The Big Picture - Satellite Remote Sensing Applications in Rangeland Assessment and Crop Insurance

Presented at the Agricultural Outlook Forum 2005

by

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Crop Insurance Division

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Background

- The USDA Risk Management Agency (RMA) awarded several contracts through a competitive process to research and develop a viable risk management tool for forage productivity losses.
- Watts and Associates, Inc. (W&A) was awarded one of the contracts. W&A is an economic consulting firm focused on crop insurance development based in Billings, MT.
- TerraMetrics Agriculture, Inc. (TMAI) is subcontracted to gather data and develop and assimilate a rangeland and pasture productivity index based on satellite remote sensing. TMAI is based in Lawrence, KS.

Program Objective

- Design an insurance product that compensates livestock producers for losses related to declines in range, pasture, and non-irrigated hay production.

**Note: This product is not amenable to usual RMA program designs because of the lack of farm level production data and ability to assess losses at the farm gate.

Potential Trigger Mechanisms Investigated

- Remote Sensing
  - Satellite information (AVHRR, MODIS, etc.)
  - Doppler Radar
- Aggregate proxy type approaches
  - Group Risk Plan (GRP) Range
  - Other Proxy Crops
  - Weather Data

Overview of Recommended Insurance Product Design

- Dual Trigger Design:
  - A **satellite remote sensing index** will be developed to determine forage production variability at the sub-county level. This will be the focus of our presentation.
  - A **proxy index** will be developed at the county level. In this project, the proxy is simply a substituted crop or weather variable that has measurable yields or quantities that are used as a substitute for range production. This trigger will be similar to the GRP Rangeland trigger.

Satellite Remotely Sensed Trigger

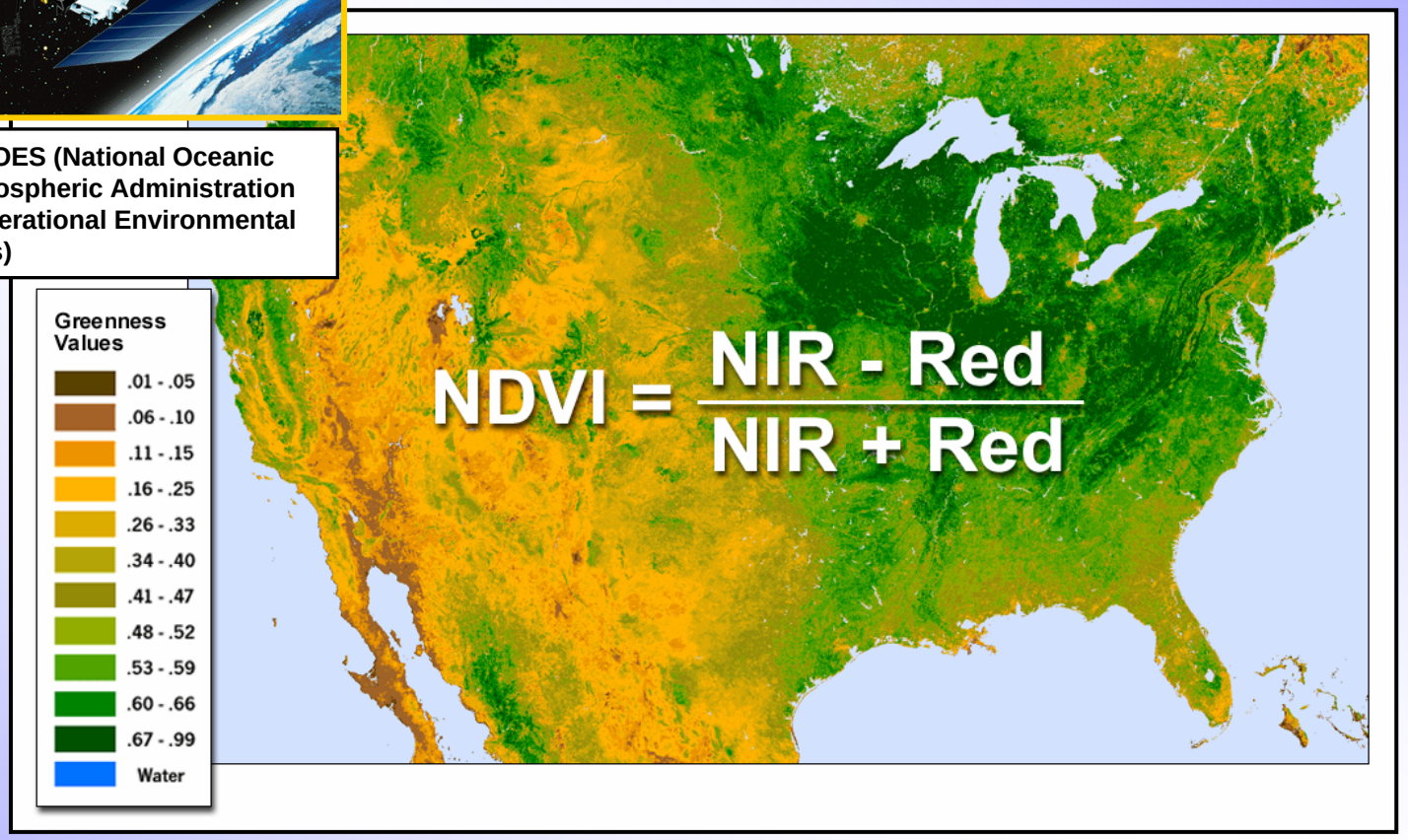
- The first trigger is constructed using the Normalized Difference Vegetation Index (NDVI).
- Readily computed for all insurable grids at the sub-county scale or larger.
- Readily translatable to estimated range production.
- Available and reliable data since 1989, and the **A**dvanced **V**ery **H**igh **R**esolution **R**adiometer (AVHRR) program has continued funding.

Dual Trigger Mechanisms

- The dual trigger provides more assurance to the producers that a timely payment will be made when range productivity is low.
- Our analysis finds that the dual trigger increases the efficacy of this risk management tool.
- While many safeguards and assurances provide confidence in the satellite index, the proxy trigger is important because the use of satellite remote sensing in this field is relatively new.

Normalized Difference Vegetation Index (NDVI)

NOAA POES (National Oceanic and Atmospheric Administration Polar Operational Environmental Satellites)



The NDVI that can be computed for each AVHRR pixel is highly correlated with photosynthetically active vegetation (green live biomass). Areas with greater amounts of green biomass have higher NDVI values. Rangelands, pasturelands, and dryland hay stressed by drought will have lower than normal NDVI values.

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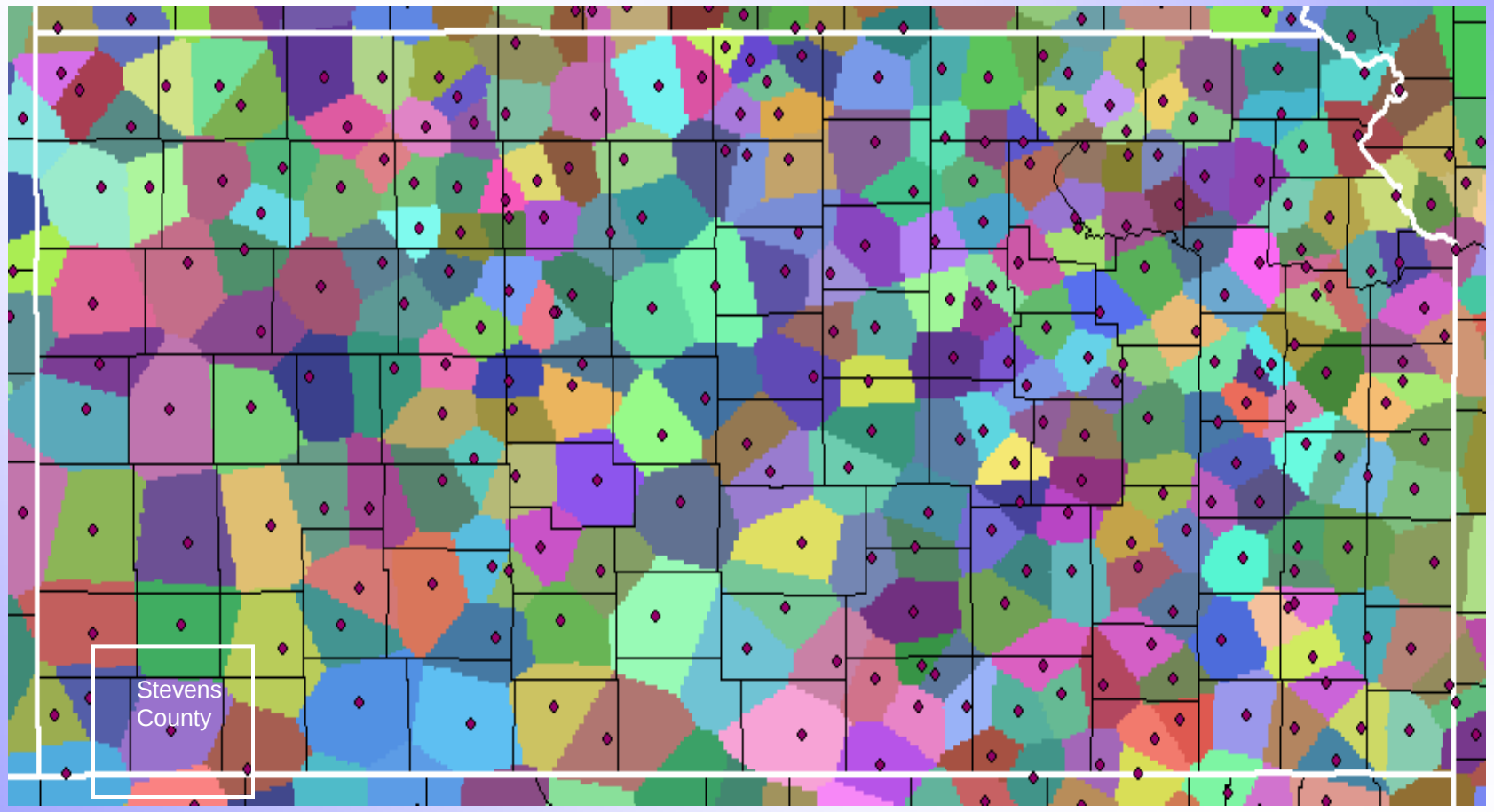
Satellite Remotely Sensed Trigger

