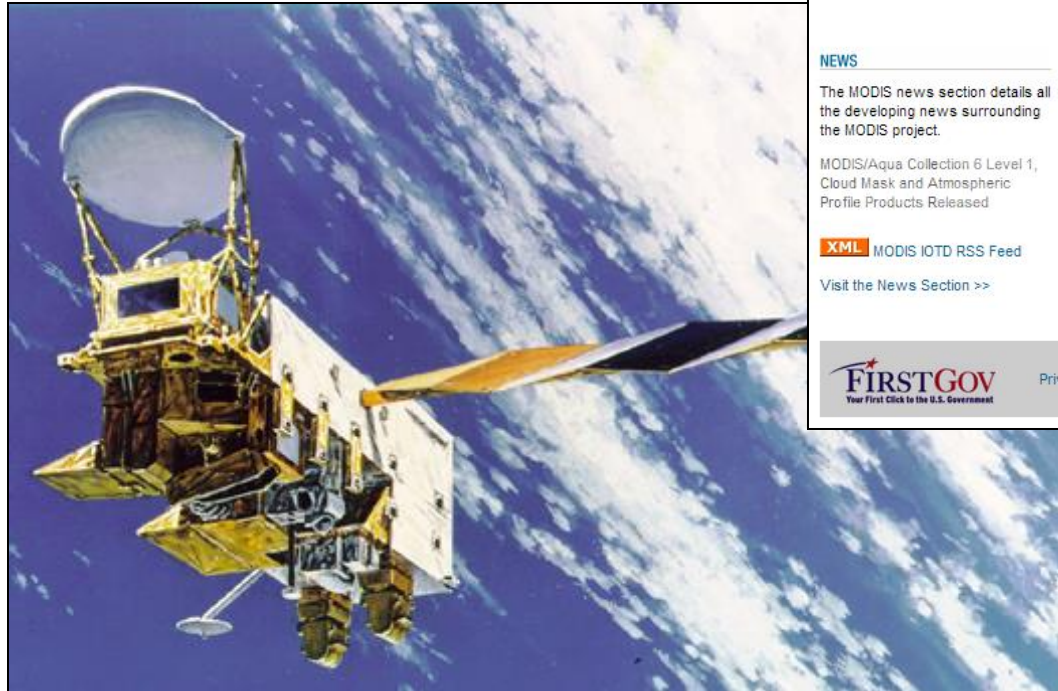



Phenology with Crop Production report timing

Corn 5-year average 2006-2010



Moderate Resolution Imaging Spectroradiometer (MODIS)



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DATA

The MODIS Data section contains everything from ATBDs to Product Descriptions to tutorials on ordering MODIS data from the various DAACs. Peruse the Data section today.

NEWS

The MODIS news section details all the developing news surrounding the MODIS project.


MODIS/Aqua Collection 6 Level 1, Cloud Mask and Atmospheric Profile Products Released

XML MODIS IOTD RSS Feed





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IMAGES

Super Typhoon Jelawat (18W) in the Philippine Sea

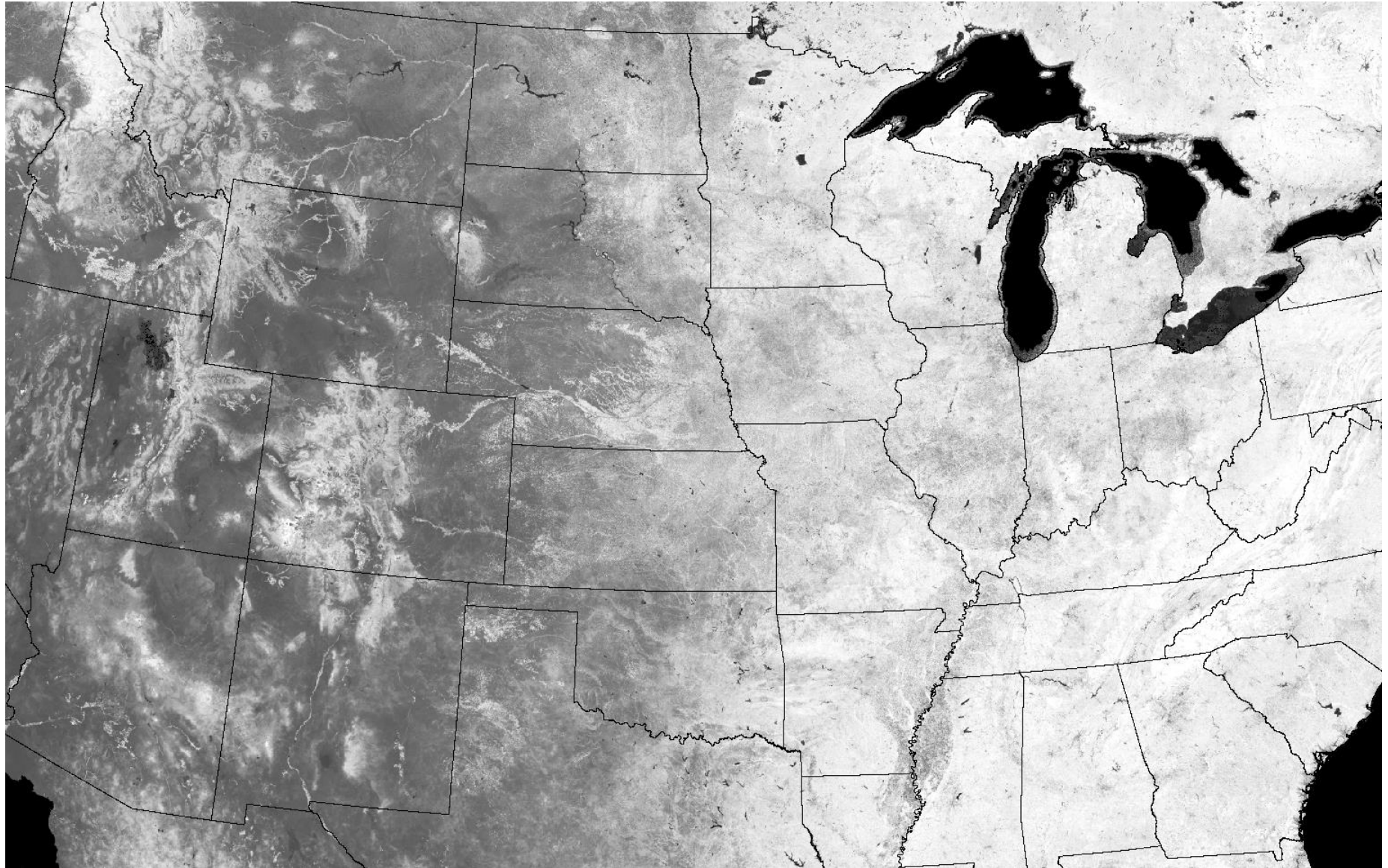


DISCIPLINES

-  Atmosphere
-  Land
-  Ocean
-  Calibration

 Privacy Policy and Important Notices  Curator: Brandon Maccherone
NASA Official: Shannell Frazier

MODIS NDVI data example



Calculation from surface reflectance 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

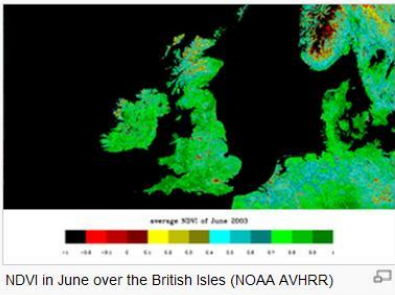
- Brief history
- Rationale
- Performance and limitations
- See also
- References
- External links

Brief history

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




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]



average NDVI of June 2003

NDVI in June over the British Isles (NOAA AVHRR)



