INTEGRATING REMOTE SENSING CAPABILITIES INTO THE DOMESTIC CROP PRODUCTION AND YIELD FORECASTING MANDATES OF USDA

Operational Prediction of Crop Yields using MODIS Data and Products

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Objectives

✓ Develop an algorithm for operational classifications of corn and soybean fields in the U.S. Corn Belt.

✓ Develop 1) hydrological (only); 2) hydrological with remote sensing parameters; and 3) a simplified process model and algorithms for large areas to supplement NASS farm & field data collections for operational assessment of crop condition and yields at county level.

✓ Provide timely and accurate information for potential use in NASS’s operational program.
NASS Operational Needs

- **Timeliness**
  - Must meet NASS report deadlines
  - Processing capabilities must match crop phenology

- **Accuracy**
  - What is the Truth?
  - 10% rule
  - Trends/History

- **Reliability**
  - Satellite/sensor, or climatic disturbances must not delay delivery of estimates
  - Contingency plans essential - must have alternative, nonsurvey-based indicators available

- **Consistency**
  - Transition to new sensors
  - Standard methodology across States, crops
  - Standard processing platform
### Estimating Programs for Major Data Series
#### National & State

#### Indications

<table>
<thead>
<tr>
<th>CROPS:</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
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<tbody>
<tr>
<td>Row Crops</td>
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<td>Small Grains</td>
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<td>Indications Optional</td>
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- **Yield Forecasts**: (Objective Yield & Farmer Surveys)
- **Remote Sensing Potential**
- **Weekly Crop Progress & Condition**
- **Acreage & Production**
- **State - County Estimate Surveys – Harvested Acres & Yield**

**NASS Crop Production** reports based on 1\textsuperscript{st} of month, published by the 12\textsuperscript{th}. 

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**Note**: The table illustrates the timeline and frequency of data collection and reporting for major crop data series, with specific emphasis on the yield forecasts, remote sensing potential, weekly crop progress, and acreage and production data. The timeline spans from January to December, highlighting the periodicity and regional focus of these data series.
Estimating States

- Wheat
- Corn
- Soybeans

Legend:
- Speculative State
- Non-speculative State
- Corn Silage State
- Non-estimating State
- Yield Model Research

Year Indicators:
- 1993
- 2002
- 2005
Data Integration to Monitor and Assess Agricultural Crop Production

**Data**
- Satellite data
- Ground truth for Classification
- Soils
- Weather
- Farming Practices

**Models**
- Crop Classification
- Canopy Reflectance Model
- Crop Yield Models

**Products**
- Land Use/ Cover
- Leaf Area Index
- Soil Moisture
- Crop Condition
- Crop Yield
**Terra - MODIS (Moderate Resolution Imaging Spectroradiometer)**

**Satellite Band Characteristics - NASA**

- **Coverage:** 2330 km, (cross to flight direction)
- **Spectral range:** 405nm-14,385nm (36 channels)
- **Space resolution:** 250 m (channels 1-2),
  500 m (channels 3-7),
  1000 m (channels 8-36)
- **Periodicity:** Two flights a day - 16 days of trajectory repetition

**Primary MODIS bands and products currently used in these studies:**

<table>
<thead>
<tr>
<th>Surface Reflectance</th>
<th>Land/Vegetation</th>
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</thead>
<tbody>
<tr>
<td><strong>250 m Resolution</strong></td>
<td>Landcover Product at 1 km resolution</td>
</tr>
<tr>
<td>1- 620 - 670 nm</td>
<td>Leaf Area Index Product at 1 km resolution</td>
</tr>
<tr>
<td>2- 841 - 876 nm</td>
<td>8-day composite Surface Reflectance with atmospheric correction at 250m resolution</td>
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</tbody>
</table>
NDVI Time Series from the MODIS-Terra 8-day Composite Product
The Savitzky-Golay Filter is used to account for negatively biased noise. The result produces a smoothed curve adapted to the upper NDVI value in a time series.

Crop Classification - MODIS 8-day composite images

**Method:** A Decision Tree Algorithm

- Operational evaluation conducted for 4 crop seasons (2002-2005)
- Accuracy compared with the USDA/NASS Landsat classification

**Results:** For Iowa 2005 crop season

- Overall accuracy for Corn Crop Classification was 82.7% and kappa coefficient of 0.65.
- Soybean Classification accuracy was 84.7%, kappa coefficient of 0.69.
Separation of Corn and Soybean Crops

- The first step is distinguishing the “crop pixels” from others.
  - Condition used is that NDVI value in day of year (DOY) 129 must be less than 0.40 and in DOY 209 must be higher than 0.78.

- The second step of the classification is separation of corn and soybean pixels.
  - Profile fit to a third degree polynomial
  - The mean value of the second derivatives of the polynomial between DOY 169 and 177 are used.
  - Green up rate for corn pixels on that DOY begins to decrease and NDVI profile is convex.
  - For soybean pixels, green up rate is increasing and NDVI profile is concave
Classification of Corn and Soybean Crops - Iowa, 2005

Resolution: 250 m

Corn
Soybean

100 km
MODIS – VIS-NIR
Corn and Soybean Classification Mask

MODIS – VIR/NIR 8-Day Composite 250 m
MODIS-Thermal 8-Day Composite 1 Km

Data Masked And County Averaged

County Yield Algorithm
Yield = f (NDVI, Ts)

Yield Index

Operational Algorithm

Corn Soybean
Crop Yield Assessment using MODIS NDVI and Thermal Parameters

\[ NDVI = \frac{1}{n} \sum_{i=1}^{n} NDVI_{\text{county}} \]
Extreme drought hits heart of US cornbelt

SOURCE: NATIONAL DROUGHT MITIGATION CENTER, DATA AS OF AUG. 9, 2005; SCOTT WALLACE - STAFF
Crop Model vs. Official Yield Estimates
On Cropland Data Layer
2005 Iowa Corn - County Level
Crop Model vs. Official Yield Estimates
On Cropland Data Layer
2005 Iowa Soybeans - County Level
Corn 8-Day Available Transpirable Soil Water (ATSW), IL-2006

ATSW (mm)
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
Corn Yield at 10 km, 2006, IL

No Remote Sensing. Sowing Doy= 120. Density= 8 plants/m2
Summary

1. Time series data are critical for monitoring and assessment of crop condition and potential yields at U.S. regional scales.

2. The 8-day temporal and spatial resolution is practical and suitable for operational monitoring of crop condition and yields at U.S. regional scales.

3. The BRDF and cloud contamination problems in the 8-day composite images cause significant errors in the data application at local scales.

4. Using NDVI is preferred because it reduces BRDF influence. SG-Filtering is helpful for correction of NDVI profiles.

5. The 16-day composite is a marginal improvement over the 8-day composite image, but does not provide the necessary temporal resolution.
6. MODIS surface reflectance product at 250m (MOD09) was found to be adequate for categorizing the major corn and soybean crop areas in Iowa and Illinois.

7. The categorization was useful to monitor crop condition at county level but is not recommended for acreage estimation.

8. The NDVI and surface temperature parameters derived from MODIS 8-day composite products are used to develop crop yield spatial variability.

9. The availability of MODIS data within two weeks of acquisition is adequate for current applications.

10. Accuracy of the crop yield is dependent on image and processing quality.
THANK YOU!

GRAZIE!