- Satellite imagery acquired by the National Oceanic and Atmospheric Administration (NOAA) AVHRR scanner is used compute the NDVI, which in turn is used to monitor rangeland (including pasture and dryland hay) response to varying climatic conditions and characterize relative plant productivity.

Remote Sensing Resolutions

Locations of Kansas Weather Stations for Precipitation and Temperature Data and Areas of Coverage as estimated using Thiessen Polygons



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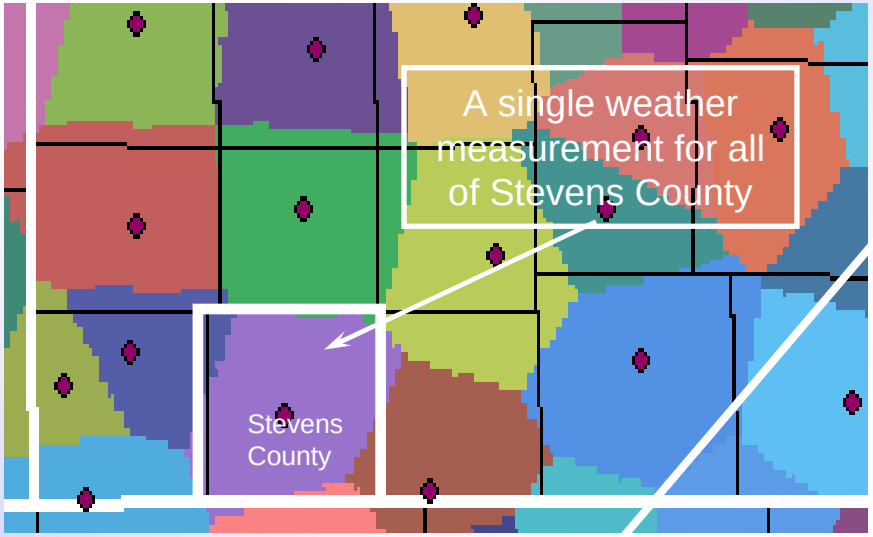
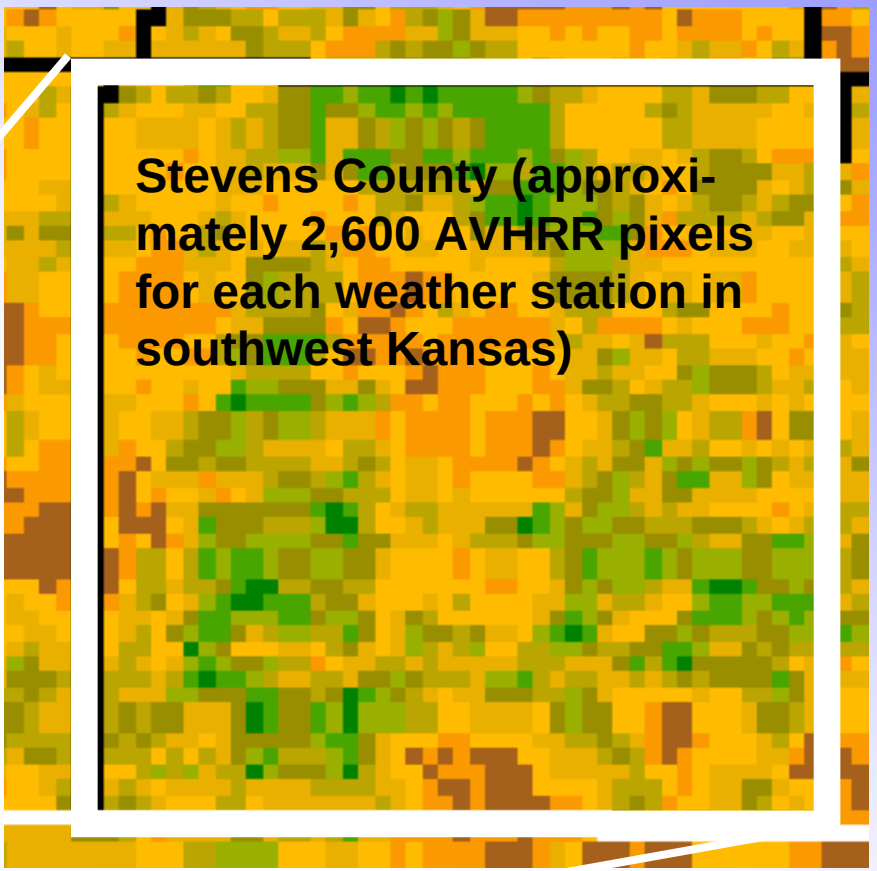
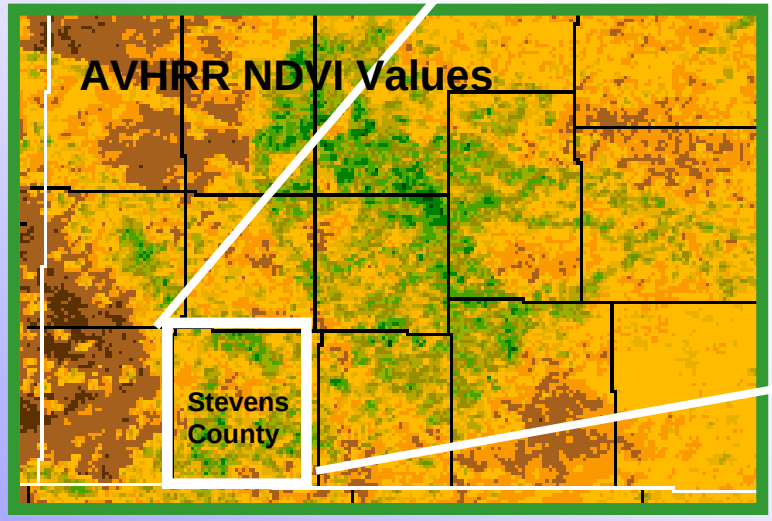
Remote Sensing Resolutions







Hundreds of 1-km NDVI pixels showing variation in crop and rangeland conditions that would not be detected from meteorological measurements.