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

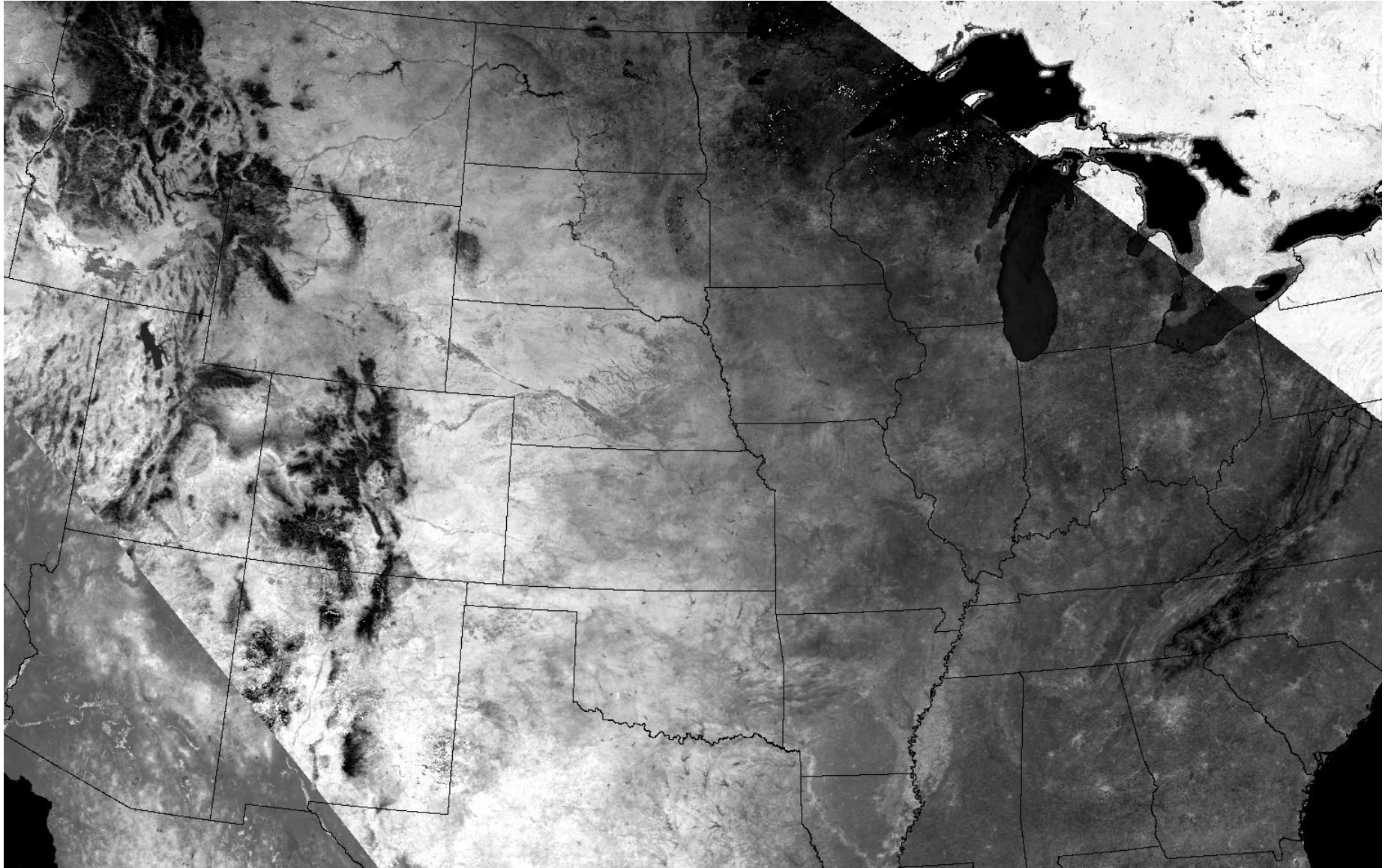
NIR = near-infrared
VIS = visible

Ranges from -1.0 to 1.0

NDVI is a related to

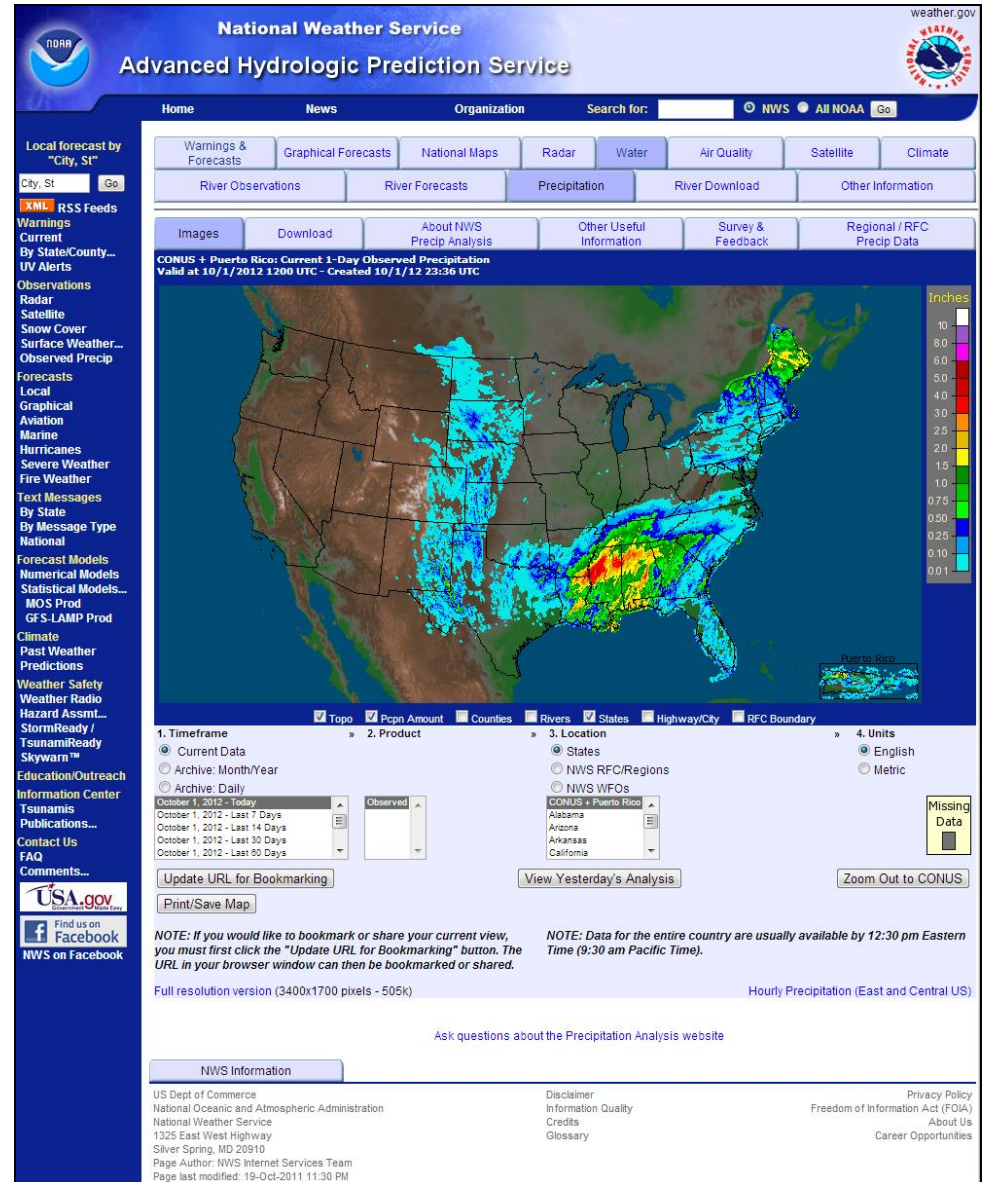
- Plant health
- Chlorophyll content
- “Greenness”
- Biomass
- Vegetation vigor

MODIS LST data example

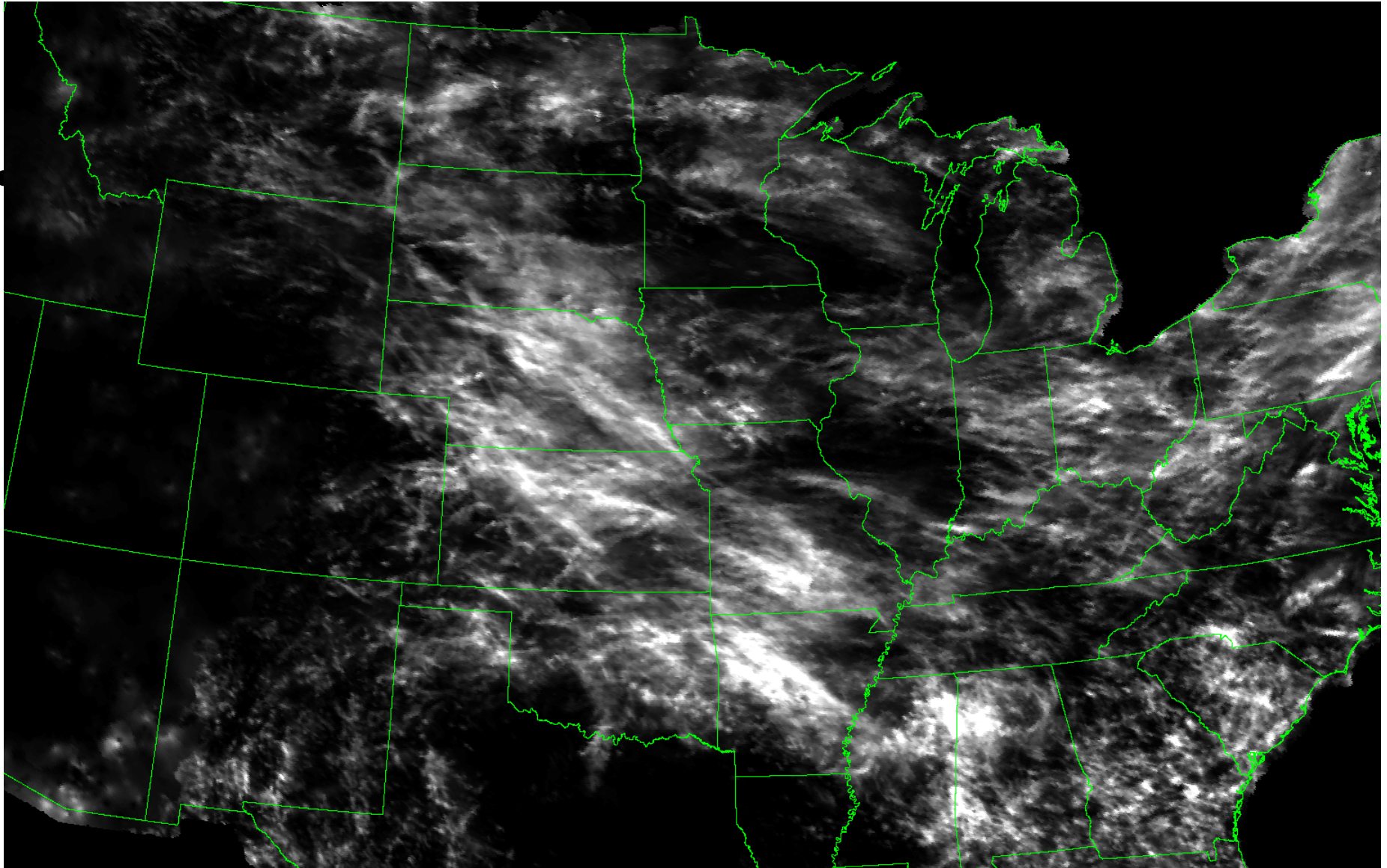


Nexrad-based Precipitation estimates

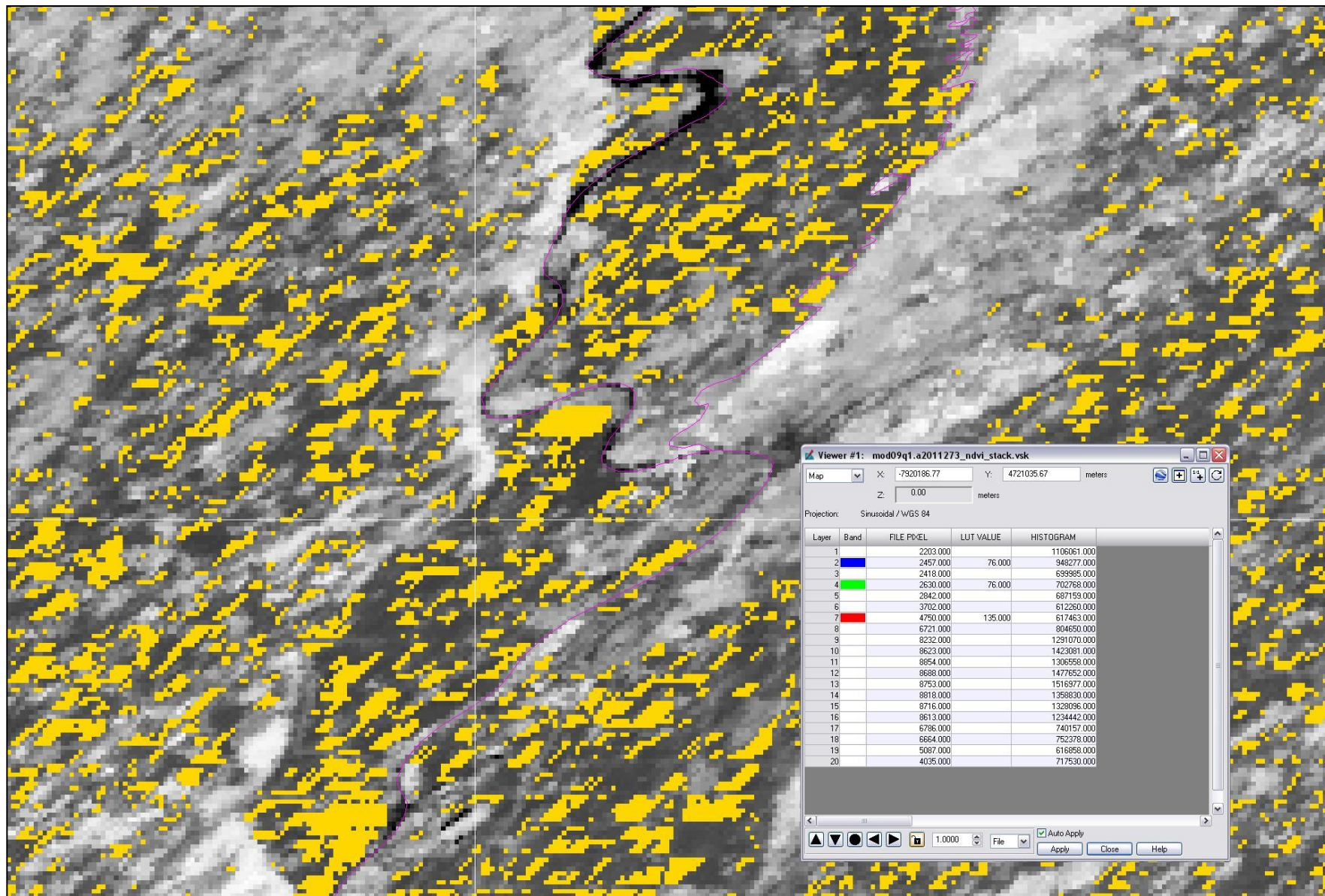
- GIS-ready product
 - ESRI Shapefile format
- Generated daily
 - Little latency
- ~4km grid
- 2005 - current