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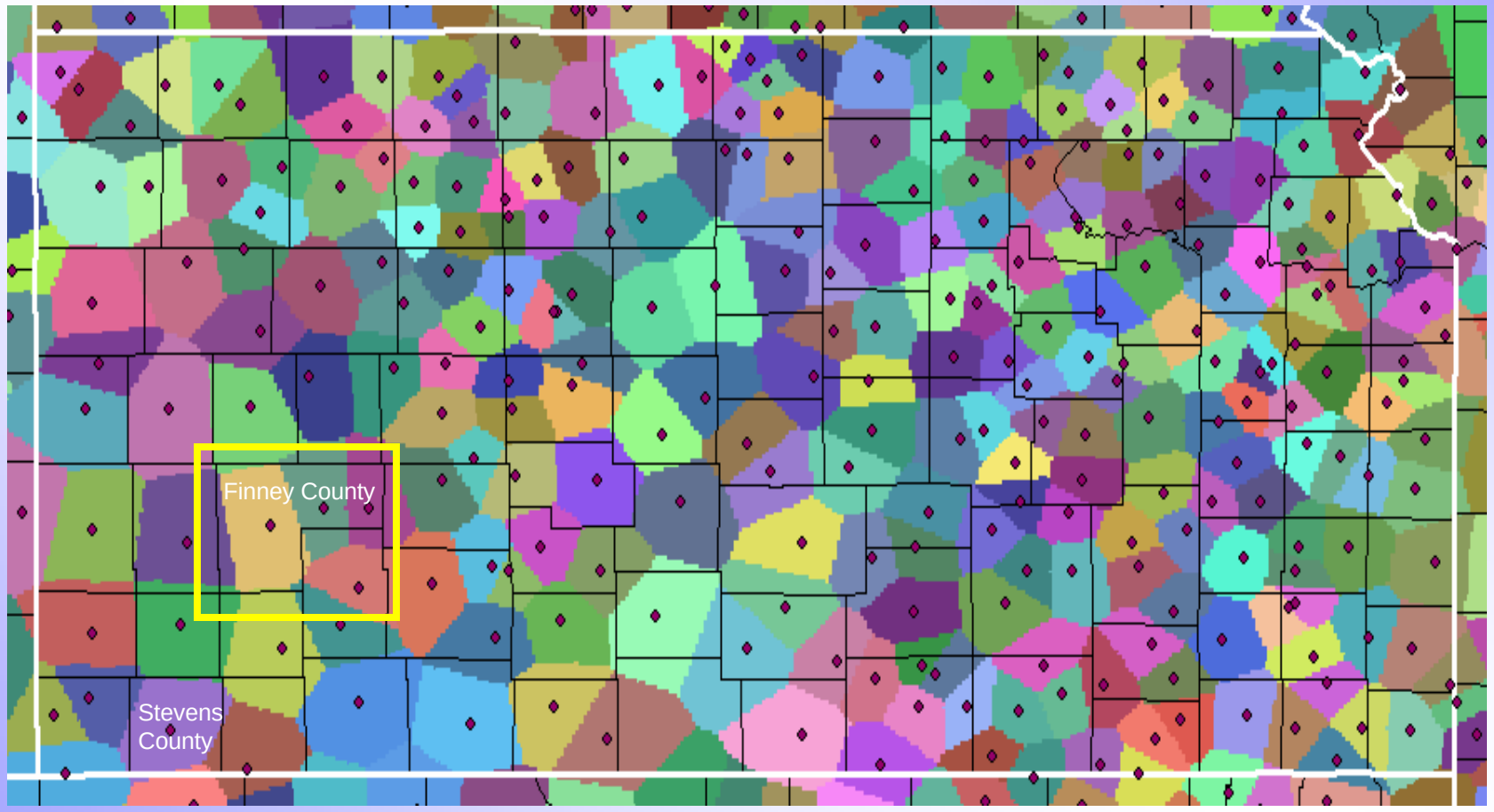
Remote Sensing Resolutions

Locations of Kansas Weather Stations for Precipitation and Temperature Data and Areas of Coverage as estimated using Thiessen Polygons



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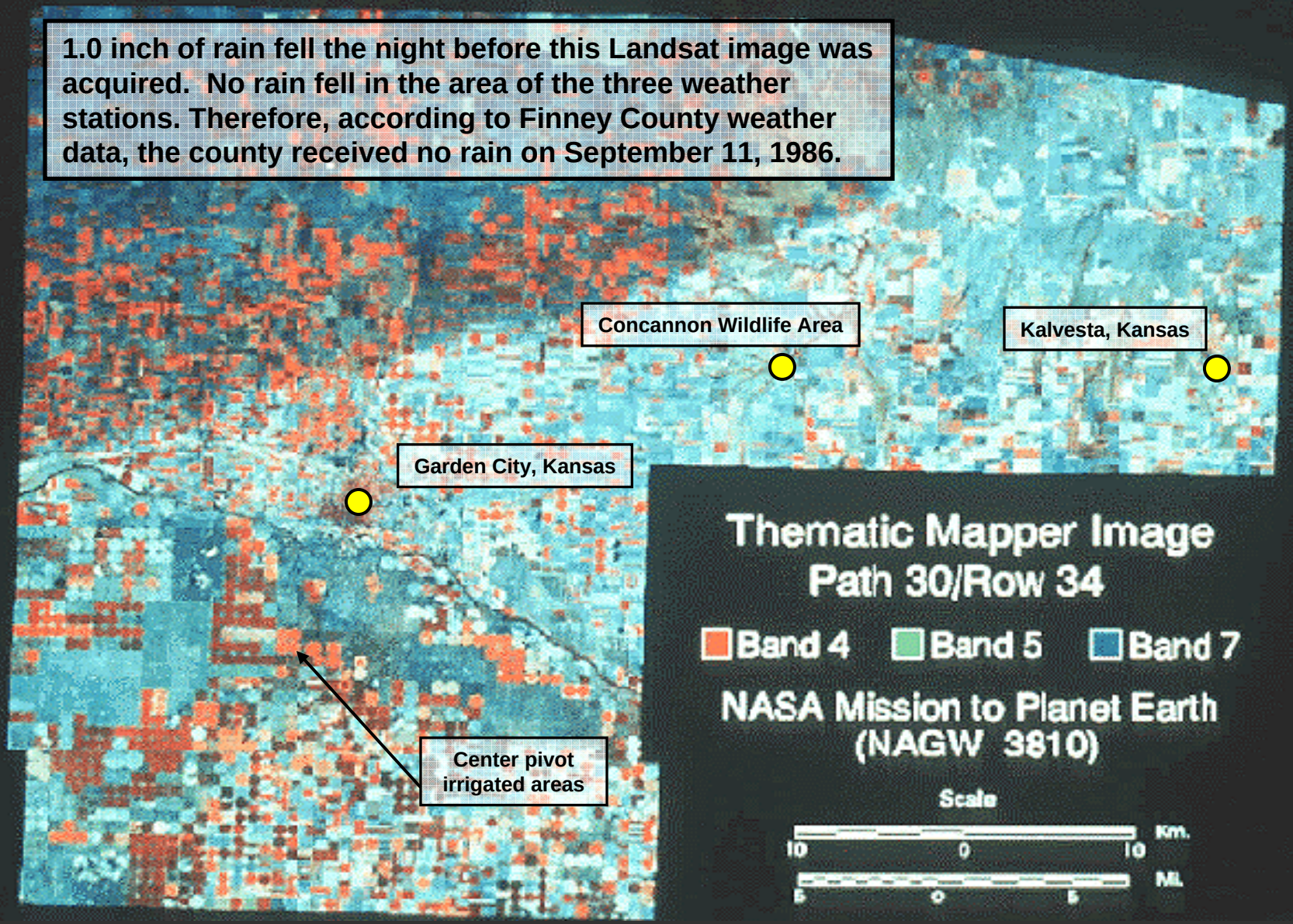
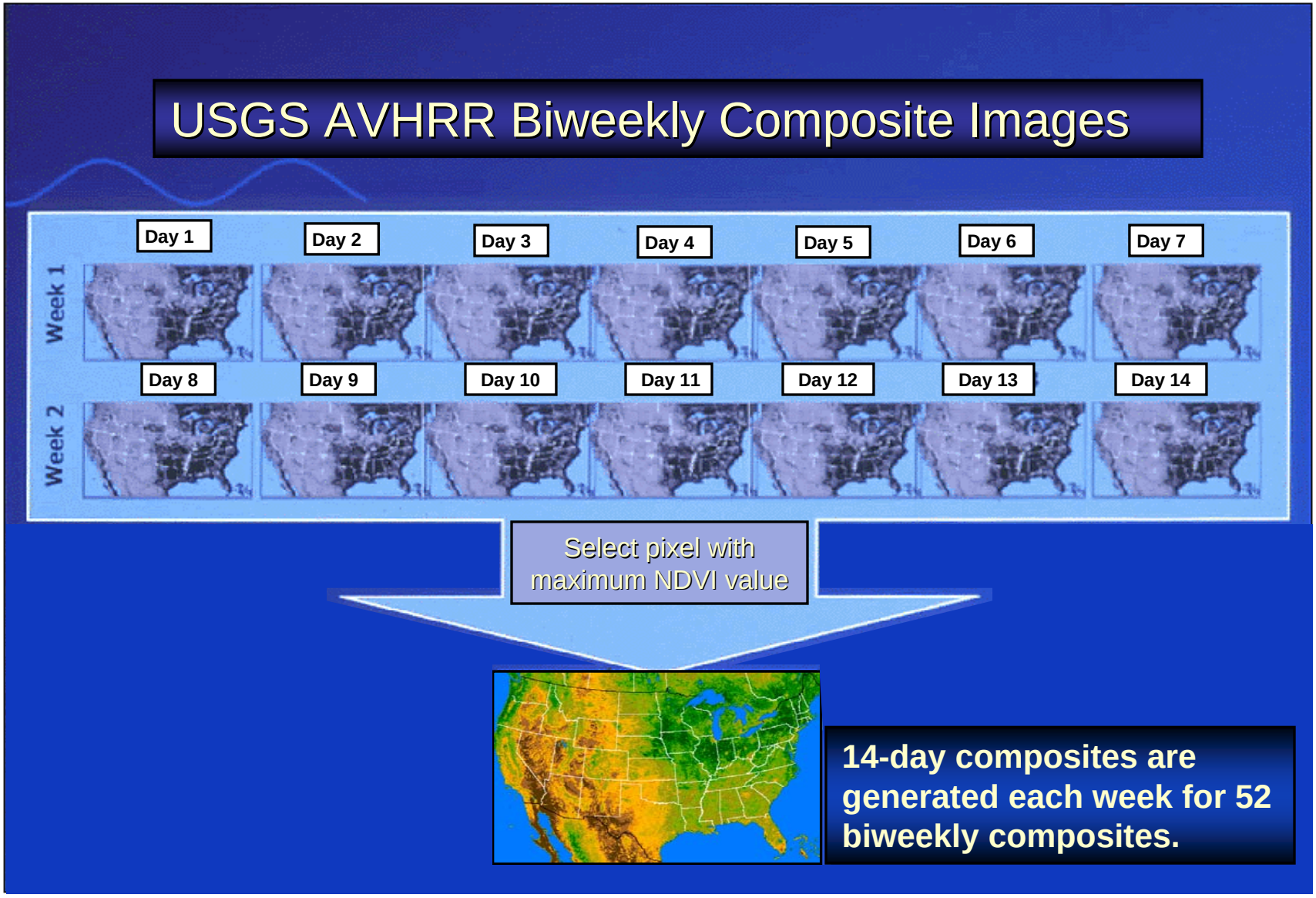
Finney County, Kansas - September 11, 1986