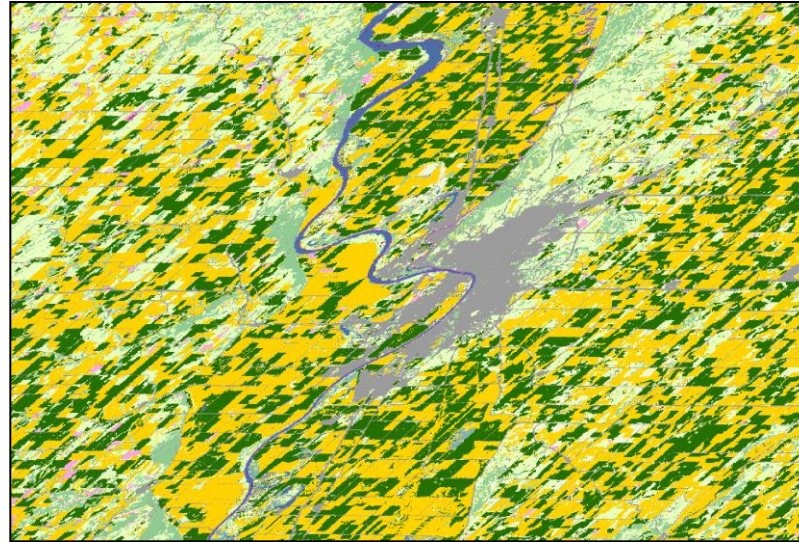
NexRad Rainfall Data example



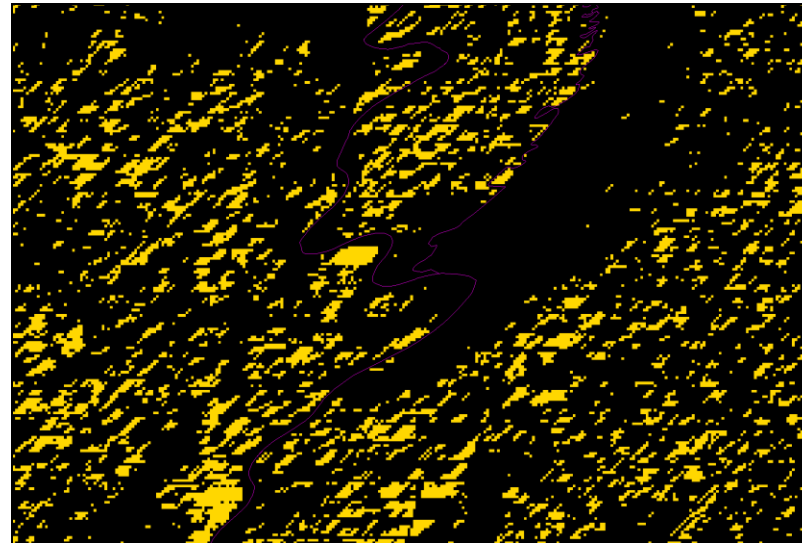
Intersecting corn "mask" with MODIS data



Establishing the pixels that are only corn



NASS CDL



MODIS-scaled
High probability sample
of corn areas

County-level modeling with “composite” modeling

- Historical NASS county-level yields as dependent variable
 - 2006-2011
- Analysis over “Speculative” corn and soybean region
- Four timely possible predictor (independent) variables
 - NDVI (Normalized Difference Vegetation Index)
 - derived from Terra satellite MODIS surface reflectance imagery
 - LST (Land Surface Temperature) from day and night
 - derived from Aqua satellite MODIS thermal imagery
 - Precipitation
 - derived from NOAA/NWS Nexrad composite
- Utilizing 8-day composited mosaic products for each
 - Mid-February through late September
- Modeling/mining using Rulequest Cubist software
 - Regression tree based

County-level database developed

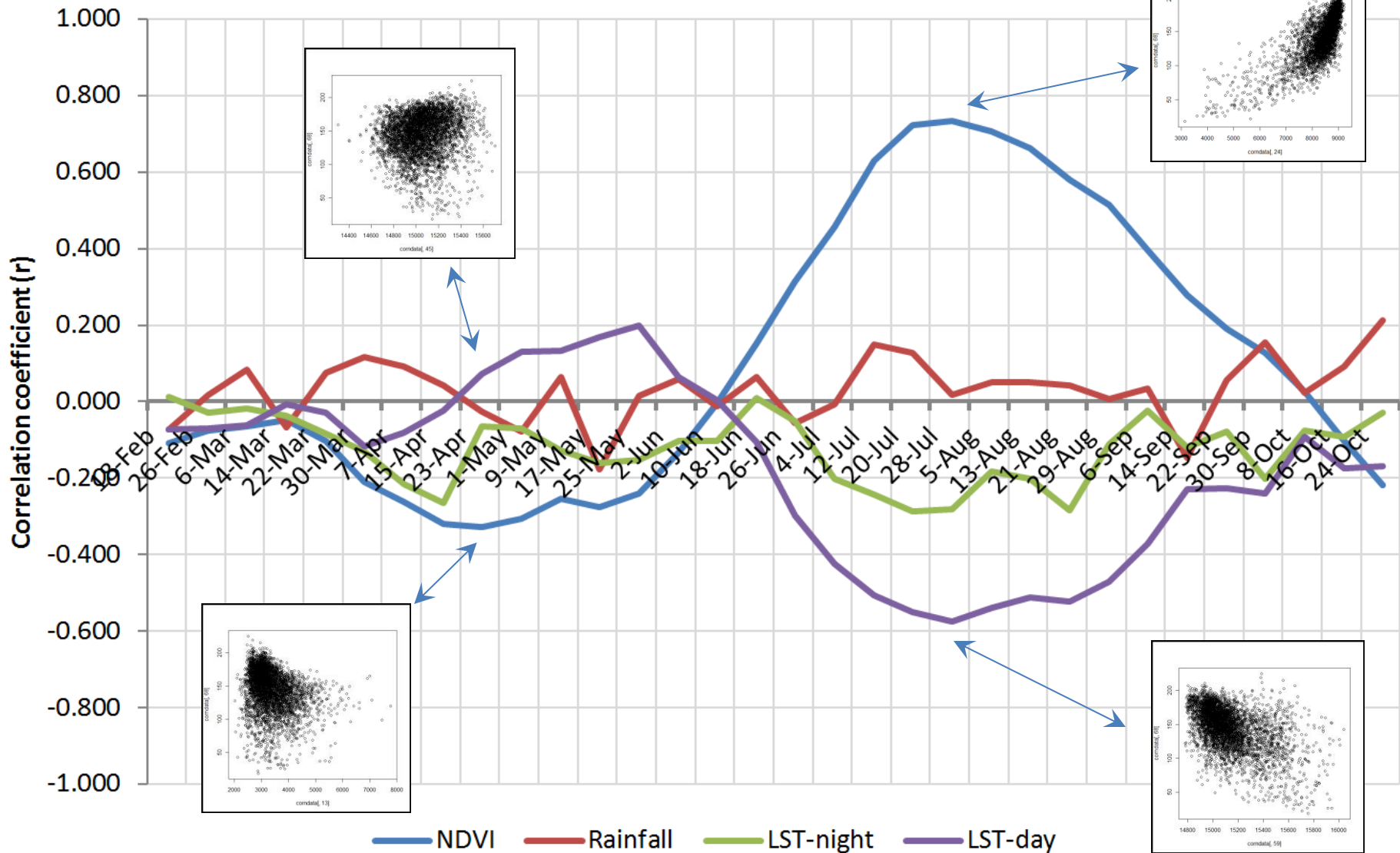
- Potential predictor variables (independent)
 - State (All major production Corn Belt states)
 - County (for each that had a published estimate, ~1000 of them)
 - Year (2006 – 2011)
 - 32 for each ranging every 8 days from February 18 – October 30
 - NDVI
 - Daytime LST (1:30 PM)
 - Nighttime LST (1:30 AM)
 - NWS Precipitation estimates
 - Thus 132 in total
- Forecast variable (dependent)
 - NASS published county level yield
- Sample size to evaluate ~5000 records

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
1	20	119	2009	2263.17	2276.58	2303.59	2348.65	2434.37	2359.19	2266.35	2288.19	2367.71	2512.1	2629.59	28
2	20	69	2009	2288.49	2311.38	2342.2	2339.95	2407.06	2383.9	2340.03	2488.27	2703.84	2684.03	2654.48	28
3	20	119	2007	2276.42	2251.23	2264.43	2352.61	2469.31	2547.4	2619.07	2684.33	2815.85	2966.01	3141.06	33
4	20	81	2009	2218.23	2247.03	2304.9	2340.96	2421.18	2349.36	2270.35	2346.69	2446.1	2476.15	2472.75	24
5	31	137	2009	2167.21	2154.48	2139.61	2156.15	2212.33	2278.63	2384.85	2470.95	2573.56	2613.23	2606.06	27
6	20	175	2007	2232.36	2255.85	2303.21	2438.8	2705.49	2732.7	2735.31	2733.36	2854.66	3053.56	3107.51	32
7	17	187	2008	1766.18	2556.21	2600.69	2643.94	2644.2	2590.61	2594.14	2706.57	2852.78	3125.75	3459.15	34
8	19	93	2009	1981.28	2104.24	2312.87	2173.23	2118.37	2141.06	2191.56	2315.99	2460.3	2716.56	2887.91	30
9	31	185	2009	2116.76	2196.12	2298.1	2295.07	2297.18	2361.89	2379.85	2411.81	2493.01	2683.23	2960.81	31
10	17	203	2008	2163.13	2259.22	2355.42	2618.68	2614.77	2551.36	2627.17	2764.98	2829.49	2942.49	3344.19	33
11	17	109	2008	2527.91	2730.11	2685.04	2709.46	2770.32	2661.12	2665.43	2793.58	2972.49	3209.61	3650.63	35
12	31	81	2009	2142.37	2188.07	2278.81	2282.22	2292.83	2342.79	2365.32	2406.9	2496	2665.16	2881.11	31
13	17	203	2007	964.94	2274.4	2601.68	2709.84	2777.16	2584.11	2568.92	2783.05	3024.46	3052.39	3121.62	34
14	19	165	2009	2077.56	2064.12	2053.83	2155.59	2357.15	2276.43	2252.18	2341.4	2441.82	2643.78	3136.29	34
15	20	81	2007	2350.12	2276.67	2247.89	2383.91	2661.31	2660.21	2643.89	2631.8	2883.8	3317.63	3184.67	34
16	17	175	2008	1352.35	1906.66	2479.59	2545.58	2607.91	2503.92	2507.45	2621.58	2781.29	2988.94	3283.28	35
17	31	99	2009	2141.86	2118.68	2121.94	2139.96	2196.7	2261.97	2360.63	2444.19	2524.94	2535.12	2579.6	26
18	19	35	2009	2131.72	2203.73	2379.83	2237.11	2157.33	2182.48	2230.26	2375.26	2546.31	2704.29	2947.32	31
19	20	22	2009	2313.33	2313.33	2313.33	2313.33	2313.33	2313.33	2313.33	2313.33	2313.33	2313.33	2313.33	23

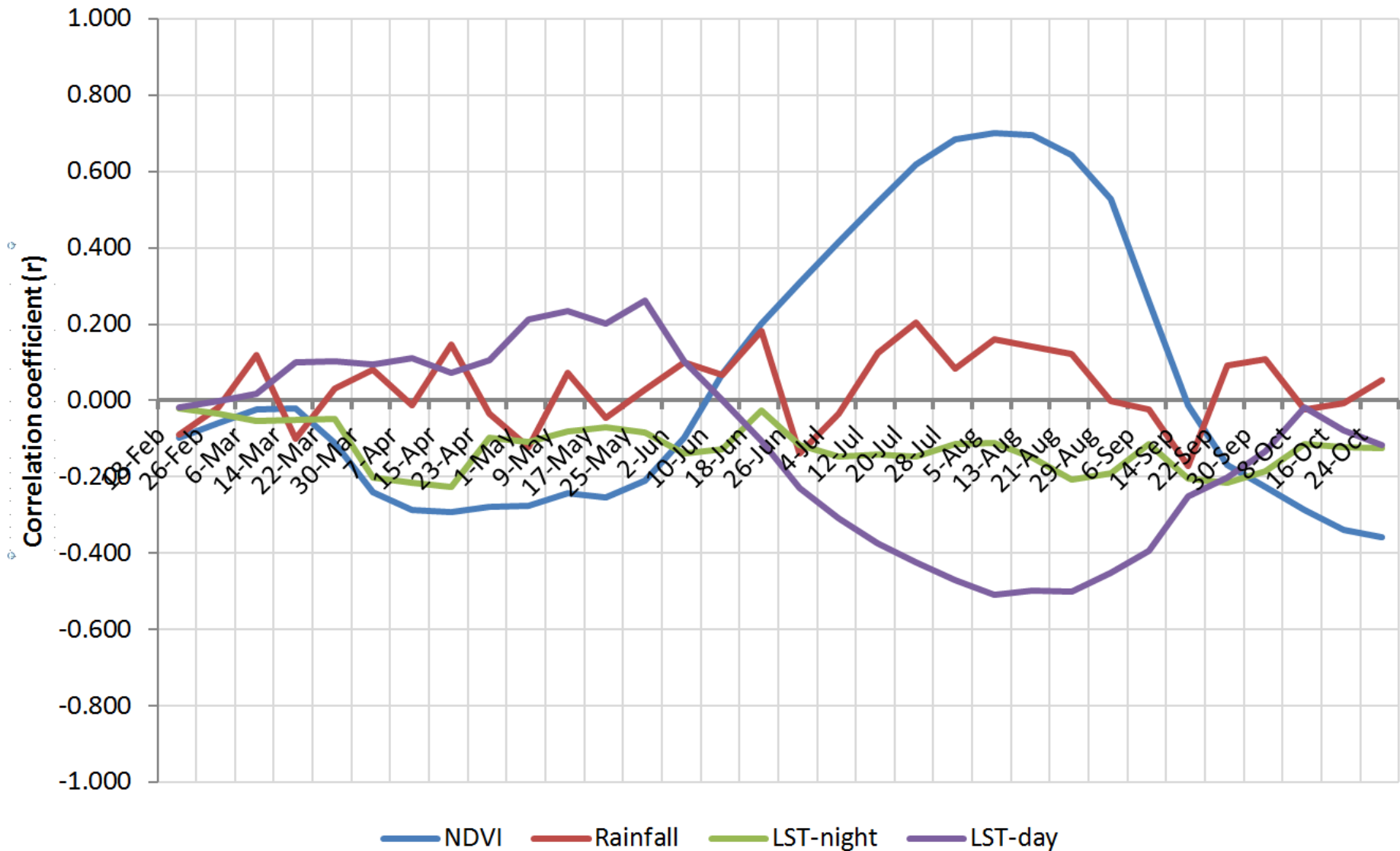
■ ■ ■

L	BM	BH	BO	BP
98.5	15049.9	15100.7	14962.4	225
911.1	14966.6	15021.6	14898	219
29.4	15280.7	15183.5	15095.1	215
60.4	15013.3	15065.8	14938.8	212
66.6	14578	14519.3	14533.3	211
455	15331.1	15236.9	15109.8	207
40.3	14845.2	14543	14629.6	207
16.4	14537.5	14458.7	14470.1	207
678	14508.9	14480.1	14463.9	207
76.6	14873.8	14508.4	14620.5	206
68.4	14885.8	14568.7	14658.5	206
76.1	14501.9	14447.6	14462.2	205
14.6	15111.4	14740.3	14567.9	204
33.3	14608.8	14509.7	14527.9	204
56.2	15275	15216.8	15107.6	203
63.8	14841.5	14532.1	14606	203
55.4	14547.6	14507.1	14520.7	203
62.7	14564.6	14480.9	14480.3	203
62.1	14588.8	14488.3	14488.3	203

Corn yield dependence at county level speculative region, 2006-2011



Soybean yield dependence at county level speculative region, 2006-2011



“Voodoo Modeling”

- Rulequest Cubist

- Learning tool to predict continuous rather than discrete outcomes
- Allow for “composite” predictions using both
 - Instance-based
 - “Nearest neighbor”
 - Predicts the target value of a new case by finding the n most similar cases in the training data, and averaging their target values.
 - Model-based, via decision trees and piecewise linear regression
 - Divide and conquer strategy
 - Recursive splitting of training data to minimize intra-subset variation
 - Thus, for composite of instances and models:
 - Cubist finds the n training cases that are “nearest” (most similar) to the case in question. Then, rather than averaging their target values directly, Cubist first adjusts these values using the rule-based model.
- Also, does “Committee” models
 - made up of several rule-based models. Each member of the committee predicts the target value for a case and the members' predictions are averaged to give a final prediction

The screenshot shows a dialog box titled "Model Construction Options". It contains several settings for model construction:


- Form of Model:**
 - Rules alone
 - Instances and rules
 - Let Cubist decide
- Use nearest instances
- Committee of members
- Cross-validate folds
- Use sample of % cases
- Lock sample
- Maximum rules:
- Extrapolation allowed: %
- Unbiased rules

Buttons at the bottom: OK, Defaults, Cancel.

Rulequest Cubist

Cubist [network version]

File Edit Help

 **CS_corn_5year**

attribute definitions [CS_corn_5year.names]
 training cases to be analyzed (CS_corn_5year.data)
 test cases [CS_corn_5year.test]
 rule-based model [CS_corn_5year.model]
 output file [CS_corn_5year.out]

Model Construction Options

Form of Model

Rules alone
 Instances and rules
 Let Cubist decide

Use nearest instances
 Committee of members

Cross-validate folds
 Use sample of % cases
 Lock sample

Maximum rules
 Extrapolation allowed %
 Unbiased rules

OK Defaults Cancel

Results for CS_corn_5year

File Edit

Model 1:

Rule 1/1: [47 cases, mean 64.59, range 18.3 to 135, est err 17.24]

```

if
  NDVI_14 <= 5292.634
  NDVI_22 <= 6741.589
  LST_1330_02 <= 14435.63
  LST_1330_04 <= 14906.01
then
  yield = -88.46 + 0.0695 LST_1330_02 - 0.0856 LST_1330_04
    + 0.0499 LST_1330_05 + 0.0267 NDVI_31 - 0.037 LST_1330_07
    - 0.0148 NDVI_09 + 0.0031 NDVI_25 + 0.015 LST_1330_23
    + 0.0053 LST_1330_03 + 0.0024 NDVI_28 - 0.004 NDVI_12
    - 0.009 LST_1330_22 + 0.0027 NDVI_20 + 0.0025 NDVI_11
    - 0.007 LST_1330_21 - 0.0013 NDVI_24 + 0.0014 NDVI_23
    - 0.0013 NDVI_29 + 0.004 LST_1330_30 + 0.006 LST_1330_32
    - 0.005 LST_1330_24 + 0.005 LST_1330_10 + 0.001 NDVI_22
    - 0.0007 NDVI_03 - 0.0006 NDVI_01 - 0.003 LST_1330_19
    + 0.0009 NDVI_04 + 0.0005 NDVI_02 + 0.0008 NDVI_19
    + 0.003 LST_1330_26 + 0.003 LST_1330_16 + 0.001 NDVI_32
    - 0.002 LST_1330_13 - 0.002 LST_1330_31 - 0.002 LST_1330_11
    - 0.0007 NDVI_08 - 0.002 LST_1330_09 - 0.0006 NDVI_10
    + 0.0004 NDVI_21 + 0.001 LST_1330_12
  
```

Rule 1/2: [44 cases, mean 100.00, range 49 to 152, est err 9.61]

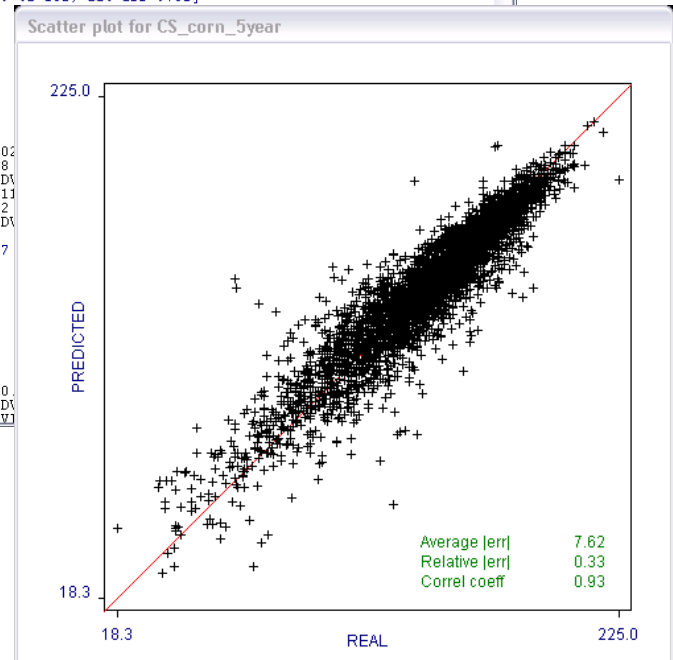
```

if
  NDVI_05 > 2600.681
  NDVI_14 <= 5292.634
  NDVI_21 <= 8340.541
  NDVI_31 > 3287.235
  LST_1330_03 <= 14082.5
  LST_1330_12 <= 15346.29
  LST_1330_32 > 14185.42
then
  yield = -1570.12 + 0.0973 LST_1330_02
    - 0.0578 LST_1330_01 - 0.038
    + 0.0373 NDVI_20 + 0.0149 NDV
    + 0.0263 LST_1330_04 + 0.0111
    + 0.0201 LST_1330_05 + 0.022
    - 0.0032 NDVI_27 - 0.0063 NDV
  
```

Rule 1/3: [37 cases, mean 104.21, range 37

```

if
  NDVI_04 > 2356.286
  NDVI_14 <= 5292.634
  NDVI_16 <= 6590.642
  NDVI_21 <= 8340.541
  LST_1330_02 > 14435.63
  LST_1330_04 <= 14906.01
then
  yield = -545.78 + 0.0109 NDVI_25 - 0.
    + 0.0121 NDVI_04 - 0.0109 NDV
    + 0.0044 NDVI_16 + 0.004 NDV
  
```



Example county-level prediction output

Case No	Given Value	Predicted Value
1	1701.0	92.49 +- 24.78
2	1703.0	138.24 +- 24.78
3	1705.0	64.58 +- 24.78
4	1707.0	129.20 +- 24.78
5	1709.0	106.46 +- 24.78
6	17011.0	132.43 +- 24.78
7	17013.0	104.15 +- 24.78
8	17015.0	150.99 +- 24.78
9	17017.0	127.98 +- 24.78
10	17019.0	123.06 +- 24.78
11	17021.0	122.79 +- 24.78
12	17023.0	79.02 +- 24.78
13	17025.0	45.30 +- 24.78
14	17027.0	59.63 +- 24.78
15	17029.0	94.61 +- 24.78
16	17031.0	140.96 +- 24.78
17	17033.0	65.67 +- 24.78
18	17035.0	83.40 +- 24.78
19	17037.0	143.90 +- 24.78
20	17039.0	124.48 +- 24.78
21	17041.0	125.98 +- 24.78
22	17043.0	137.51 +- 24.78
23	17045.0	104.61 +- 24.78
24	17047.0	76.02 +- 24.78
25	17049.0	66.14 +- 24.78
26	17051.0	62.86 +- 24.78
27	17053.0	101.90 +- 24.78
28	17055.0	54.85 +- 24.78
29	17057.0	109.45 +- 24.78
30	17059.0	113.84 +- 24.78
31	17061.0	104.00 +- 24.78
32	17063.0	100.02 +- 24.78
33	17065.0	64.23 +- 24.78
34	17067.0	110.53 +- 24.78
35	17069.0	69.21 +- 24.78
36	17071.0	127.78 +- 24.78
37	17073.0	121.29 +- 24.78
38	17075.0	128.79 +- 24.78
39	17077.0	63.20 +- 24.78
40	17079.0	70.46 +- 24.78
41	17081.0	46.99 +- 24.78
42	17083.0	94.22 +- 24.78
43	17085.0	123.96 +- 24.78
44	17087.0	73.05 +- 24.78
45	17089.0	131.46 +- 24.78
46	17091.0	130.11 +- 24.78
47	17093.0	120.26 +- 24.78
48	17095.0	128.95 +- 24.78
49	17097.0	120.66 +- 24.78
50	17099.0	128.53 +- 24.78