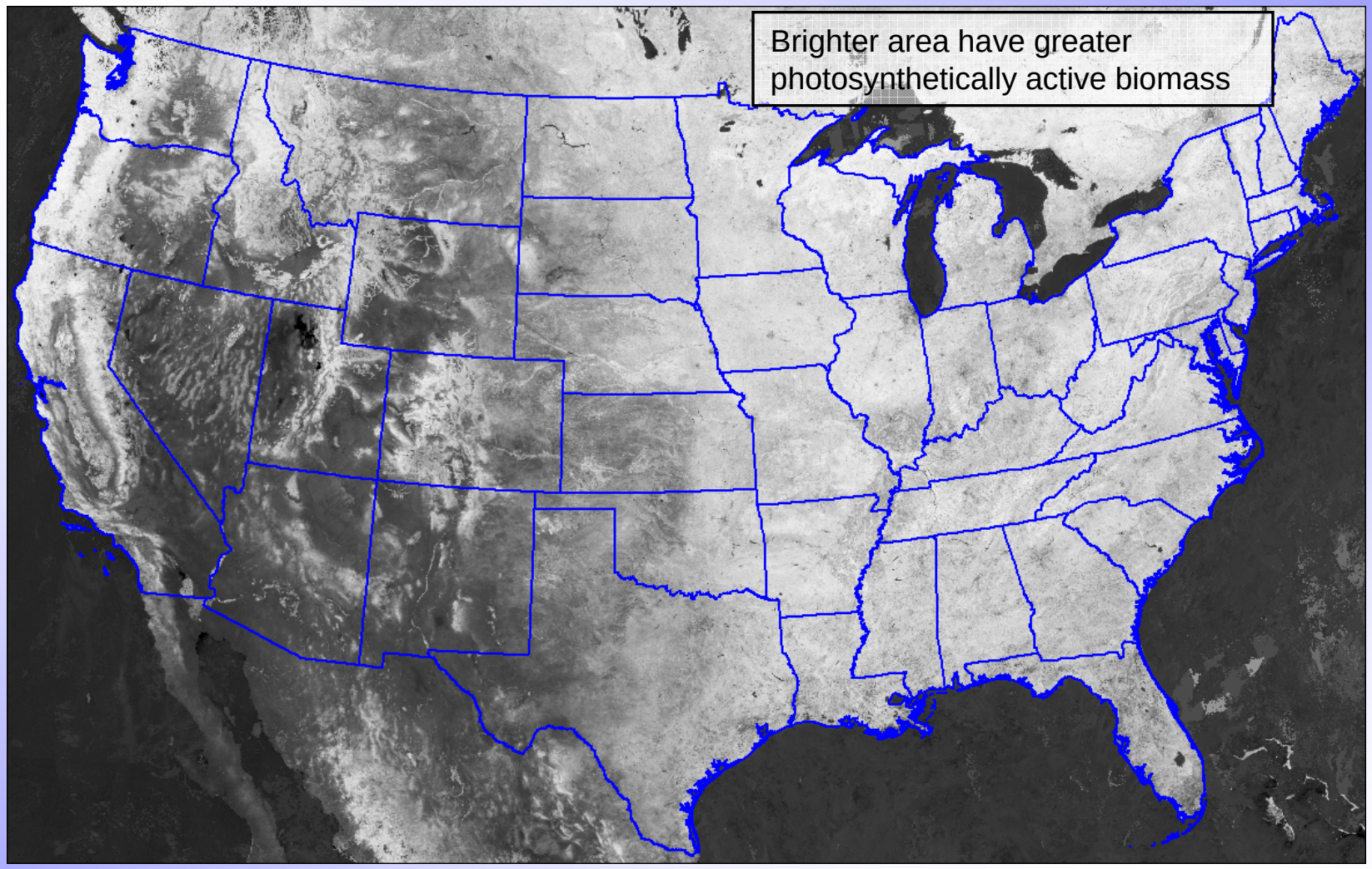


Finney County weather stations

Creation of NDVI Maximum Value Composite Imagery



Maximum Value NDVI Composite



U.S. NDVI composite image, July 9 – July 22 (2003)

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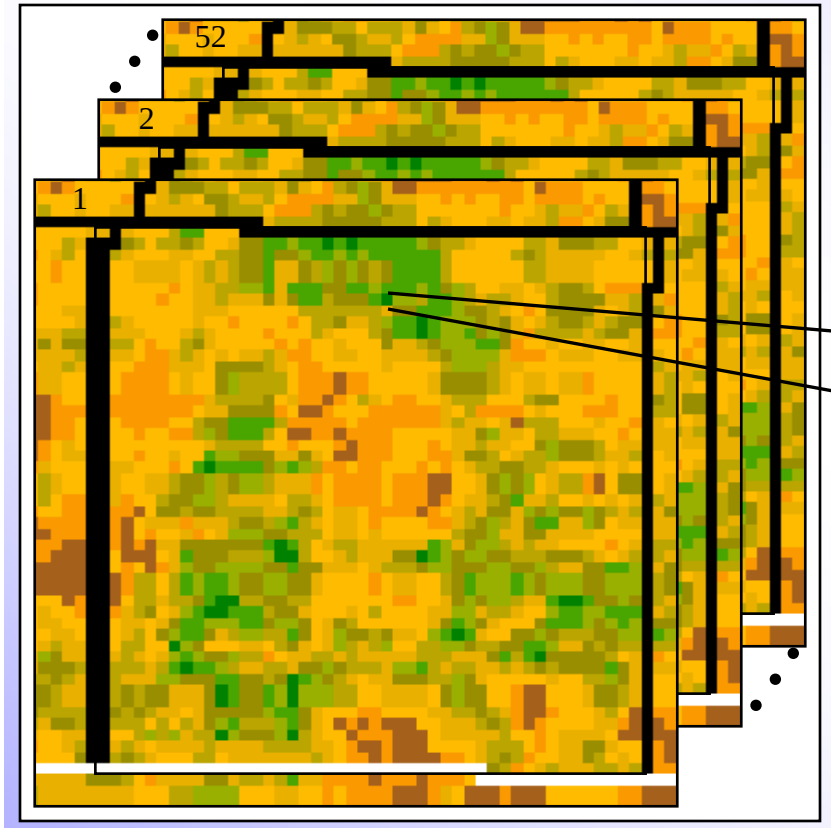
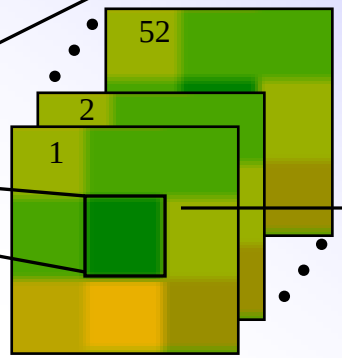
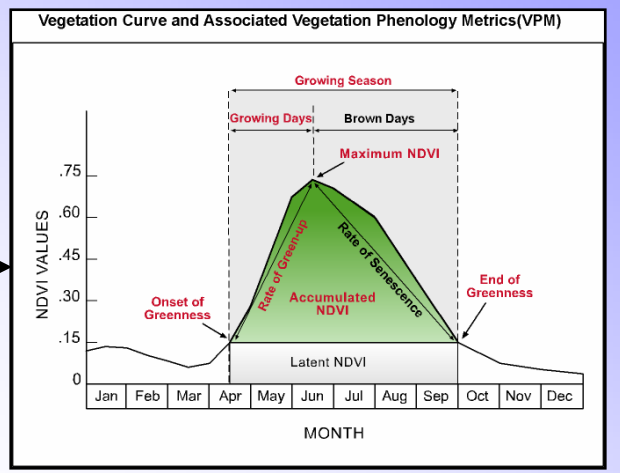
Example of Satellite Image Multitemporal Datasets



Multiple dates of NDVI data



A single AVHRR pixel (250 acres)



Vegetation Growth Curve showing the metrics that can be associated with each pixel throughout the growing season.