Corn

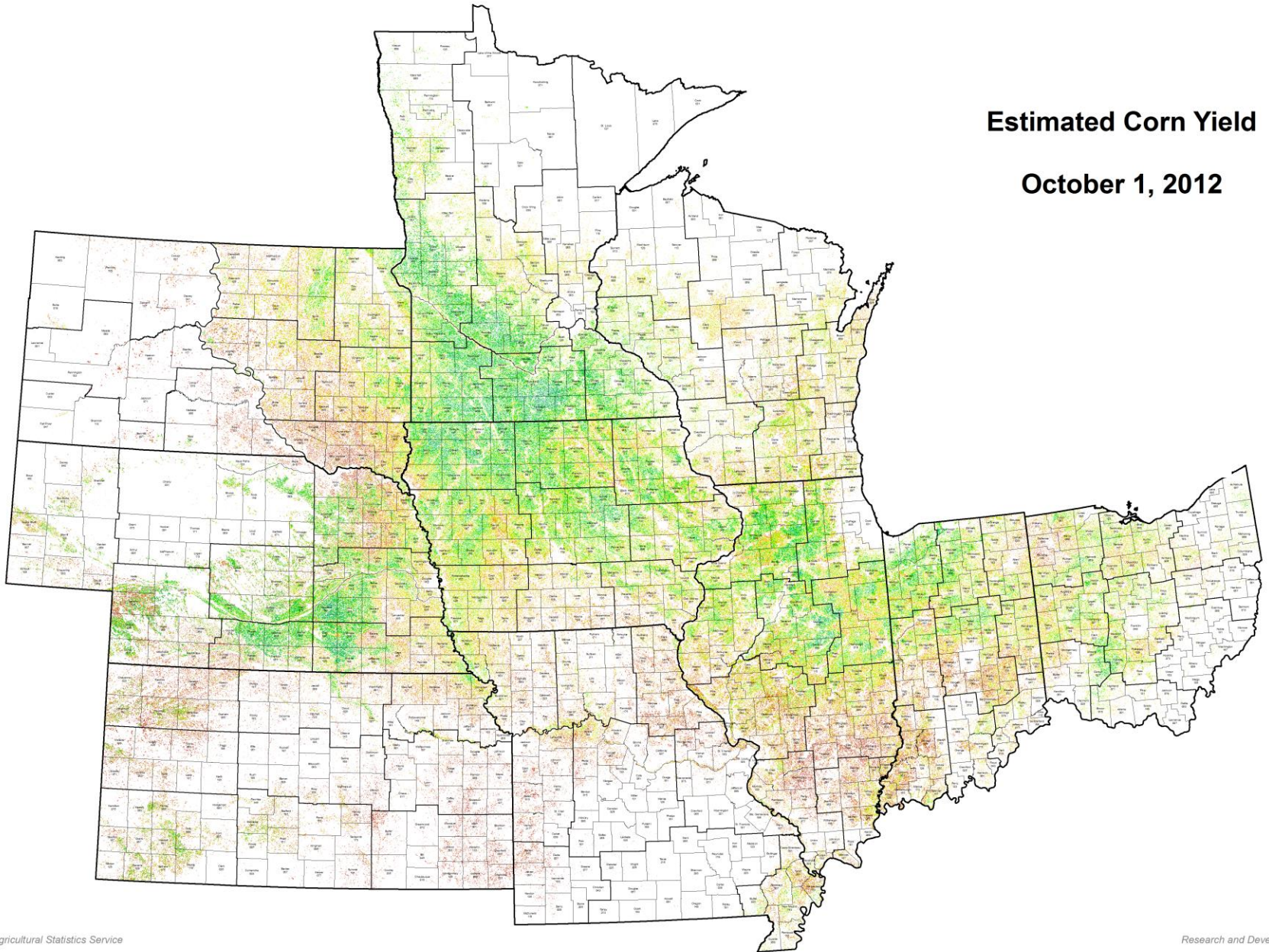
Case No	Given Value	Predicted Value
1	501.0	45.30 +- 7.60
2	503.0	32.20 +- 7.60
3	505.0	4.31 +- 9.50
4	507.0	4.31 +- 9.50
5	509.0	4.31 +- 9.50
6	5011.0	4.31 +- 9.50
7	5013.0	4.31 +- 9.50
8	5015.0	4.31 +- 9.50
9	5017.0	36.80 +- 7.60
10	5019.0	10.88 +- 7.60
11	5021.0	39.92 +- 7.60
12	5023.0	4.31 +- 9.50
13	5025.0	4.31 +- 9.50
14	5027.0	4.31 +- 9.50
15	5029.0	19.68 +- 7.60
16	5031.0	34.14 +- 7.60
17	5033.0	28.26 +- 7.60
18	5035.0	43.82 +- 7.60
19	5037.0	39.48 +- 7.60
20	5039.0	4.31 +- 9.50
21	5041.0	39.78 +- 7.60
22	5043.0	38.52 +- 7.60
23	5045.0	11.48 +- 7.60
24	5047.0	4.31 +- 9.50
25	5049.0	4.31 +- 9.50
26	5051.0	4.31 +- 9.50
27	5053.0	4.31 +- 9.50
28	5055.0	33.53 +- 7.60
29	5057.0	28.21 +- 7.60
30	5059.0	12.47 +- 7.60
31	5061.0	4.31 +- 9.50
32	5063.0	31.07 +- 7.60
33	5065.0	4.31 +- 9.50
34	5067.0	34.07 +- 7.60
35	5069.0	41.76 +- 7.60
36	5071.0	4.31 +- 9.50
37	5073.0	36.72 +- 7.60
38	5075.0	34.29 +- 7.60
39	5077.0	41.19 +- 7.60
40	5079.0	42.98 +- 7.60
41	5081.0	26.32 +- 7.60
42	5083.0	10.81 +- 7.60
43	5085.0	34.80 +- 7.60
44	5087.0	4.31 +- 9.50
45	5089.0	4.31 +- 9.50
46	5091.0	22.51 +- 7.60
47	5093.0	43.11 +- 7.60
48	5095.0	36.57 +- 7.60
49	5097.0	4.31 +- 9.50
50	5099.0	4.31 +- 9.50

Soybeans

Weight by a 3-year average of harvested acres to derive ASD, state, and region estimates

Estimated Corn Yield

October 1, 2012

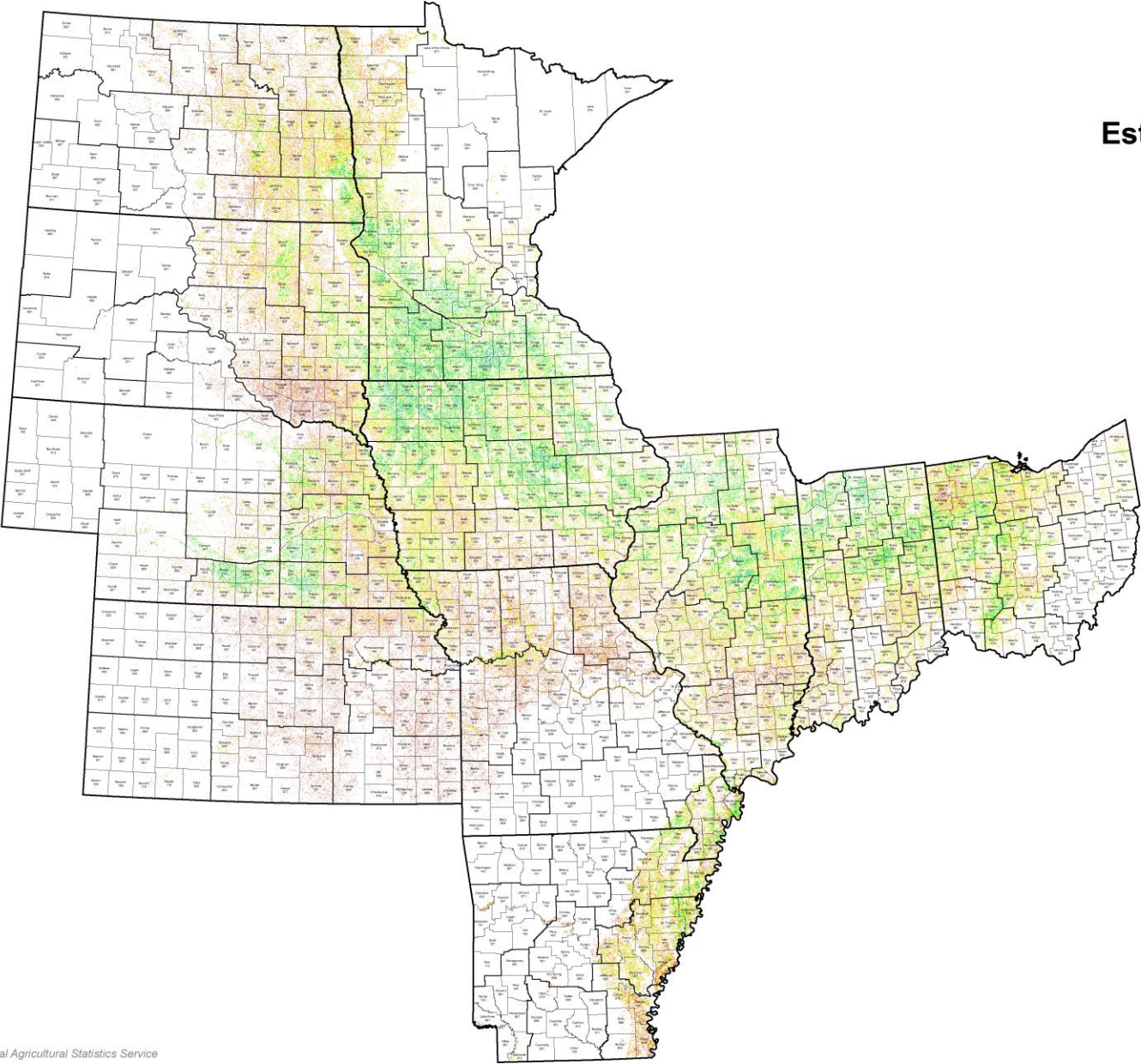


USDA/National Agricultural Statistics Service

Research and Development Division

Estimated Soybean Yield

October 1, 2012

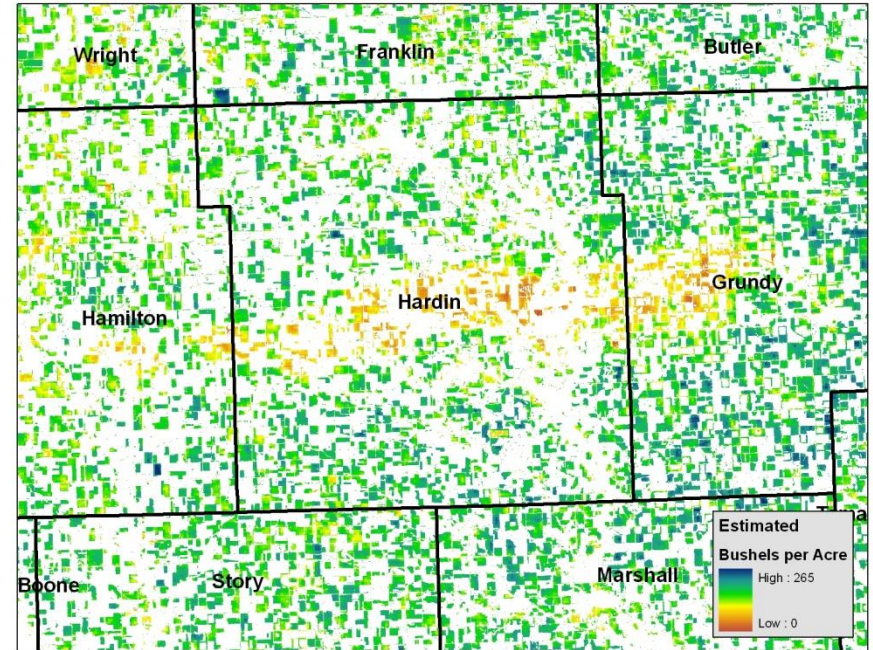
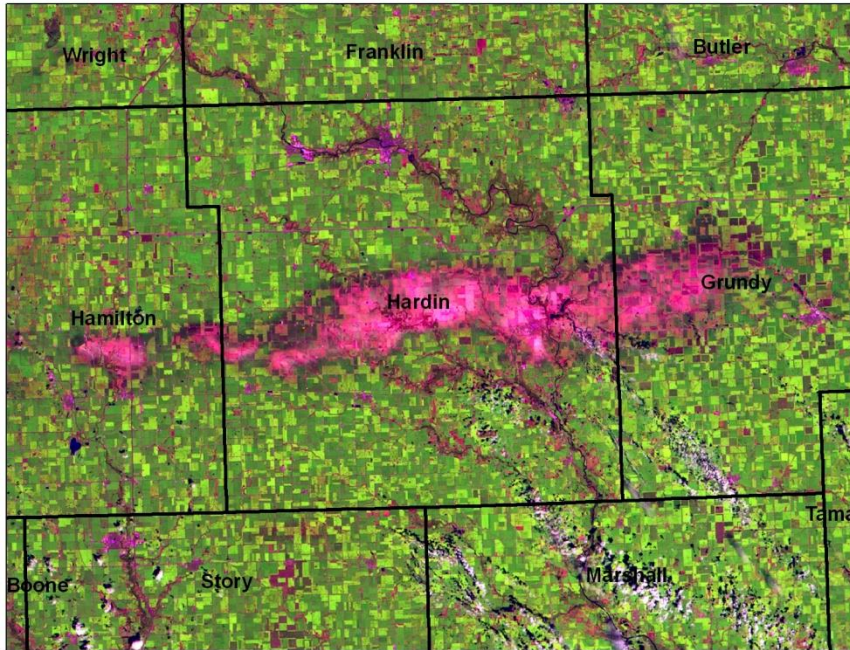


USDA/National Agricultural Statistics Service

Research and Development Division

Reality check

Scene of a large hailstorm



2012 Remote sensing vs NASS yield

State level average error

corn = 5.8 bu./ac.