Stevens County, Kansas (~2,600 AVHRR pixels in this county)

This figure demonstrate how an average vegetation phenology curve can be generated for the NDVI values for each 250 acre (1.0 km) area (pixel) within an area. Vegetation within a pixel that is stressed by drought have a curve that is different from the normal curve for that pixel.

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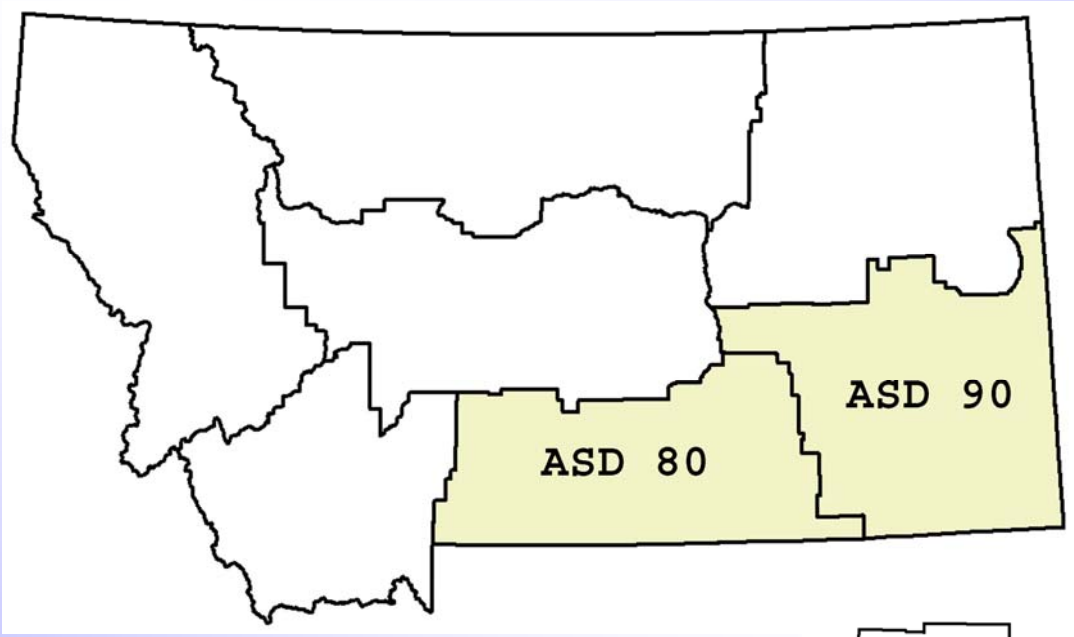
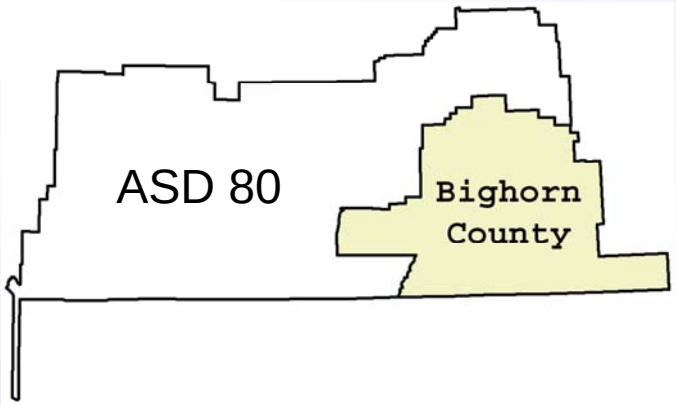
Remote Sensing Index Derivation

Case Study: Bighorn County, MT



USDA Agricultural Statistics Districts (ASD)



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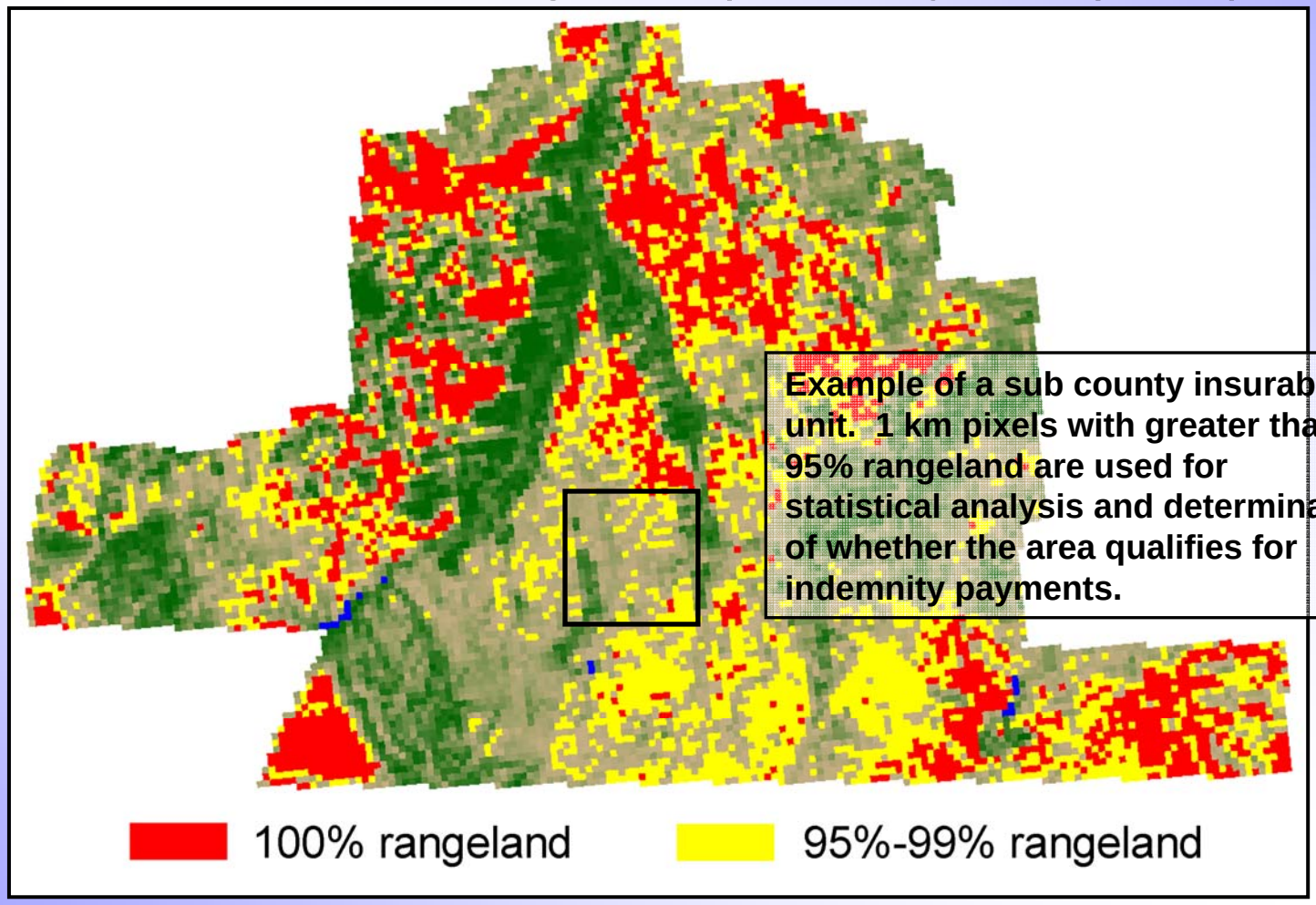
Remote Sensing Index Derivation