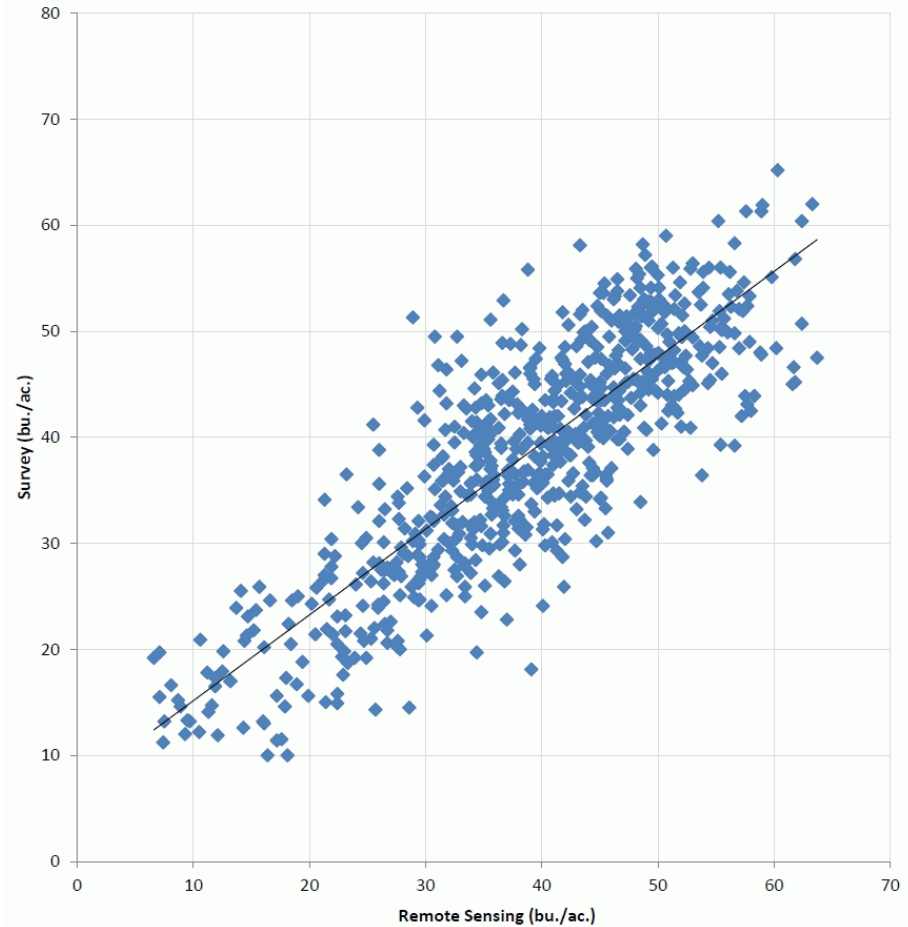
soybeans = 3.1 bu./ac.

2012 County Level Yield Comparison - Corn



$$y = 0.9635x + 4.0061$$
$$R^2 = 0.7722$$

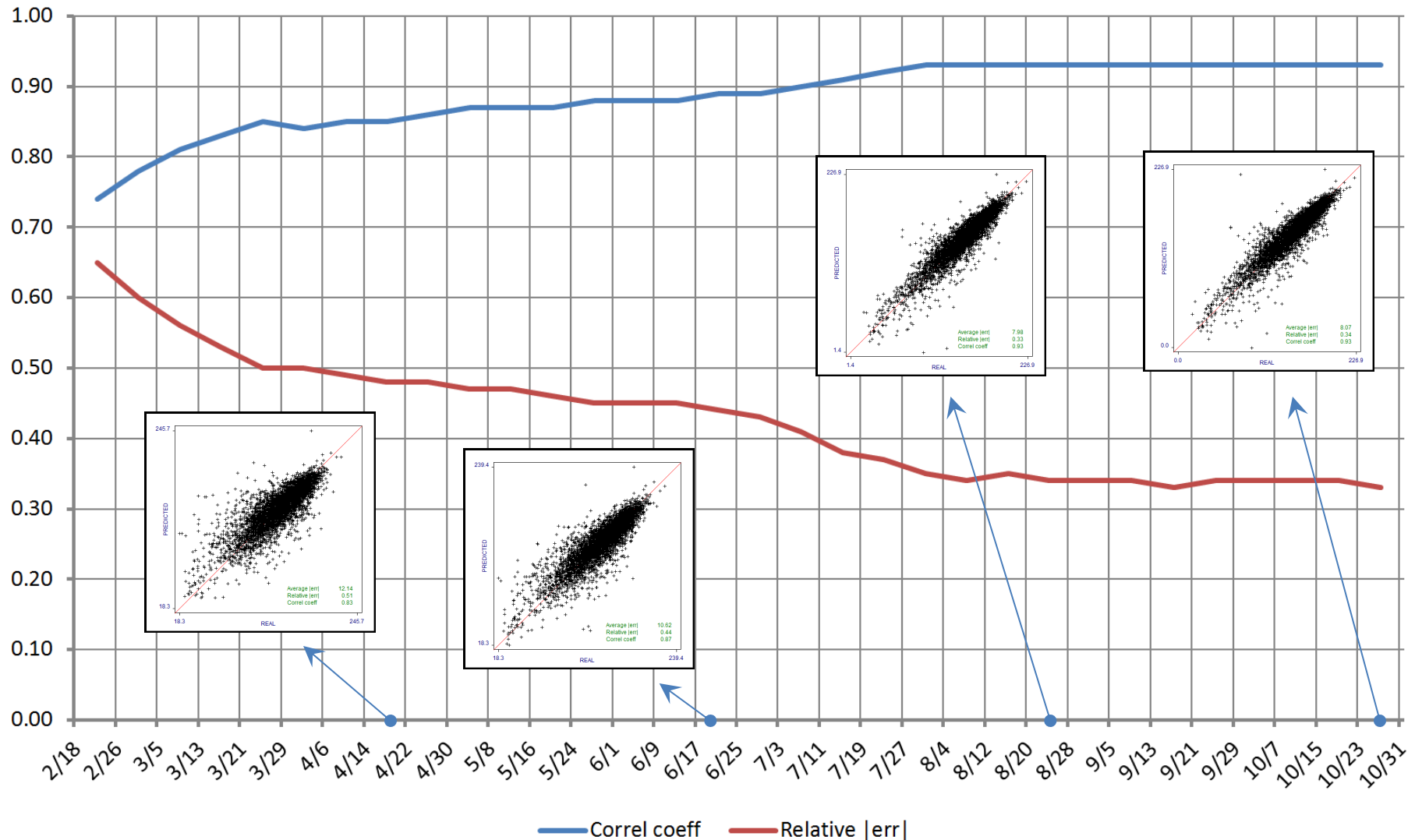
2012 County Level Yield Comparison - Soybeans



$$y = 0.8098x + 7.073$$
$$R^2 = 0.7128$$

Corn yield regression-tree model performance v. data timing

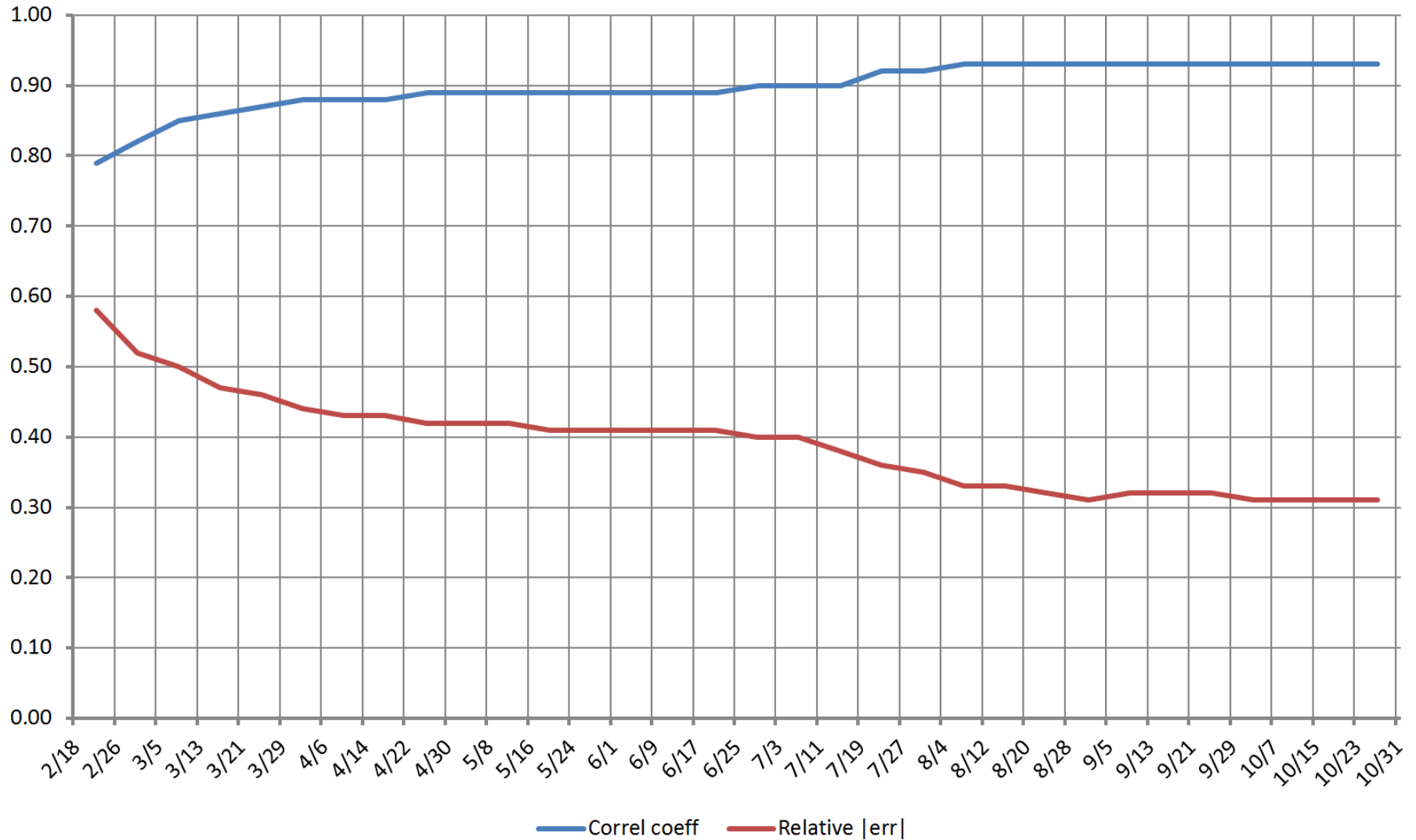
county level, speculative region, 2006-2011



The **relative error magnitude** is the ratio of the average error magnitude to the error magnitude that would result from always predicting the mean value; for useful models, this should be less than 1!

The **correlation coefficient** measures the agreement between the cases' actual values of the target attribute and those values predicted by the model.