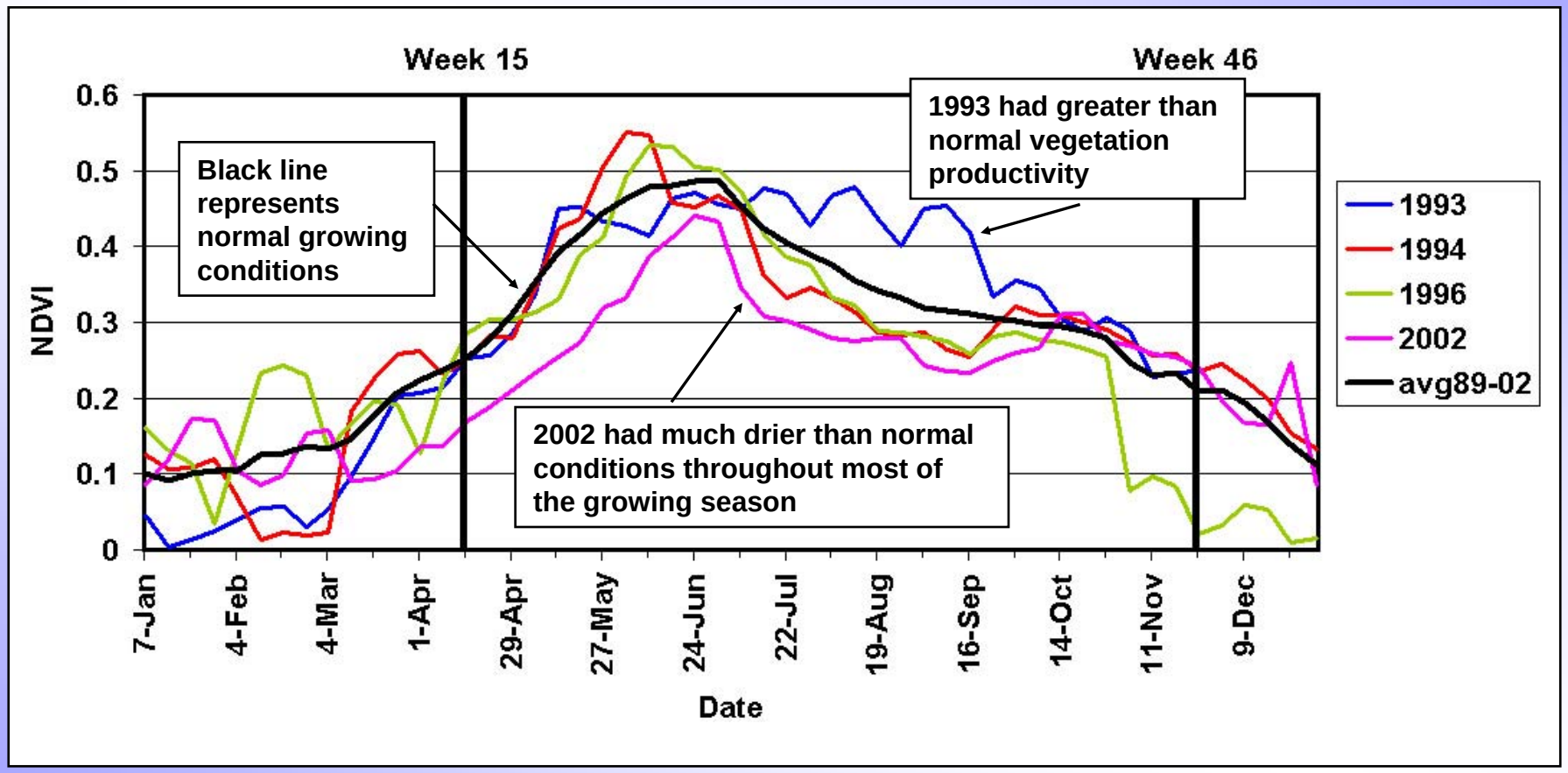
Bighorn County with 1km pixels that cover areas with 95% to 100% rangeland (red and yellow pixels)



Example of a sub county insurable unit. 1 km pixels with greater than 95% rangeland are used for statistical analysis and determination of whether the area qualifies for indemnity payments.

Remote Sensing Index Derivation

Bighorn NDVI, with season start and end



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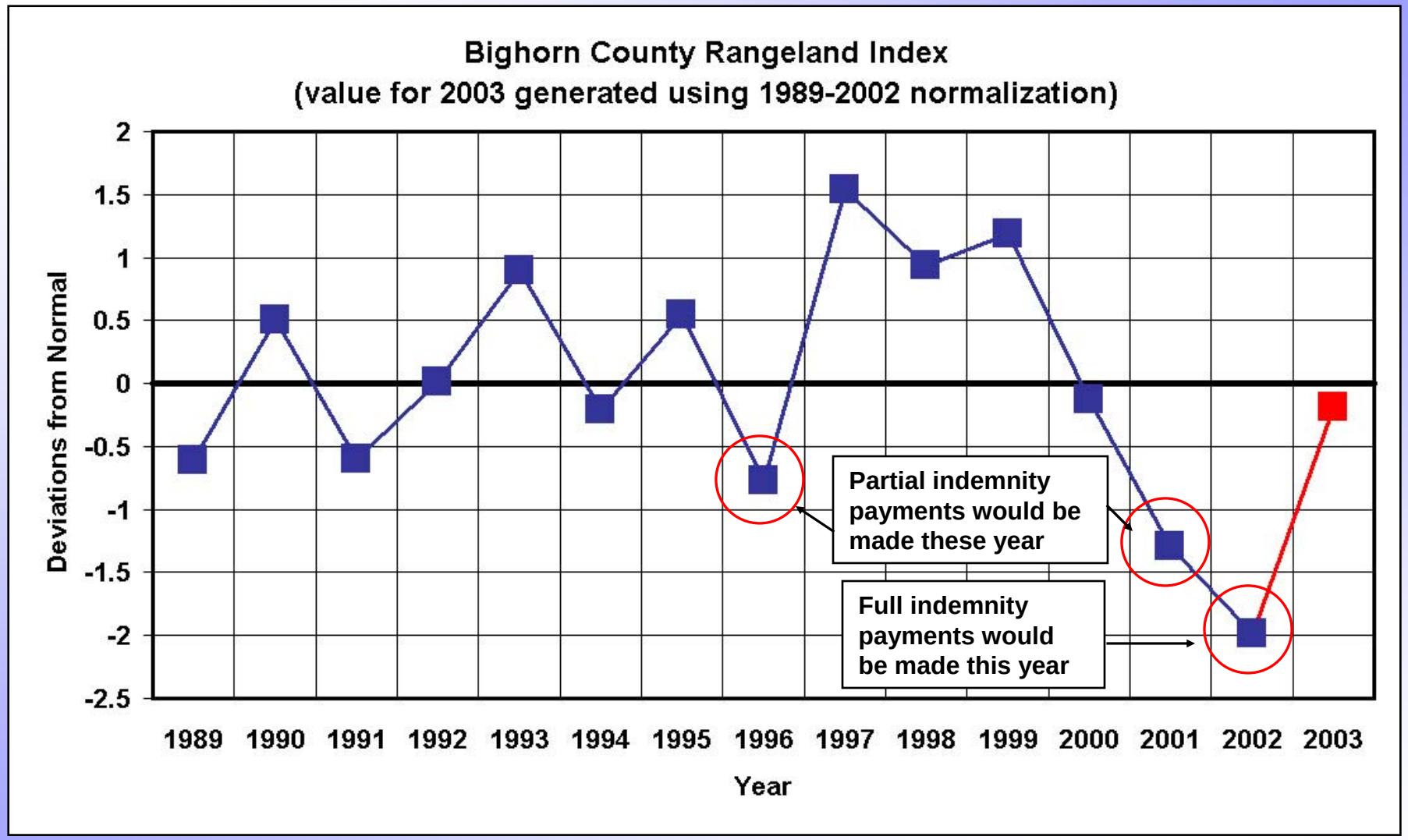
Remote Sensing Index Derivation