Soybean yield regression-tree model performance v. data timing county level, speculative region, 2006-2011

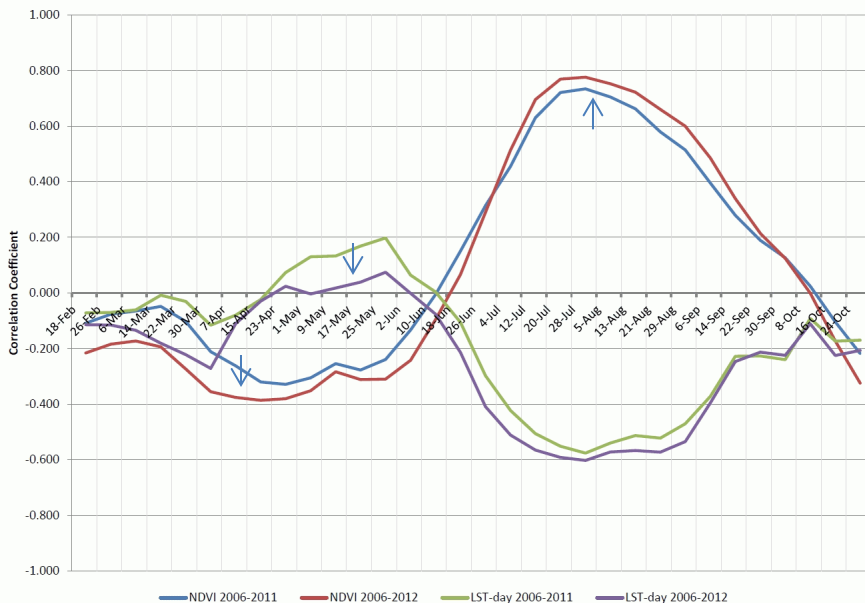


Models improvements for 2013

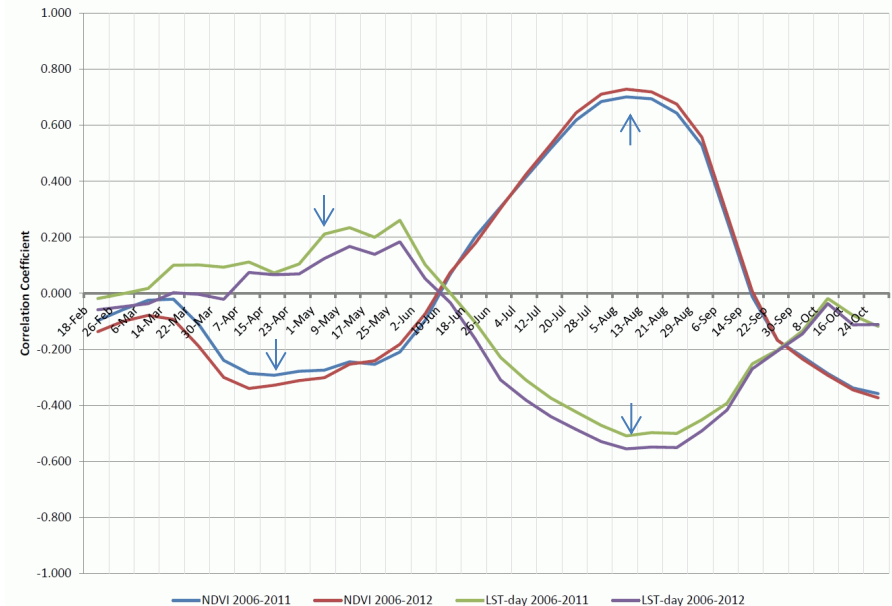
- Corn
 - relative |err|
 - correl coeff
- Soybeans
 - relative |err|
 - correl coeff

	2012	2013
– relative err	0.33	0.30
– correl coeff	0.93	0.95
– relative err	0.31	0.30
– correl coeff	0.93	0.94

Speculative Region Corn



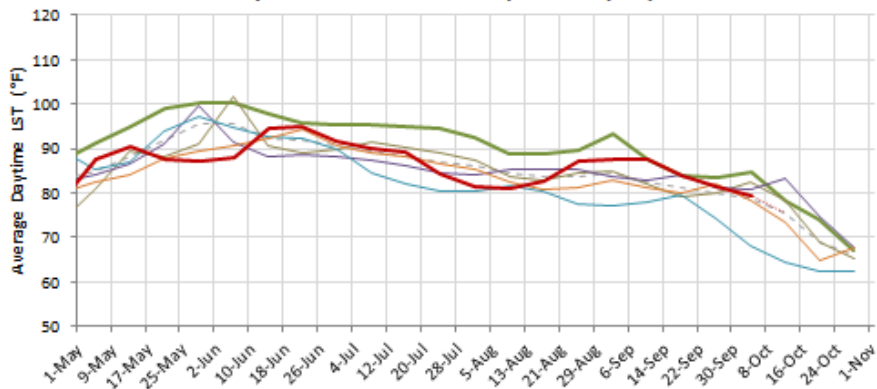
Speculative Regions Soybeans



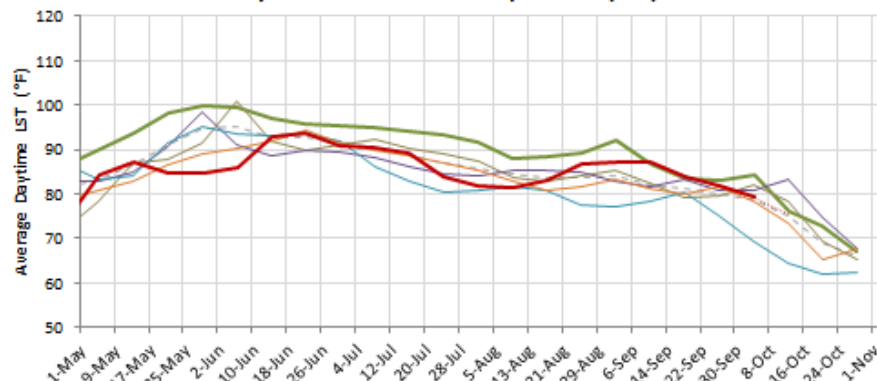
- Absolute error unchanged
 - ~8.0 bu/ac for corn, ~2.5 for soybeans

MODIS-derived crop dynamics based on CDL areas

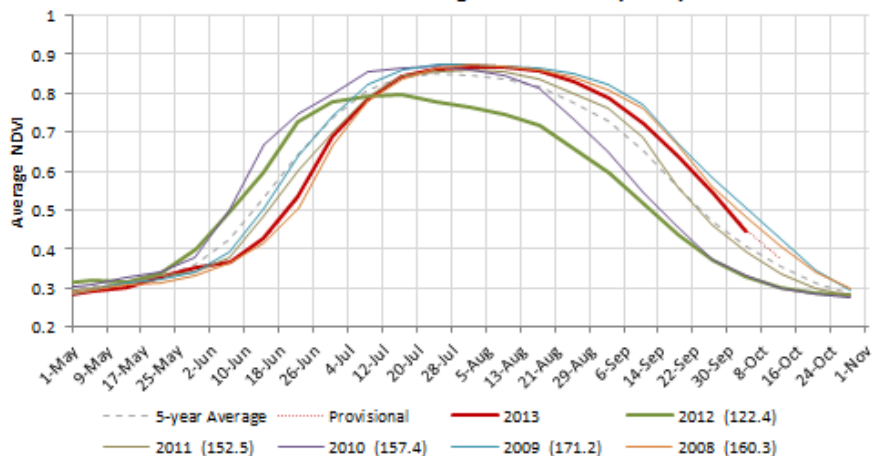
Daytime Land Surface Temperature (LST)



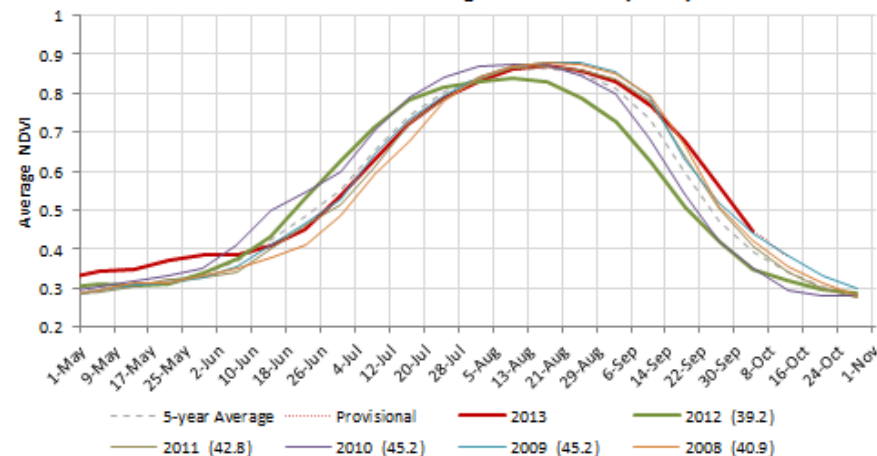
Daytime Land Surface Temperature (LST)



Normalized Difference Vegetation Index (NDVI)



Normalized Difference Vegetation Index (NDVI)