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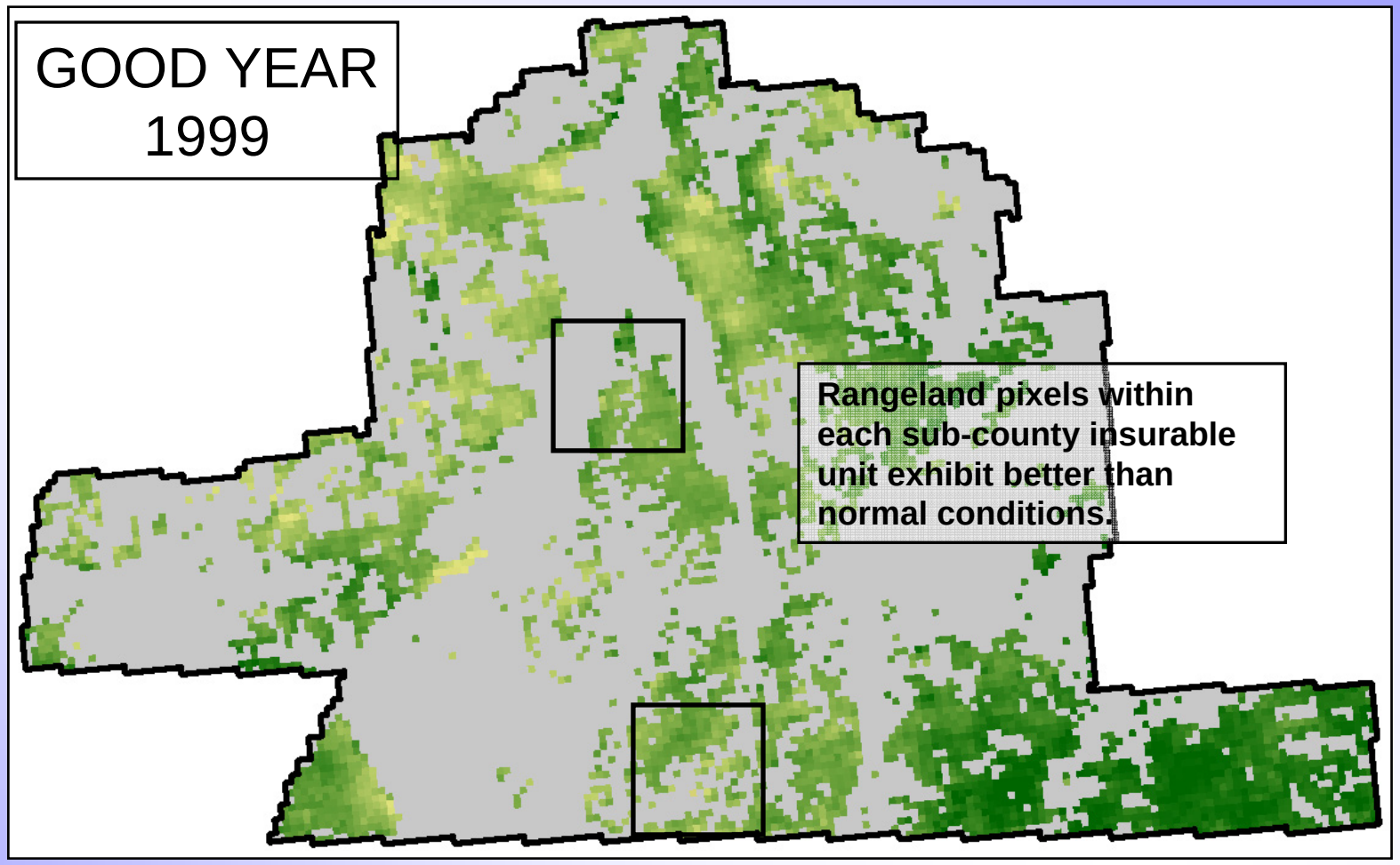

Deviations from normal

Below Normal		Normal		Above Normal
<-2	-1	0	1	>2

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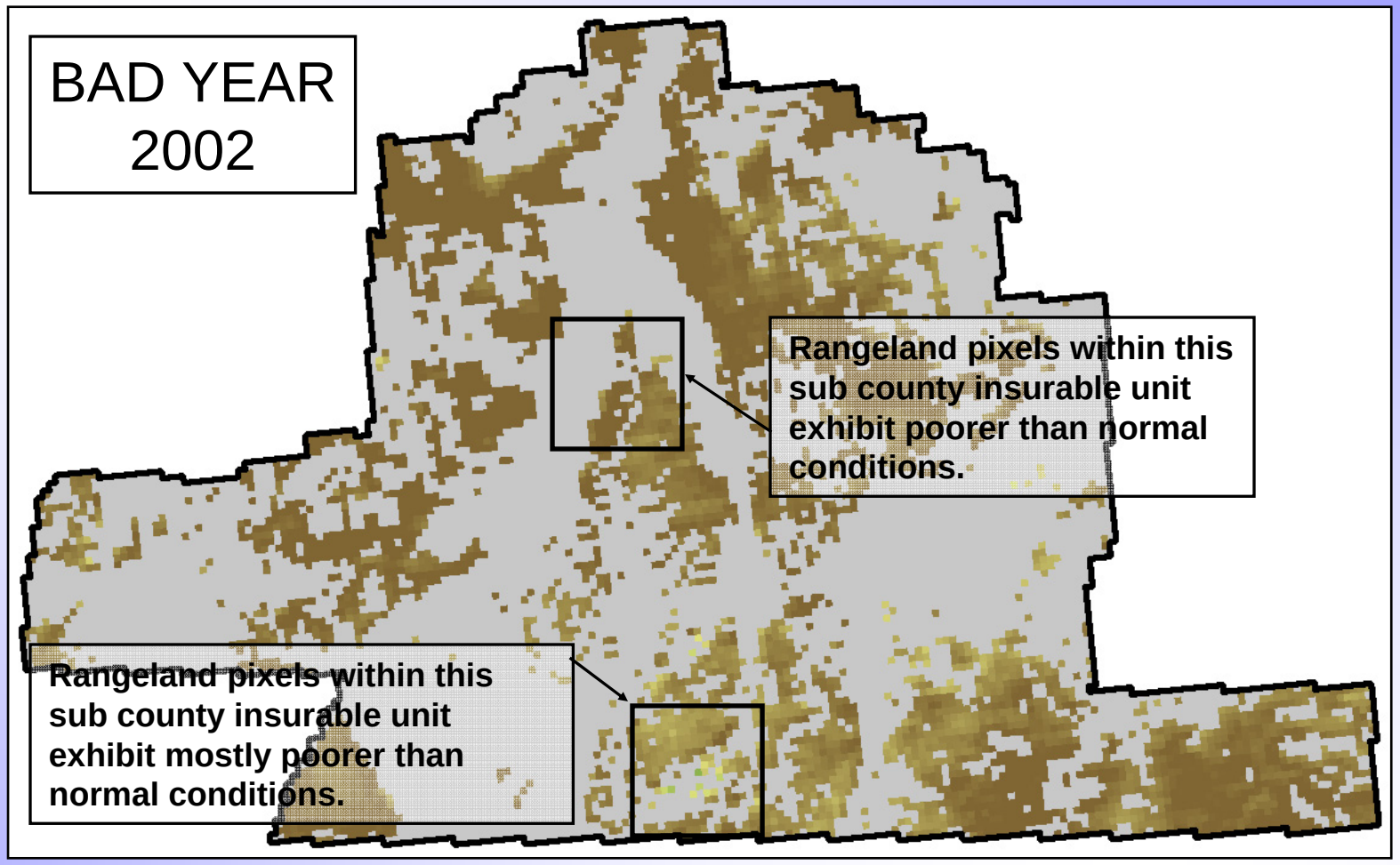
Remote Sensing Index Derivation



Deviations from normal

Below Normal		Normal		Above Normal
<-2	-1	0	1	>2

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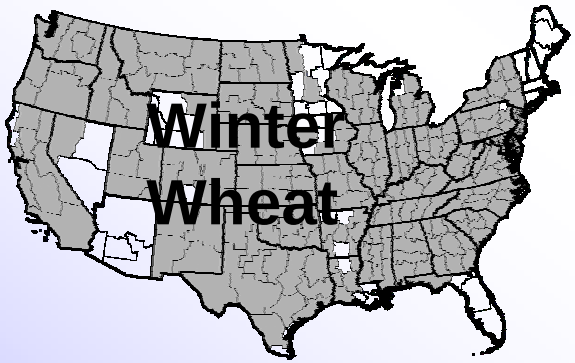
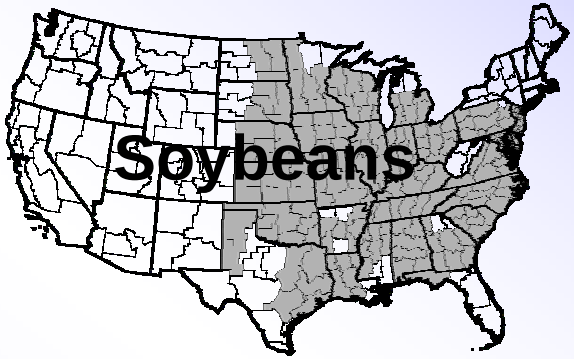
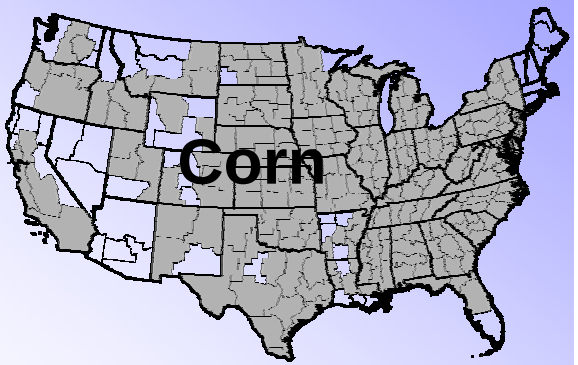
Rejected Trigger Mechanisms for this Product

- Various other trigger mechanisms were evaluated, including:
  - Doppler weather radar for precipitation;
  - MODIS for the NDVI index;
  - AVHRR thermal band for temperature;
  - Weather station temperature (GDD calculated); and
  - PRISM climate program.

TMAI and W&A Crop Yield Forecasting Experience







- TMAI has been conducting NDVI-based yield forecasting research since 1995. Since the 2002 growing season, TMAI has generated and released nationwide preharvest crop yield forecasts at multiple spatial scales.
- Researchers at Montana State University and W&A have conducted NDVI-based yield estimation research since 1999.

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TMAI Crop Yield Forecasting

Winter Wheat Yield Forecasting Errors, 2002-2004

Region	Avg % Nat'l Production	TMAI 26-Mar	TMAI 9-Apr	TMAI 23-Apr	TMAI 7-May	USDA 11-May	Trend
KS	23.64%	5.47	4.17	2.63	2.50	5.33	6.57
OK	8.81%	3.20	1.77	1.13	0.60	3.00	4.67
WA	8.00%	2.57	1.90	1.50	1.03	4.67	4.87
TX	6.13%	2.33	2.90	2.93	2.60	2.67	3.43
CO	5.03%	6.27	5.70	4.60	4.27	5.33	8.50
NE	4.46%	4.83	4.33	4.17	4.53	4.67	5.73
OH	4.11%	3.57	2.07	2.07	2.87	3.33	3.33
7-state total	60.18%	4.32	3.38	2.53	2.36	4.45	5.62
US	100.00%	2.13	1.23	0.30	0.60	3.03	3.37

Values shown represent average absolute error in bu/ac. Yellow indicates improved accuracy when compared to USDA initial season estimates or trend model estimates.

TMAI Crop Yield Forecasting

Corn Yield Forecasting Errors, 2002-2004*

Region	Avg % Nat'l Production	TMAI 4-Jun	TMAI 18-Jun	TMAI 2-Jul	TMAI 16-Jul	TMAI 30-Jul	USDA 11-Aug	Trend
IA	18.25%	19.17	17.03	16.70	17.93	17.77	13.67	18.93
IL	16.62%	18.77	17.43	13.47	14.27	13.63	8.67	19.00
NE	11.83%	13.33	11.67	11.17	9.53	9.50	10.33	12.60
MN	9.31%	14.03	14.17	17.97	17.50	17.43	11.00	7.60
IN	8.33%	17.50	18.07	13.37	13.97	12.97	6.00	16.80
5-state total	64.32%	17.03	15.87	14.60	14.87	14.51	10.38	15.87
US	100.00%	10.97	9.47	8.07	6.50	5.57	5.90	10.10

Values shown represent average absolute error in bu/ac. Yellow indicates improved accuracy when compared to USDA initial season estimates or trend model estimates.

*USDA November estimates have been used as a proxy for 2004 final estimated yield.

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TMAI Crop Yield Forecasting

Soybean Yield Forecasting Errors, 2002-2004*

Region	Avg % Nat'l Production	TMAI 4-Jun	18-Jun	2-Jul	16-Jul	30-Jul	USDA 11-Aug	Trend
IA	17.31%	7.10	6.43	6.60	6.80	6.83	8.00	6.73
IL	17.09%	4.63	4.20	3.57	3.47	3.60	5.17	5.20
MN	9.66%	6.37	7.27	7.93	7.97	7.93	7.17	6.67
IN	8.98%	5.87	5.47	4.60	4.23	4.40	4.33	6.63
OH	6.79%	5.83	6.17	4.90	4.70	4.47	5.33	6.97
MO	6.34%	5.93	5.53	5.63	4.67	3.87	5.33	5.67
6-state total	66.16%	5.95	5.73	5.47	5.34	5.30	6.12	6.24
US	100.00%	3.23	2.93	3.13	3.23	3.23	3.67	3.70

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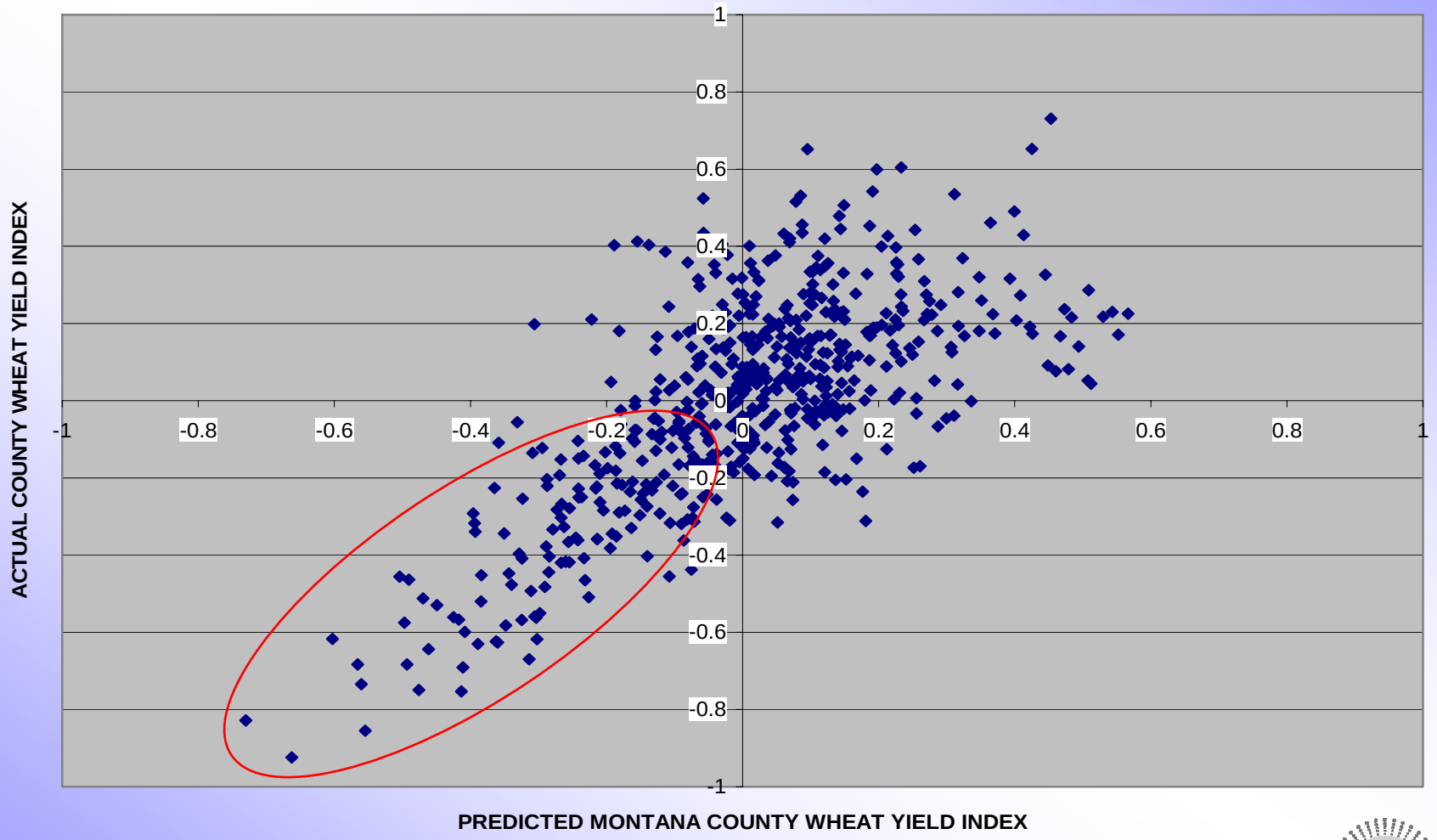
W&A Wheat Yield Forecasting

Predicted vs. Actual Montana County Wheat Yield Index



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Conclusions

- Satellite and aggregate proxies contain useful information to predict crop yields. Using satellite remote sensing to predict rangeland productivity should be less difficult than usage for crop yields because:
  - Crop rotation is not a factor with rangeland;
  - Technology-induced productivity trending is not a factor (e.g., genetics, fertilizer, etc.); and
  - Harvest conditions are not relevant.
- We believe the technology is sufficiently developed and reliable for the development of a range insurance program.