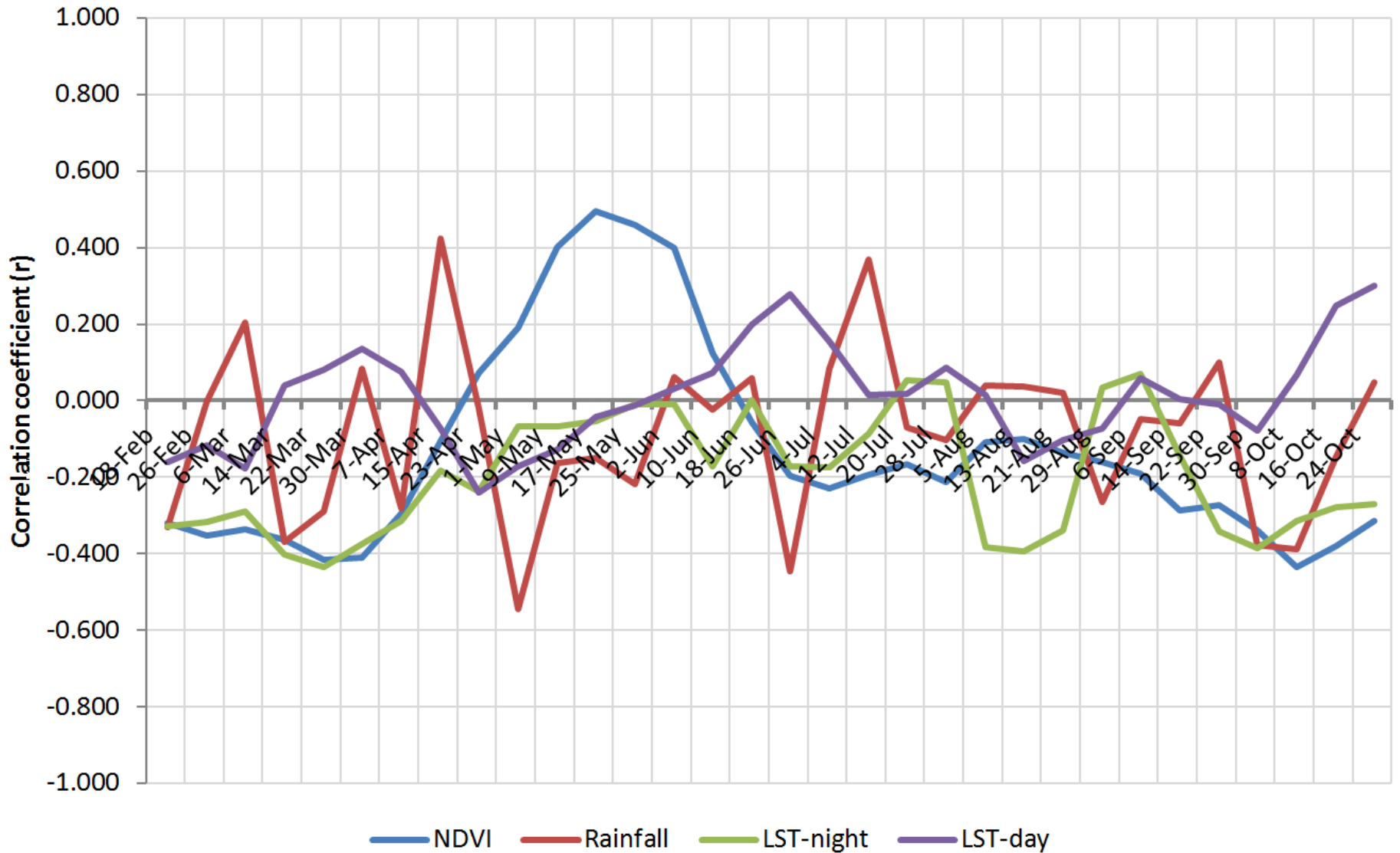
Corn

Soybeans

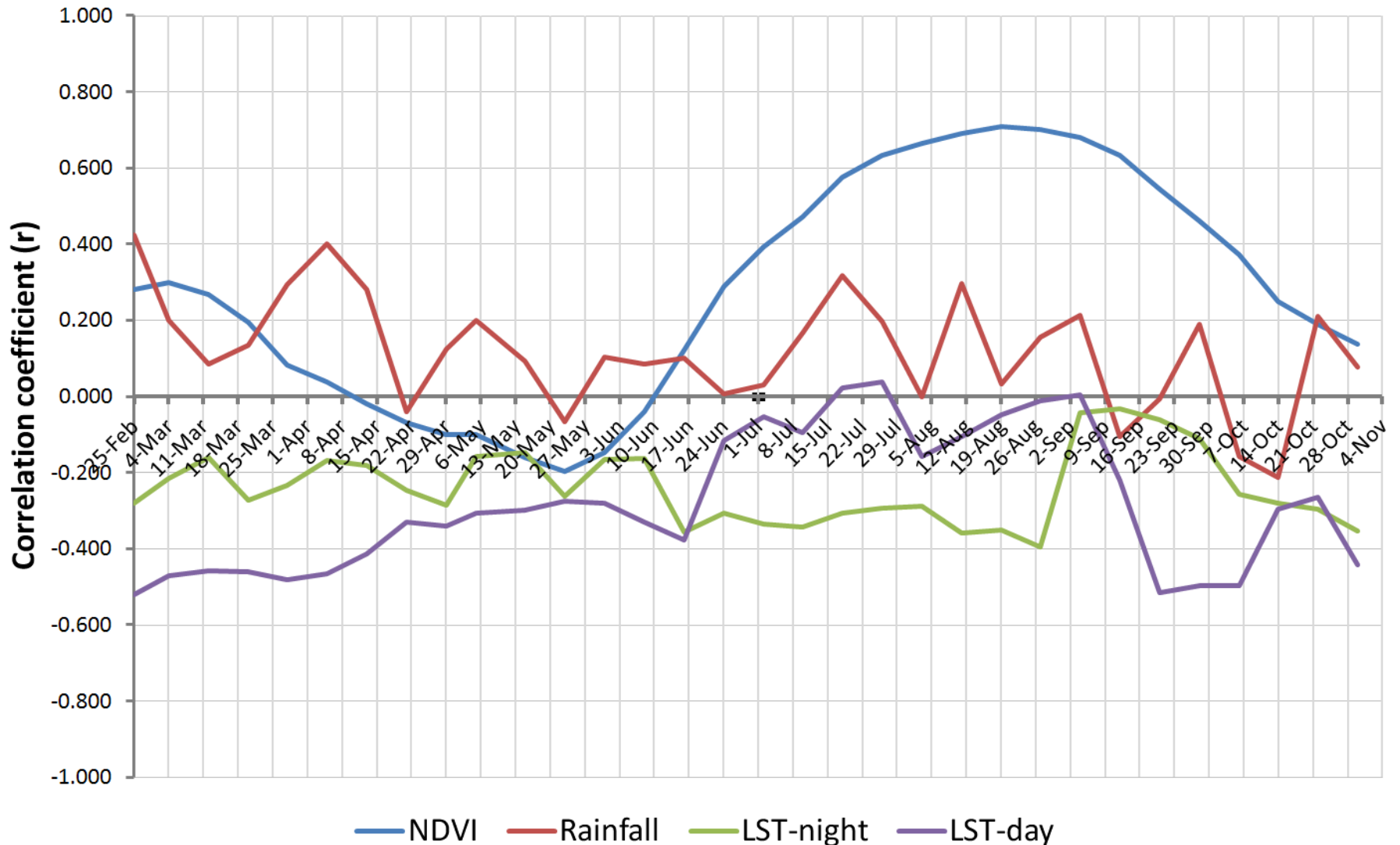
This winter: Build full understanding all common MODIS derived variables and how they relate to various crops' yields

- Explore fully beyond only corn and soybeans
 - Wheat
 - Rice
 - Potatoes
 - Sorghum
 - Cotton
- Compare the full suite of common MODIS variables
 - NDVI
 - LAI
 - FPAR
 - LST (daytime and nighttime)
 - and more....
- Test Both Terra and Aqua platforms
 - Assess the AM vs PM overpass time
- Look at pixel scale issues
 - 250 m vs. 500 m vs. 1000 m (particularly for NDVI)

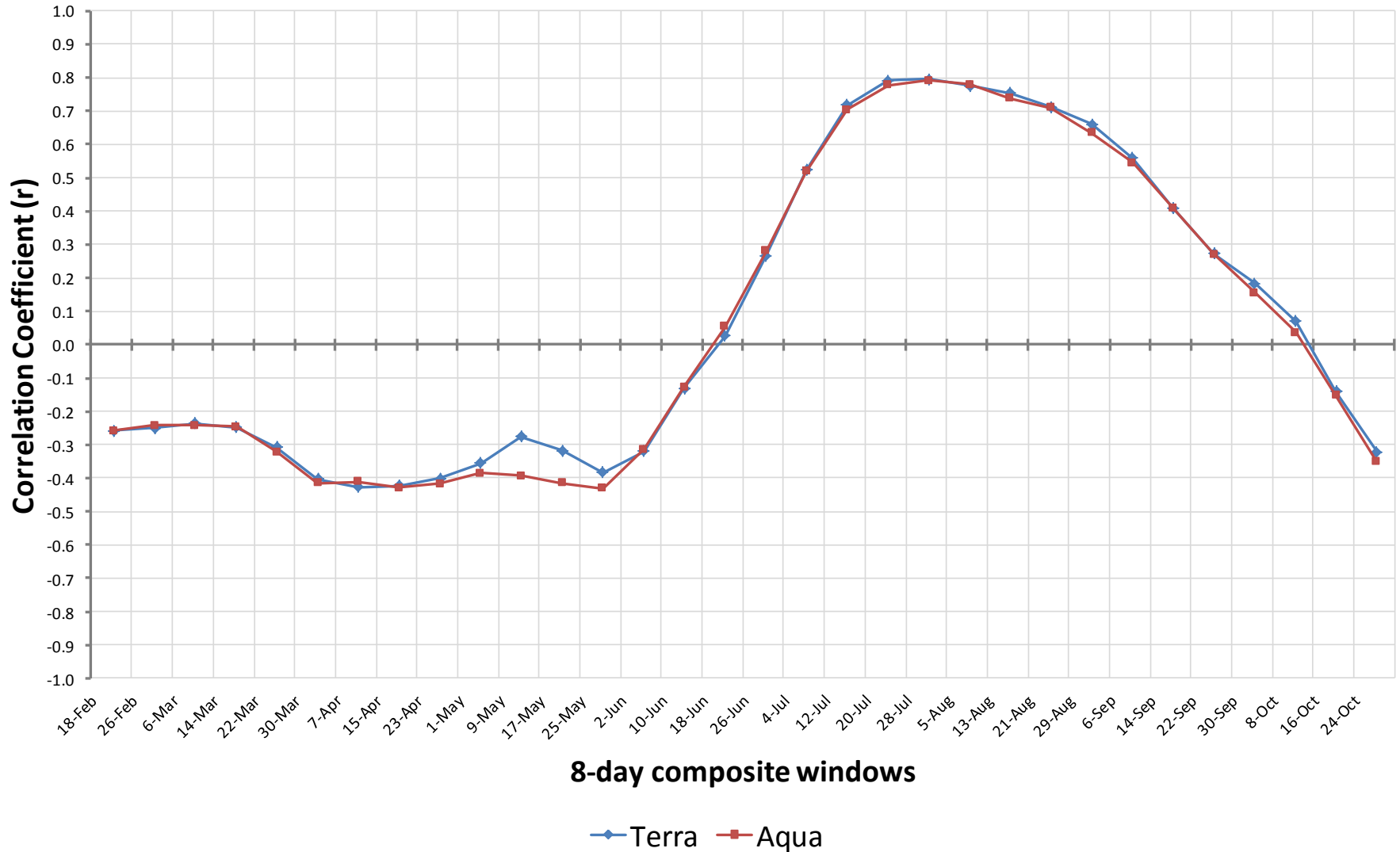
Winter wheat yield dependence at county level Kansas, 2006-2011



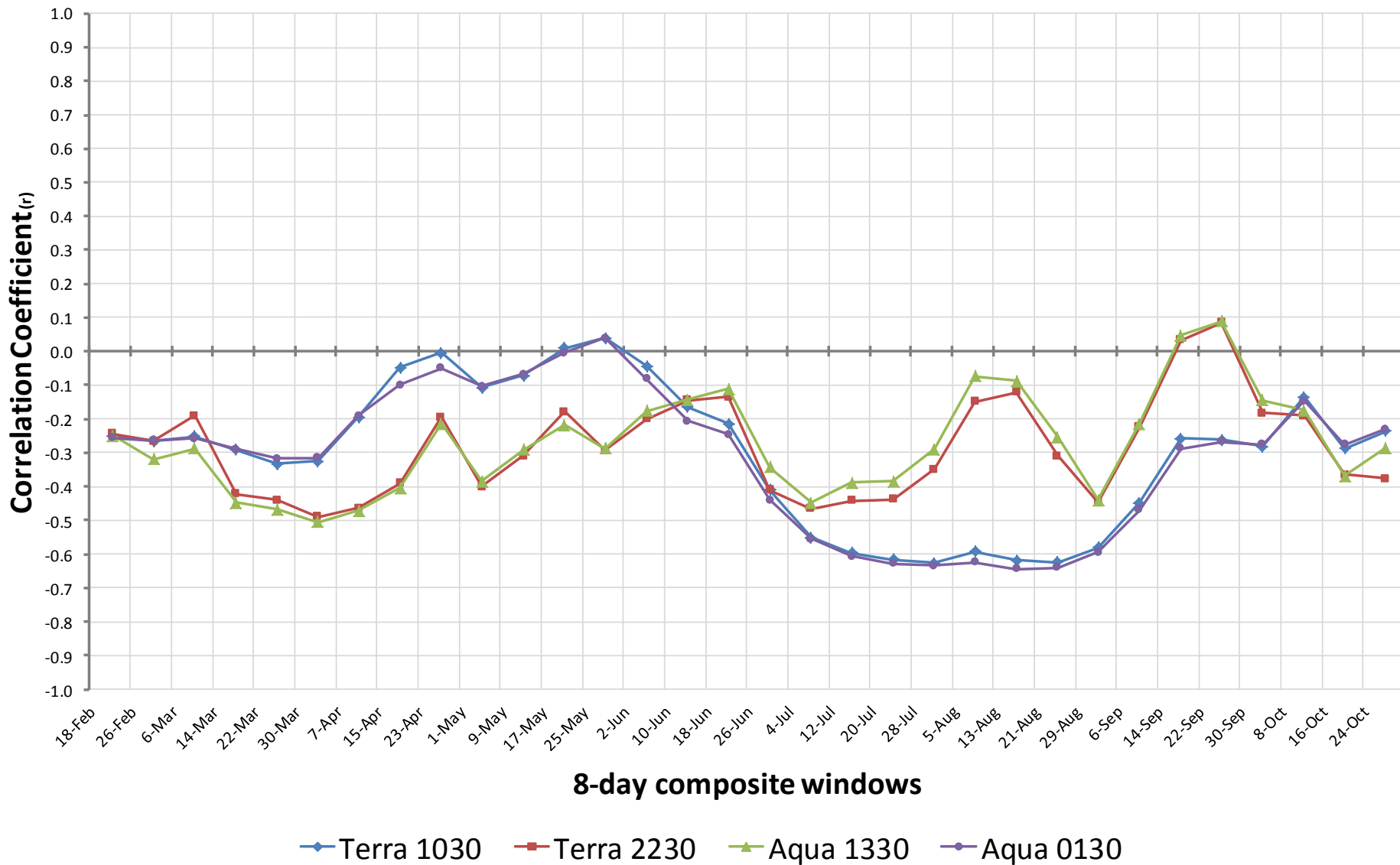
Cotton yield dependence at county level TX & AR, 2005-2011



Corn yield correlations to NDVI from the different MODIS platforms



Corn yield correlations to LST from the different MODIS platforms



In summary

- Corn and soybeans yield predictors
 - NDVI most useful
 - Daytime LST also useful
 - Precipitation not useful
 - Nighttime LST not useful
- Full exploration of other MODIS variables and other crops has begun



Thanks

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703-877-8000 x169

www.nass.usda.gov
www.nass.usda.gov/Research_and_Science
nassgeodata.gmu.edu/CropScape

